Fishes of the Sacramento-San Joaquin Estuary and Adjacent Waters, California: A Guide to the Early Life Histories

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by

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PREFACE

Johnson Wang's "Fishes of the Sacramento-San Joaquin Estuary and Adjacent Waters, California: A Guide to the Early Life Histories" is a monumental work documenting and describing egg and larval life histories and life stages of fishes found in California's Sacramento-San Joaquin River Delta and Estuary. It was originally published in 1986 as an Interagency Ecological Study Program (IEP) technical report. It has been used extensively by public resource agencies and private companies. Due to its value and significance as a reference for the region, the Bureau of Reclamation has digitalized the original manuscript, keeping the original wording and format, and restored the accompanying line drawings.

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INTRODUCTION

This document offers taxonomic and ecological information on eggs, larvae, and juveniles of 125 species of fish in the Sacramento-San Joaquin Estuary and nearby waters. The other study areas include three major systems: Millerton Lake, a completely enclosed freshwater environment, is located in the foothills of the Sierra Nevada on the upper San Joaquin River. This lake supports a self-reproducing landlocked American shad population, a unique feature in North America. Moss Landing Harbor-Elkhorn Slough is largely a marine habitat in which salinities do not fall below polyhaline (25 ppt) except occasionally at times of heavy rainfall in its small drainage basin. The combination of ocean and tidal currents in Monterey Bay and extensive marshland along Elkhorn Slough provides a protected environment for spawning and a nursery ground for estuarine and marine species. Tomales Bay is located just north of San Francisco Bay. A small but complete estuarine system, Tomales Bay is rich in nutrients and fish because of its association with shallow coastal waters. It supports an important commercial herring fishery and recreational fishing for a wide variety of species.

The text of this work includes descriptions of early life stages, life histories, characteristic comparisons between related species, a glossary, references, and an index of scientific names of fishes. More than 400 original biological illustrations were drawn by Mark B. Adams and the author.

The Sacramento-San Joaquin Estuary, a large and hydrologically complex estuary, is the major passageway to California's large network of Central Valley rivers and streams. Its complexity as an aquatic ecosystem is increased by the pronounced seasonal character of freshwater outflow. Fish inhabiting the system range from freshwater to marine species. Use of the system differs according to species, from year-round residents, both freshwater and estuarine species, to anadromous fish whose adults pass through on the way to spawning grounds upstream and whose juveniles return on the way to the ocean, and to marine species who enter the bay and estuary for feeding, spawning, and nursing on tides and in seasons.

The Sacramento-San Joaquin Estuary is nourished by nutrients originating from inland river systems, ocean currents, and discharging directly to the estuary. Diverse ecological habitats within the Delta, Suisun Marsh, the mud flats in South Bay and San Pablo Bay, the sandy central bay, and rocky coast support one of the most diversified fish fauna assemblages to be found on the West Coast.

Several individuals and groups are actively studying aquatic organisms in these regions. They include the California Department of Fish and Game (CDFG), especially through the Stockton, Fresno, and Monterey research laboratories; the state university systems, particularly the University of California at Davis (UC Davis), San Francisco University, Moss Landing Marine Laboratory and Bodega Marine Laboratory, California Academy of Sciences in San Francisco, and federal agencies like the National Marine Fisheries

Service in Tiburon. Previous fishery investigations of the Sacramento-San Joaquin Estuary have resulted in descriptions of juveniles or adults, or have described abundances and distribution of early life stages. Useful reference documents published include those of Skinner (1962), Miller and Gotshall (1965), Ganssle (1966), Aplin (1967), Miller and Lea (1972), Fry (1973), Kukowski (1972), Bane and Bane (1971), Jones (1962), and Moyle (1976); the most pertinent works on early life stages of fishes in the region are Chadwick (1958), Ahlstrom (1965), Eldridge (1977), Nybakken *et al.* (1977), and Wang (1981).

Knowledge of spawning requirements, as well as the early development of fishes, is vital to management of fish populations. There is much interest at present in the geographical and seasonal distribution and abundance of early life stages, but there has been no single compendium of ecological information on early life histories of fish community in the areas studied. The author hopes this document will prove useful to fishery biologists, conservationists, students of natural history, and others who are interested in renewable fishery resources of these major aquatic systems, and that the information it contains will be of use to people studying systems elsewhere.

The Sampling Program

Samples were collected by several methods. Plankton entrained in cooling waterflows were sampled at the Potrero and Hunters Point power plants on San Francisco Bay, the Oleum Power Plant on San Pablo Bay, the Pittsburg and Contra Costa power plants on Suisun Bay and the Western Delta, and the Moss Landing Power Plant on Monterey Bay (inside of Moss Landing Harbor). Plankton surveys were made, inshore as well as offshore, from San Francisco Bay up to the Sacramento-San Jaoquin Delta, in the San Joaquin River in Millerton Lake, in Moss Landing Harbor-Elkhorn Slough, and along the shores of Tomales Bay (see maps).

To confirm identification of several species and to obtain information regarding the species' ecological requirements, the author conducted additional collections at many tributaries and coastal lagoons and creeks (such as Rodeo and Muir Beach lagoons and Pine Gulch Creek) in the study areas (see Maps 1-4).

Samples were taken from the following water bodies:

1. Sacramento-San Joaquin Estuary

    a. San Francisco Bay (from South Bay to Richardson Bay)

    b. San Pablo Bay

    c. Carquinez Strait

    d. Suisun Bay and Montezuma Slough of Suisun Marsh

   e. Delta (from Walnut Grove to Tracy Pumping Station and to Chipps Island)

   f. Lower Sacramento River and Lower San Joaquin River (as far as Sacramento and Stockton, respectively)

   g. Major tributaries within the Sacramento-San Joaquin Estuary

2. Upper Sacramento River and San Joaquin River
   a. In vicinity of Red Bluff Diversion Dam on Sacramento River
   b. Loon Lake, Union Valley Reservoir, Ice House Reservoir, and rivers of the American River system
   c. Millerton Lake and Kerckhoff Reservoir, Upper San Joaquin River

3. Moss Landing Harbor-Elkhorn Slough

   a. Moss Landing Harbor (west of U.S. Highway 1 Bridge)

   b. Elkhorn Slough (east of U.S. Highway 1 Bridge to its uppermost portion)

4. Tomales Bay
   a. Eastern shore of Tomales Bay and associated tributaries
   b. Adjacent waters of Tomales Bay, such as Bodega Bay, Point Reyes, Bolinas Lagoon, and Muir Beach

Plankton nets with a 0.5-mm mouth opening and 0.505-mm nominal mesh were used to collect ichthyofauna (eggs, larvae, and early juveniles). Entrainment sampling was done with high volume pump samplers having a 0.505-mm mesh liner. A 4x3 ft. (1.2- × 1.0 m) beach seine with 0.505-mm mesh was also used.

Juvenile and adult fish were collected with the following types of equipment: a Coffelt VV-15 AC/pulsed DC electroshocker; a 16x4 ft (4.8 ×1.2 m) otter trawl with 1.5 inch (1.3 cm) mesh liner; 100 × 6 ft (30.4 x 1.8 m) nylon monofilament experimental gill nets, one with mesh of 0.5-1.5 in (1.3 to 3.8 cm), and one with 2-4 inch mesh (5.1 to 10.1 cm); three beach seines, one 50 × 60 ft (15.4 × 1.8 m with 0.25 inch (6.0 cm) mesh in wings and bag, one 20x4 ft (6.1 × 1.2 m) with 0.4-cm mesh, and a fyke net with 0.25 inch (0.6-cm) mesh and 50 ft (15.2-m) wings. Collection of juvenile and adult fish provided valuable information on the times and places of spawning which aided the collection and identification of early life stages.

In the Sacramento-San Joaquin Estuary, samples were collected from 1978 to 1983. Samples were processed up to June 1983; as of 1985 the fish sampling program is still carried on by the CDFG, Stockton Office. Sampling on the Sacramento River near Redding and Red Bluff was done in 1982; upper American River sampling was conducted in 1981 and 1982, and at Millerton Lake from 1980 to 1982. Moss landing Harbor-Elkhorn Slough sampling was started in 1979 and finished in 1981. Sampling in Tomales Bay was carried on from 1979 to 1982. More than 20,000 samples were collected in these surveys. All specimens were sorted and identified by Ecological

Analysts, Inc. (EA) and State biologists under direct supervision of or in consultation with the author. Identification of uncommon specimens was made possible by the assistance of experts from other institutions and organizations (see Acknowledgments). Additional data used in this document originated from available literature.

Arrangement of the Text

In the species accounts, arrangement of taxonomic order and the common and scientific names used generally follows those of the fourth edition of the American Fisheries Society's "*Common and Scientific Names of Fishes from the United States and Canada*" (Robins *et al.* 1980). If a species was not listed in that work, names were taken from "*A Guide to the Coastal Marine Fishes of California*" (Miller and Lea 1972) or "*Pacific Fishes of Canada*" (Hart 1973). A list of fishes described in this work, data on their spawning, and their occurrence in the study area begins on page 14.

Each chapter of the manual describes those members of a family of fishes that were collected in the study area. An introduction to the family at the beginning of the chapter also lists names of other species of the family that have been reported in the study area. Plates illustrating early life stages are inserted at the end of each chapter. Each species account is arranged as follows:

COMMON AND SCIENTIFIC NAMES

SPAWNING

Location	Specific spawning locations are indicated if they are known; otherwise the general area is indicated. In some cases, a species spawns over a wide area.
Season	Most fishes spawn for several months; range of spawning times is indicated.
Temperature	Upper and lower limits of preferred spawning temperature ranges are given when known.
Salinity	Preferred ranges of salinity for spawning, expressed as seawater, polyhaline, mesohaline, and oligohaline, freshwater, and euryhaline (see Glossary).
Substrates	Observed substrates, including rock, gravel, sand, mud, vegetation, algae, and manmade (*i.e.*, cans, bottles,tires). Fishes with pelagic or free-floating eggs do not need substrate.
Fecundity	Estimates based on subsamples or counts of mature eggs in the ovaries. Estimates from one or a few specimens

should be regarded as indicative only, since fecundity varies with age and environmental factors.

Major sources of information: Pertinent literature and data gathered in this study.

TAXONOMIC CHARACTERISTICS

EGGS (illustrations of early, middle, and late developmental stages may be presented).

Shape	Spherical (most species), teardrop (*e.g.*, gobies), elliptical (*e.g.*, anchovies), or irregular (*e.g.*, darters).
Diameter	Of newly fertilized eggs, measured across the maximum distance of outer margin of chorion. If eggs are not spherical, measurements are taken along both the long and short axes.
Yolk	Color, texture, and size of yolk are indicated. Oil globule(s): size, number, and color of this initial food source (and sometimes flotation device) are described.
Chorion	Smoothness, thickness, transparency, and elasticity are indicated for chorion filaments, stalks, attaching discs, hexagonal (honeycomb) sculpturing, or multiple layers.
Perivitelline space	Width of vitreous space between chorion and yolk is measured in early developmental stage.
Egg mass	Fish eggs are deposited singly or in clusters. Clusters are formed by adhesion (*e.g.*, sunfishes and Pacific herring) or by tangling of chorion filaments (*e.g.*, silversides).
Adhesiveness	Most demersal eggs have some degree of adhesiveness to prevent them being washed out of spawning area. Most freshwater eggs are adhesive; most marine eggs are not.
Buoyancy	Two basic types of eggs, pelagic and demersal, are indicated. Some marine spawners have pelagic eggs; freshwater and estuarine spawners most often have demersal eggs. There are certain exceptions: anadromous fishes such as striped bass and American shad have semi-demersal eggs (slightly heavier than freshwater).

Major sources of information are listed.

LARVAE (prolarvae and postlarvae are illustrated).

Length at hatching	Total length (from tip of snout to tip of tail) of newly hatched larvae.
Snout to anus length	Expressed as a percentage of the total length of larva. Location of the anus may change with development stage.
Yolk sac	Size, shape, location, and extension of yolk sac are described
Oil globule(s)	Size, color, number, and location are included.
Gut	Length, shape (straight, curled, or coiled), and thickness.
Air bladder	Location, shape size, and pigmentation.
Teeth	Type, size and number of rows of teeth on upper jaw (maxillary and premaxillary) and lower jaw.
Size at completion of yolk-sac stage	Range of total lengths of larvae when yolk-sac material is completely absorbed (this range can vary substantially with genetic and environmental factors).
Total myomeres	Number of myomeres between the most anterior myoseptum and the most posterior true myoseptum; combined number of preanal and postanal myomeres.
Preanal myomeres	Counted from a line perpendicular to the long axis of fish's body at posterior margin of the anus.
Postanal myomeres	Counted from the first complete myomere behind perpendicular line at posterior margin of the anus to the most posterior myoseptum.
Last fin(s) to complete development	Stage when last fin and finrays complete development, when postlarval fish becomes a juvenile.
Pigmentation	Includes melanophores and chromatophores on body and finfold (particularly useful within families).
Distribution	Both general geographic distribution and specific range are described.

Major sources of information: Pertinent literature references are included.

JUVENILES (one illustration of the juvenile life stage may be included).

Dorsal fin	Number of spiny rays is expressed by Roman numerals; soft rays of the second dorsal fin are indicated by Arabic numerals.

Anal fin	Number of spiny anal rays is expressed by Roman numerals; soft anal rays are indicated by Arabic numerals.
Pectoral fin	Number of spines are expressed by Roman numerals; soft rays by Arabic numerals. Number of spines and rays of dorsal, anal, and pectoral fins are important taxonomic characteristics for juvenile and adult fishes.
Adipose fin	Presence of this fleshy, rayless fin, usually located behind the dorsal fin and above the caudal peduncle
Mouth	Inferior, superior, terminal, large, small, oblique, or other relative terms.
Vertebrae	Total number of regular vertebrae.
Distribution	Both general geographic distribution and specific information on ranges and habitats are included.

Major sources of information: Pertinent literature is included.

LIFE HISTORY

This will include:

Geographic distribution, ranges, origin, and local records of distribution.

Spawning biology, including spawning run or movement, habitat and substrates, period and frequency of spawn, sexual dimorphism, and other characteristics.

Characteristics of eggs, including incubation period, development, and temperature requirements.

Characteristics of newly hatched yolk-sac larvae and portlarvae, including habitat stratum, behavior, movement, and biology.

Characteristics of juvenile fish including habitat, stratum, behavior, movement, feeding, and biology.

Sexual maturity, longevity, size, economic or other value, and comments on ecological status.

References

A list of literature used in describing life history and taxonomic characteristics for each species is given.

Specimen Credits

Credit is given to people or institutions that donated or loaned specimens to this study.

Specimen Verification

Credit is given to a person who helped confirm the identification.

Limitations of the Study

- The 125 species described in this document represent the majority of fish species present in study areas, but do not constitute entire fish community in any of the areas.

- Early life stages of hagfishes were not collected; early life stages of Chondrichthyes are not described because of their large size and recognizable features at hatching or birth. Hagfishes and Chondrichthyes reported in the study areas are listed in the following pages.

- From 30 to 400 specimens were examined for each of the most abundant species; other species were collected in limited numbers and were not examined in such detail. Descriptions are based, to the extent possible, on specimens collected in surveys, but where necessary, use has been made of other sources of specimens from study areas or their vicinities. These other sources include Pacific Gas and Electric's (PG&E) ichthyoplankton reference collection of marine species; Tiburon Laboratory's Richardson Bay collection, CDFG Bay-Delta collection; and author's personal collection. A permanent voucher collection has been established at the CDFG, Stockton Office.

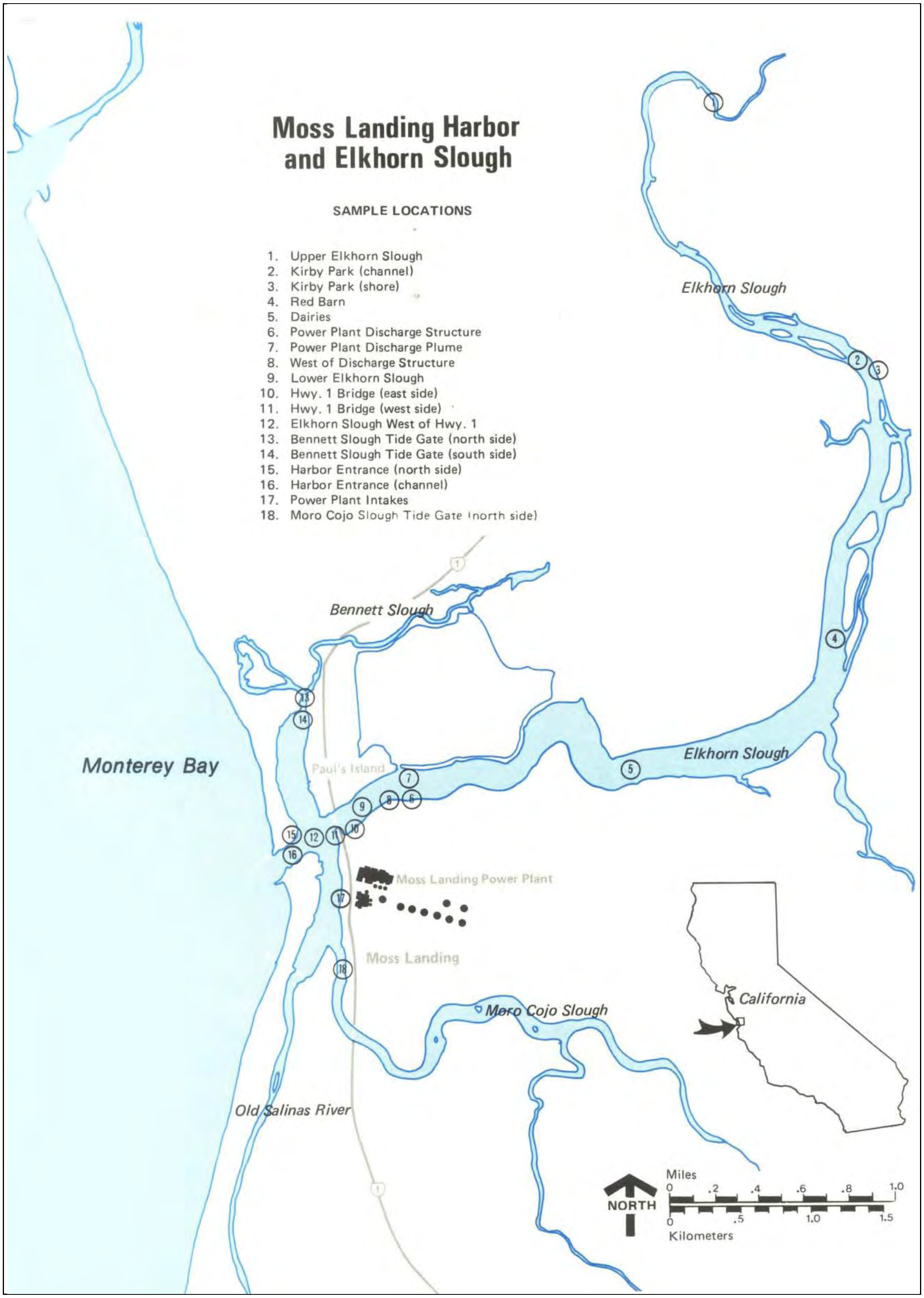
- All descriptions are based on preserved specimens. Pigmentations such as chromatophores are indistinguishable from melanophores.

- If specimens of fertilized eggs were unavailable, mature unfertilized eggs were used in the description and the substitution noted in the text.

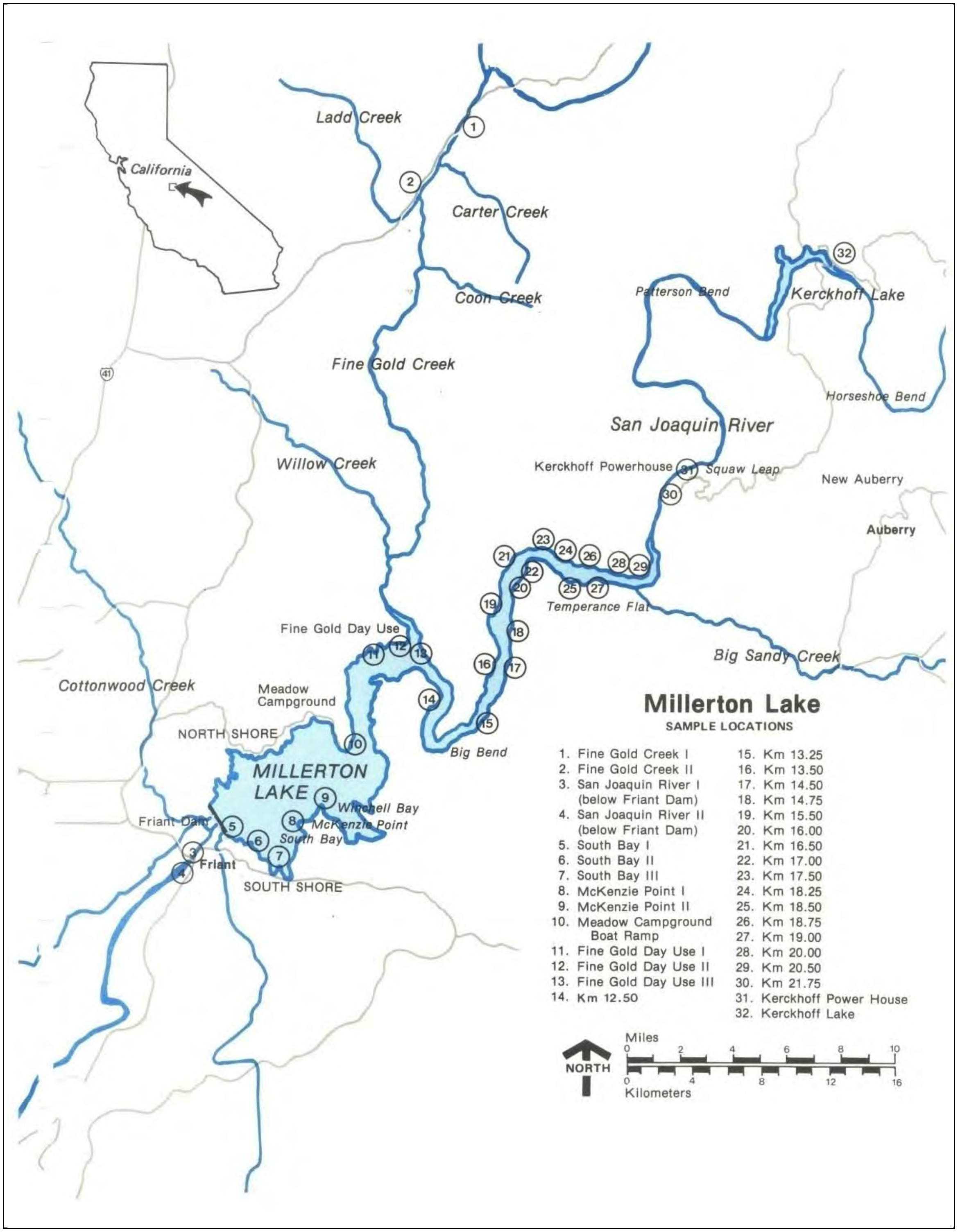
- Subheadings have been deleted from the species account when information was lacking from available literature or this study.

- The format was changed in some species accounts because of special characteristics of species (*e.g.*, Petromyzontidae).

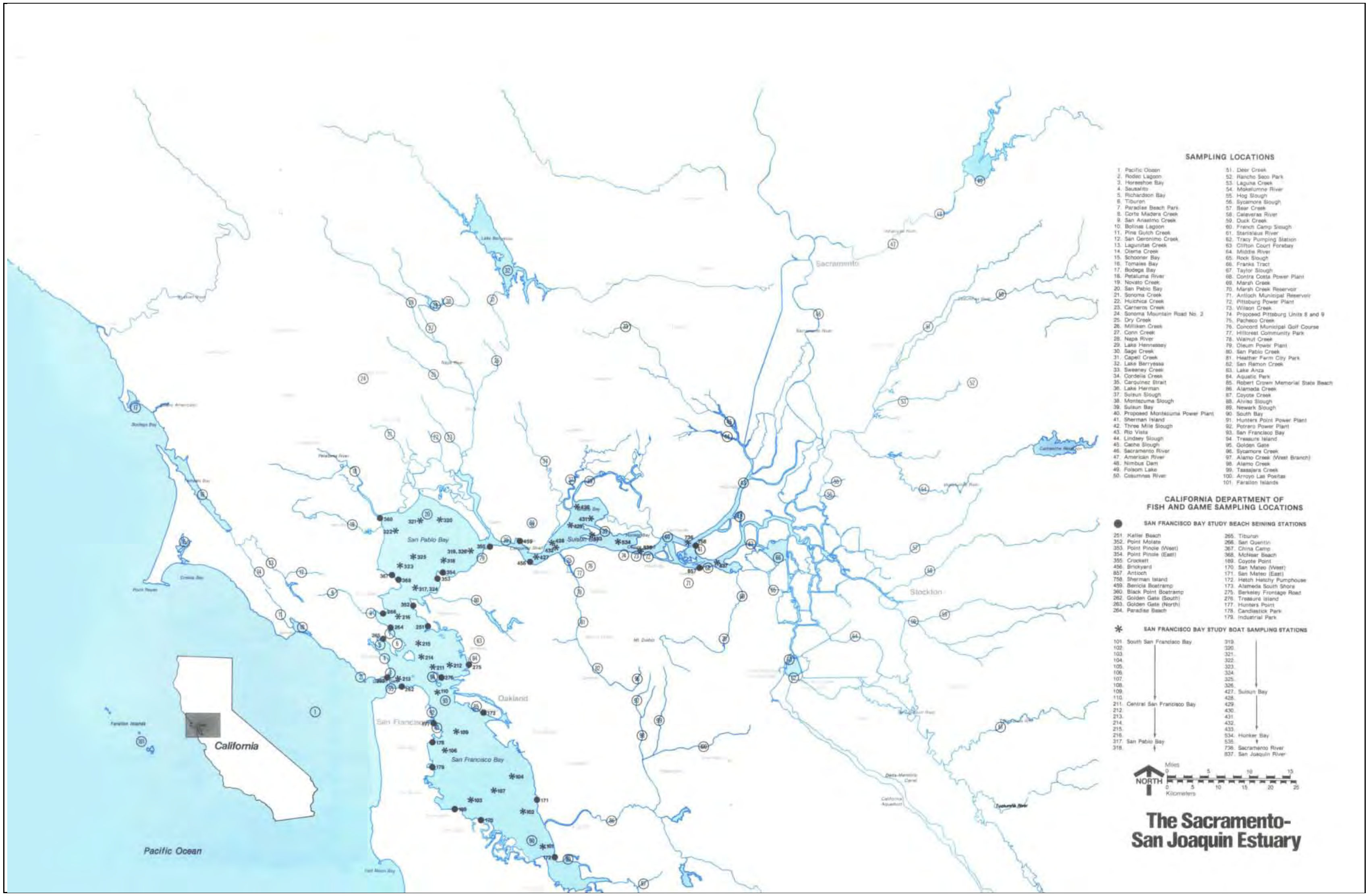
- All information is based on author's best knowledge.



Map 1.—Map of Moss Landing Harbor and Elkhorn Slough sample locations.



Map 2.—Millerton Lake sample locations.



Map 3.—Sacramento-San Joaquin Estuary.

Map 4.—Tomales Bay and Point Reyes sample locations.

List of Hagfishes, Sharks, Rays, and Chimaeras Reported in the Sacramento-San Joaquin Estuary and Adjacent Waters

Family Myxinidae – Hagfishes
Pacific hagfish, *Eptatretus stouti* (Lockington)

Family Hexanchidae – Cow Sharks
Sixgill shark, *Hexanchus griseous* (Bonnaterre)
Sevengill shark, *Notorynchus maculatus* Ayres

Family Squalidae – Dogfish Sharks
Spiny dogfish, *Squalus acanthias* Linnaeus

Family Squatinidae – Angel Sharks
Pacific angel shark, *Squatina californica* Ayres

Family Rhinobatidae – Guitarfishes
Thornback, *Platyrhinoidis triseriata* (Jordan and Gilbert)
Shovelnose guitarfish, *Rhinobatos productus* (Ayres)

Family Torpedinidae – Electric Rays
Pacific electric ray, *Torpedo californica* Ayres

Family Rajidae – Skates
Big skate, *Raja binoculata* Girard
California skate, *Raja inornata* Jordan and Gilbert
Longnose skate, *Raja rhina* Jordan and Gilbert
Roughtail skate, *Raja trachura* Gilbert

Family Dasyatidae – Stingrays
Round stingray, *Urolophus halleri* Cooper

Family Myliobatidae – Eagle Rays
Bat ray, *Myliobatis californica* Gill

Family Chimaeridae – Chimaeras
Spotted ratfish, *Hydrolagus colliei* (Lay and Bennett)

Information Source

Aplin 1967, Bane and Bane 1971, Ganssle 1966, Green 1975, Kukowski 1972b, Messersmith 1966, Nybakken *et al.* 1977, Standing *et al.* 1975.

Fishes which use the Sacramento-San Joaquin Estuary and Adjacent Waters as Spawning and/or Nursery Grounds, 1978-1983

Note: F = Freshwater M = Mesohaline S = Seawater
O = Oligohaline P = Polyhaline D = Deepsea
(See glossary for definitions)

Taxon	Spawning Season					Occurrence		
Common Name *Scientific Name*	Spring	Summer	Fall	Winter	Preferred Spawning and/or Nursery Habitats	Sacramento-San Joaquin Estuary and Tributaries	Moss Landing Harbor and Elkhorn Slough	Tomales Bay
River lamprey *Lampetra ayresi*	x				F	x		
Pacific lamprey *Lampetra tridentata*	x				F	x		x
Kern brook lamprey, or Pacific brook lamprey *Lampetra hubbsi* or *Lampetra pacifica*		x	x		F	x		
Green sturgeon *Acipenser mediorostris*	x	x			F-O	x		
White sturgeon *Acipenser transmontanus*	x	x		x	F-O	x		
American shad *Alosa sapidissima*	x	x			F-O	x		
Pacific herring *Clupea harengus pallasi*	x			x	P-M	x	x	x
Threadfin shad *Dorosoma petenense*	x	x			F-O	x	x	x
Chinook salmon *Oncorhynchus tshawytscha*	x	x	x	x	F	x		
Rainbow trout or Steelhead *Salmo gairdneri*	x			x	F	x		x
Whitebait smelt *Allosmerus elongates*				x	S	x		

Fishes which use the Sacramento-San Joaquin Estuary and Adjacent Waters as Spawning and/or Nursery Grounds, 1978-1983

Note: F = Freshwater; M = Mesohaline; S = Seawater
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Taxon	Spawning Season					Occurrence		
Common Name *Scientific Name*	Spring	Summer	Fall	Winter	Preferred Spawning and/or Nursery Habitats	Sacramento-San Joaquin Estuary and Tributaries	Moss Landing Harbor and Elkhorn Slough	Tomales Bay
Surf smelt *Hypomesus pretiosus*	x	x	x	x	S-P-M-O	x	x	x
Delta smelt *Hypomesus transpacificus*	x			x	F	x		
Night smelt *Spirinchus starksi*	x	x	x	x	S – P	x	x	x
Longfin smelt *Spirinchus thaleichthys*	x		x	x	F – O	x		x
Popeye blacksmelt *Bathylagus pacificus*	x	x		x	D		x	
Pacific blacksmelt *Bathylagus ochotensis*	x			x	D	x		x
California lizardfish *Syndodus lucioceps*		x	x		S	x	x	
Northern lampfish *Stenobrachius leucopsarus*	x	x	x	x	D	x	x	
Blue laternfish *Tarletonbeania crenularis*	x	x	x	x	D	x	x	
Goldfish *Carassius auratus*	x	x			F	x		
Common carp *Cyprinus carpio*	x	x			F	x		

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Taxon	Spawning Season					Occurrence		
Common Name *Scientific Name*	Spring	Summer	Fall	Winter	Preferred Spawning and/or Nursery Habitats	Sacramento-San Joaquin Estuary and Tributaries	Moss Landing Harbor and Elkhorn Slough	Tomales Bay
California roach *Hesperoleucus symmetricus*	x	x			F	x		x
Hitch *Lavinia exilicauda*	x	x			F	x		
Hardhead *Mylopharodon conocephalus*	x	x			F	x		
Golden shiner *Notemigonus crysoleucas*	x	x			F	x		
Red shiner *Notropis lutrensis*	x	x			F	x		
Sacramento blackfish *Orthodon microlepidotus*	x	x			F	x		
Fathead minnow *Pimephales promelas*	x	x			F	x		
Splittail *Pogonichthys macrolepidotus*	x			x	F-O	x		
Sacramento squawfish *Ptychocheilus grandis*	x			x		x		
Lahontan redside *Richardsonius egregius*	x	x			F	x		
Sacramento sucker *Catostomus occidentalis*	x	x		x	F	x		

Fishes which use the Sacramento-San Joaquin Estuary and Adjacent Waters as Spawning and/or Nursery Grounds, 1978-1983

Note: F = Freshwater M = Mesohaline S = Seawater
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Taxon	Spawning Season					Occurrence		
Common Name *Scientific Name*	Spring	Summer	Fall	Winter	Preferred Spawning and/or Nursery Habitats	Sacramento-San Joaquin Estuary and Tributaries	Moss Landing Harbor and Elkhorn Slough	Tomales Bay
White catfish *Ictalurus catus*	x	x			F-O	x		
Black bullhead *Ictalurus melas*	x	x			F	x		
Brown bullhead *Ictalurus nebulosus*	x	x			F	x		
Channel catfish *Ictalurus punctatus*	x	x			F	x		
Plainfin midishipman *Porichthys notatus*	x	x			S-P-O	x	x	x
Northern clingfish *Gobiesox maeandricus*	x			x	S-P	x	x	x
Pacific tomcod *Microgadus proximus*	x			x	S	x	x	x
Spot cusk-eel *Chilara taylori*			x	x	S	x	x	
Red brotula *Brosmophycis marginata*	x	x			S-P	x		
Pacific saury *Cololabis saira*	x	x	x	x	S		x	
Rainwater killifish *Lucania parva*	x	x			P-M-O	x		
Mosquitofish *Gambusia affinis*	x	x	x		F-O	x		
Topsmelt *Atherinopsis affinis*	x	x	x		S-P-M	x	x	x
Jacksmelt *Atherinopsis californiensis*	x	x	x	x	S-P	x	x	x

Fishes which use the Sacramento-San Joaquin Estuary and Adjacent Waters as Spawning and/or Nursery Grounds, 1978-1983

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Taxon	Spawning Season					Occurrence		
Common Name *Scientific Name*	Spring	Summer	Fall	Winter	Preferred Spawning and/or Nursery Habitats	Sacramento-San Joaquin Estuary and Tributaries	Moss Landing Harbor and Elkhorn Slough	Tomales Bay
California grunion *Leuresthes tenuis*	x	x			S		x	
Inland silverside *Menidia beryllina*	x	x	x		F-O	x		
Tube-snout *Aulorhynchus flavidus*	x	x			S		x	
Threespinestickleback *Gasterosteus aculeatus*	x	x	x		F-O-M	x	x	x
Bay pipefish *Syngnathus leptorhynchus*	x	x	x		S-P-M-O-F	x	x	x
Striped bass *Morone saxatilis*	x	x			F-O-M	x	x	x
Sacramento perch *Archoplites interruptus*	x	x			F-O	x		
Green sunfish *Lepomis cyanellus*	x	x			F	x		
Pumpkinseed *Lepomis gibbosus*	x	x			F	x		
Warmouth *Lepomis gulosus*	x	x			F	x		
Bluegill *Lepomis macrochirus*	x	x			F	x		
Redear sunfish *Lepomis microlophus*	x	x			F	x		

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Taxon	Spawning Season					Occurrence		
Common Name *Scientific Name*	Spring	Summer	Fall	Winter	Preferred Spawning and/or Nursery Habitats	Sacramento-San Joaquin Estuary and Tributaries	Moss Landing Harbor and Elkhorn Slough	Tomales Bay
Smallmouth bass *Micropterus dolomieui*	x	x			F	x		
Spotted bass *Micropterus punctulatus*	x	x			F	x		
Largemouth bass *Micropterus salmoides*	x	x			F	x		
White crappie *Pomoxis annularis*	x	x			F	x		
Black crappie *Pomoxis nigromaculatus*	x	x			F	x		
Bigscale logperch *Percina macrolepida*	x	x		x	F	x		
White croaker *Genyonemus lineatus*	x		x	x	S-P-M	x	x	x
Barred surfperch *Amphistichus argenteus*	x	x			S	x	x	x
Kelp perch *Brachyistius frenatus*	x	x			S	x	x	x
Shiner perch *Cymatogaster aggregata*	x	x			S-P-M	x	x	x
Black perch *Embiotoca jacksoni*	x	x	x		S-P-M	x	x	x

Fishes which use the Sacramento-San Joaquin Estuary and Adjacent Waters as Spawning and/or Nursery Grounds, 1978-1983

Note: F = Freshwater   M = Mesohaline   S = Seawater
O = Oligohaline   P = Polyhaline   D = Deepsea
(See glossary for definitions)

Taxon	Spawning Season					Occurrence		
Common Name *Scientific Name*	Spring	Summer	Fall	Winter	Preferred Spawning and/or Nursery Habitats	Sacramento-San Joaquin Estuary and Tributaries	Moss Landing Harbor and Elkhorn Slough	Tomales Bay
Striped surfperch *Embiotoca lateralis*	x	x			S-P	x	x	x
Spotfin surfperch *Hyperprosopon argenteum*		x			S	x	x	x
Walleye Surfperch *Hyperprosopon anale*	x	x			S-P-M	x	x	x
Silver surfperch *Hyperprosopon ellipticum*		x			S	x	x	x
Rainbow seaperch *Hypsurus caryi*		x	x		S		x	x
Tule perch *Hysterocarpus traski*	x	x			F	x		
Dwarf perch *Micrometrus minimus*	x	x			S-P-M	x	x	x
White seaperch *Phanerodon furcatus*	x	x	x		S-P-M	x	x	x
Rubberlip seaperch *Rhacochilus toxotes*	x	x			S-P	x	x	x
Pile perch *Rhocochilus vacca*	x	x	x		S-P-M	x	x	
Senorita *Oxyjulis californica*	x	x	x		S	x	x	
Striped kelpfish *Gibbonsia metzi*	x		x	x	S-P	x	x	x

Fishes which use the Sacramento-San Joaquin Estuary and Adjacent Waters as Spawning and/or Nursery Grounds, 1978-1983

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Taxon	Spawning Season					Occurrence		
Common Name *Scientific Name*	Spring	Summer	Fall	Winter	Preferred Spawning and/or Nursery Habitats	Sacramento-San Joaquin Estuary and Tributaries	Moss Landing Harbor and Elkhorn Slough	Tomales Bay
Giant kelpfish *Heterostichus rostratus*	x	x		x	S-P	x	x	x
Onespot fringehead *Neoclinus uninotatus*	x	x	x	x	S-P	x	x	
High cockscomb *Anoplarchus purpurescens*	x			x	S-P			x
Monkeyface prickleback *Cebidichthys violaceus*	x			x	S-P	x		x
Rock prickleback *Xiphister mucosus*	x			x	S-P	x	x	x
Xiphister spp.				x	S-P	x		
Penpoint gunnel *Apodichthys flavidus*	x			x	S-P	x		x
Pacific san lance *Ammodytes hexapterus*	x			x	S-P-M	x	x	x
Yellowfin goby *Acanthogobius flavimanus*	x	x		x	S-P-M-O-F	x	x	
Arrow goby *Clevelandia ios*	x	x	x	x	S-P-M	x	x	x
Blackey goby *Coryhopterus nicholsi*	x	x	x		S	x	x	

Fishes which use the Sacramento-San Joaquin Estuary and Adjacent Waters as Spawning and/or Nursery Grounds, 1978-1983

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Taxon	Spawning Season					Occurrence		
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Tidewater goby *Eucyclogobius newberryi*	x	x	x	x	M-O-F	x	x	
Longjaw mudsucker *Gillichthys mirabilis*	x	x	x	x	S-P-M	x	x	x
Cheekspot goby *Ilypnus gilberti*	x	x	x	x	S-P-M	x	x	
Bay goby *Lepidogobius lepidus*	x		x	x	S-P	x	x	x
Chameleon goby *Tridentiger trigonocephalus*	x	x	x		S-P-M	x		
Pacific Pompano *Peprilus simillimus*	x	x			S-P	x		x
Brown rockfish *Sebastes auriclatus*	x				S-P	x	x	x
Greenspotted rockfish *Sebastes chlorostictus*	x				S	x		
Greenstriped rockfish *Sebastes elongatus*	x	x			S	x		
Quillback *Sebastes maliger*	x				S	x		
Kelp greenling *Hexagrammos decagrammus*	x		x	x	S-P	x	x	x
Lingcod *Ophiodon elongatus*	x			x	S-P	x	x	x

Fishes which use the Sacramento-San Joaquin Estuary and Adjacent Waters as Spawning and/or Nursery Grounds, 1978-1983

Note: F = Freshwater M = Mesohaline S = Seawater
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Taxon	Spawning Season					Occurrence		
Common Name *Scientific Name*	Spring	Summer	Fall	Winter	Preferred Spawning and/or Nursery Habitats	Sacramento-San Joaquin Estuary and Tributaries	Moss Landing Harbor and Elkhorn Slough	Tomales Bay
Painted greenling *Oxylebius pictus*	x	x	x	x	S-P	x		
Prickly sculpin *Cottus asper*	x	x		x	F-O	x		x
Riffle sculpin *Cottus gulosus*	x			x	S-P	x		x
Buffalo sculpin *Enophrys bison*	x			x	S	x		x
Brown Irish lord *Hemilepidotus armatus*				x	S			x
Pacific staghorn sculpin *Leptocottus armatus*	x		x	x	S-P-M	x	x	x
Tidepool sculpin *Oligocottus maculosus*			x	x	S-P-M	x		x
Cabezon *Scorpaenichthys mamoratus*			x	x	S-P-M	x		x
Artedius spp. (Probably bonehead sculpin, *Artedius notospilotus*	x			x	S-P-M	x	x	x
Pricklebreast poacher *Stellerina xyosterna*			x	x	S-P	x	x	x
Slipskin snailfish *Liparis fucensis*	x	x		x	S-P		x	
Speckled sanddab *Citharichthys*	x	x	x	x	S	x	x	

Fishes which use the Sacramento-San Joaquin Estuary and Adjacent Waters as Spawning and/or Nursery Grounds, 1978-1983

Note: F = Freshwater M = Mesohaline S = Seawater
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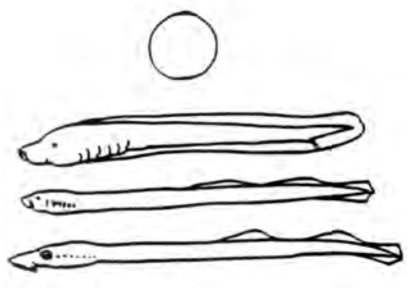
Taxon	Spawning Season					Occurrence		
Common Name *Scientific Name*	Spring	Summer	Fall	Winter	Preferred Spawning and/or Nursery Habitats	Sacramento-San Joaquin Estuary and Tributaries	Moss Landing Harbor and Elkhorn Slough	Tomales Bay
California halibut *Paralichthys californicus*	x	x	x	x	S-P	x	x	x
Diamond turbot *Hypsopsetta guttulata*	x	x	x	x	S-P-M	x	x	
English sole *Parophrys vetulus*	x		x	x	S-P-M	x	x	x
Starry flounder *Platichthys stellatus*			x	x	S-P-M-O-F	x	x	x
Curlfin sole *Pleuronichthys decurrens*	x	x	x	x	S-P	x	x	
Sand sole *Psettichthys melanostictus*	x			x	S-P	x	x	x
California tonguefish *Symphurus atricauda*			x	x	S-P	x	x	

GENERAL CHARACTERISTICS OF THE EARLY LIFE STAGES OF FISH FAMILIES



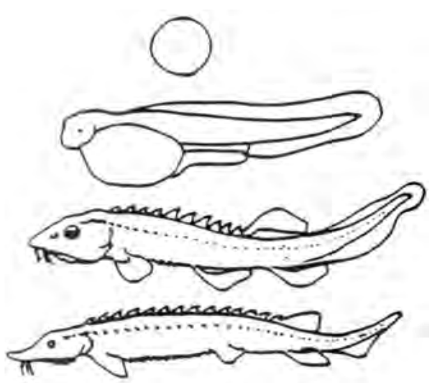
PETROMYZONTIDAE, lampreys

Eggs

Slightly elliptical to irregular.
Cream to pale green.
Holoblastic cleavage.
Demersal, adhesive.

Larvae/Juveniles (Ammocoetes)

Body elongate, laterally compressed.
Anus very posterior, near caudal region.
Jawless, mouth inferior, eyes small and underdeveloped.
Tail myotomes congested.



ACIPENSERIDAE, sturgeons

Eggs

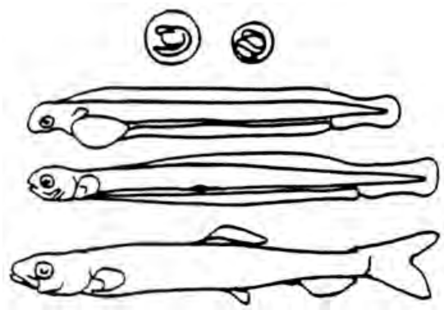
Spherical, very large.
Opaque, gray to black.
Modified Holoblastic cleavage.
Demersal, adhesive.

Larvae

Body gray, chunky, large size at hatching.
Large yolk sac.
Anus slightly posterior.
Eyes small, underdeveloped.
Caudal fin becoming asymmetrical.

Juveniles

Body shape similar to sharks.
Elongate snout, inferior mouth, barbells present.
Bony plates.



CLUPEIDAE, herrings

Eggs

Spherical.

Yolk yellowish to whitish, usually granular.

Meroblastic cleavage.

Demersal to semidemersal.

Larvae

Body thin, very elongate.

Yolk sac small, thoracic.

Anus near caudal region.

Dashed melanophores along thoracic and midventral regions.

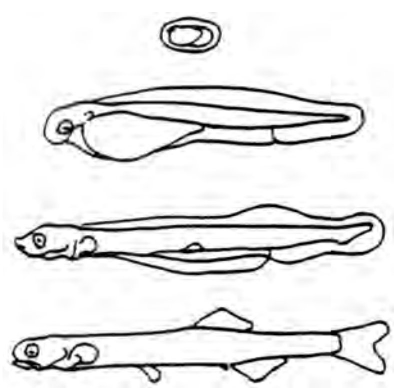
Juveniles

Body elongate, highly compressed laterally.

Origin of anal fin very posterior to insertion of dorsal fin.

Deeply forked caudal fin.

Large cycloid scales.



ENGRAULIDAE, anchovies

Eggs

Elliptical.

Yolk granular, yellowish-whitish.

Meroblastic cleavage.

Pelagic in coastal waters.

Larvae

Body elongate with finfolds.

Thoracic yolk sac.

Anus posterior (but not as far as clupeids).

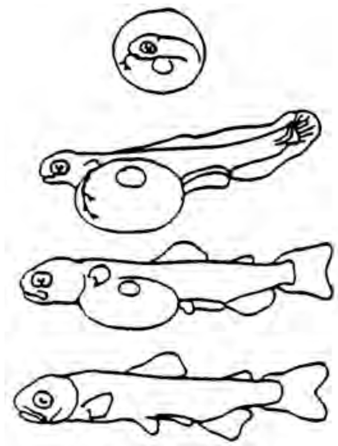
Dashed melanophores in thoracic and midventral regions.

Juveniles

Body elongate, laterally compressed.

Snout pointed, mouth inferior, maxillary extends past eye.

Origin of anal fin overlaps insertion of dorsal fin.



SALMONIDAE, trouts

Eggs

Spherical, very large (4 mm in diameter).

Yolk yellowish-orange, with many oil globules.

Meroblastic cleavage.

Demersal, adhesive.

Larvae

Newly hatched larvae have extremely large yolk sac with single oil globule.

Anus posterior.

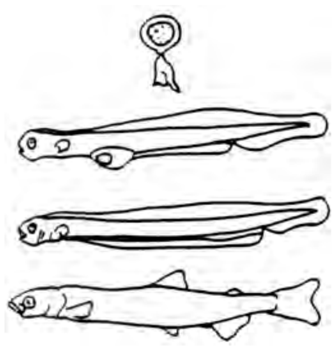
Adipose fin.

Juveniles

Body elongate but chunky.

Parr marks on sides of body.

Adipose fin.



OSMERIDAE, smelts

Eggs

Spherical.

Yolk yellowish-whitish, granular, with many oil globules.

Meroblastic cleavage.

Demersal.

Outer layer of chorion forms attachment to substrate.

Larvae

Body thin, elongate.

Yolk sac small; posterior to thoracic region, with single oil globule.

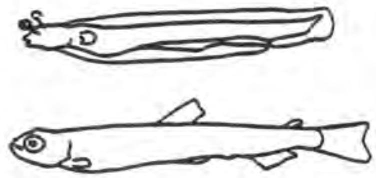
Single row of dashed melanophores along midventral region.

Juveniles

Body elongate, laterally compressed.

Origin of anal fin very posterior to insertion of dorsal fin.

Adipose fin.



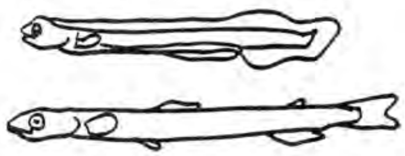
BATHYLAGIDAE, deepsea smelts

Larvae

Body elongate.
Anus near caudal region.
Elongate eye stalk.

Juveniles

Body elongate.
Eye large, may be on stalk.
Two branchiostegal rays.
Adipose fin.
Bathypelagic.



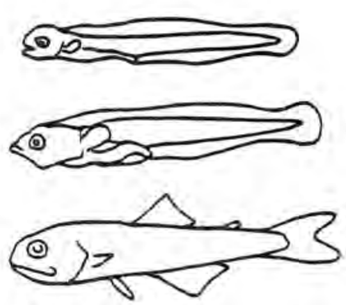
SYNODONTIDAE, lizardfishes

Larvae

Body elongate, laterally compressed.
Anus posterior.
Paired dark blotches spaces equally along entire length of gut.

Juveniles

Body cylindrical, elongate, with dark blotches embedded in skin.
Snout pointed, mouth large.
Adipose fin.



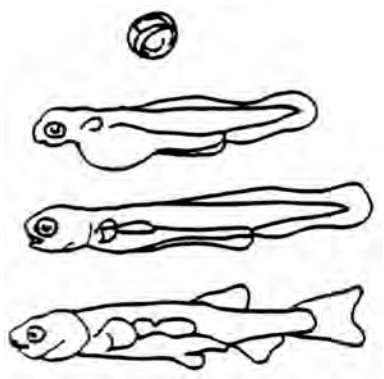
MYCTOPHIDAE, lanternfishes

Larvae

Body elongate.
Anus anterior.
May have vertically narrow eyes.

Juveniles

Body short, compressed.
Large head and mouth.
Photophores present, mostly below lateral line.
Adipose fin.



CYPRINIDAE, minnows and carps

Eggs

Spherical.

Yolk yellowish. Generally no oil globules.

Meroblastic cleavage.

Demersal and adhesive (with exception of hitch eggs.

Larvae

Body elongate, heavy pigmentation.

Yolk-sac elongate, tear-drop shape.

Anus posterior (but less than 70% of total length).

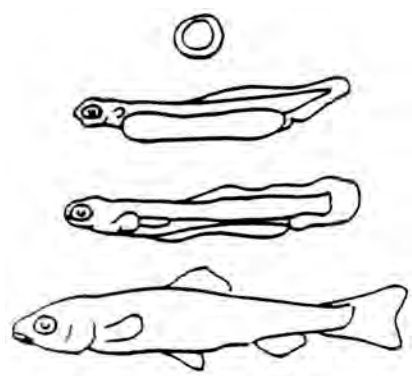
Juveniles

Body elongate, heavy pigmentation.

Mouth terminal.

Single dorsal fin.

Anal fin ray count less than 15.



CATOSTOMIDAE, suckers

Eggs

Spherical, large (ca. 3 mm in diameter).

Yolk yellowish, granular.

Meroblastic cleavage.

Demersal, adhesive.

Larvae

Body elongate, heavy pigmentation.

Yolk sac very elongate, forms three segments.

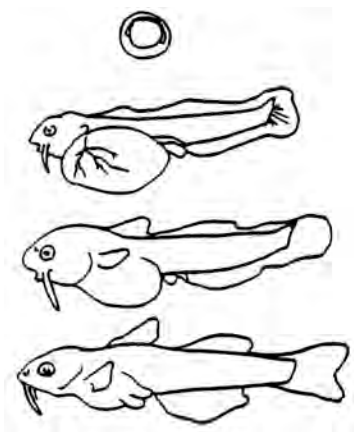
Aus near caudal region (greater than 70% of total length).

Juveniles

Body elongate.

Mouth inferior.

Air bladder has two chambers.



ICTALURIDAE, catfishes

Eggs

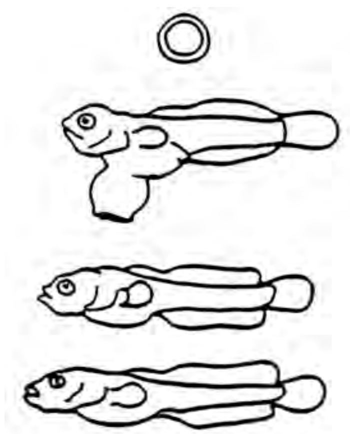
Spherical, large (ca. 3 mm in diameter).
Yolk yellowish, granular, no oil globules.
Meroblastic cleavage.
Demersal, highly adhesive, forms clusters.

Larvae

Newly hatched larvae large, chunky.
Anus midway or slightly anterior.
Yolk sac yellowish, very large.
Barbels.

Juveniles

Body cylindrical, large head.
Four pairs of barbels: two on maxillary, two on lower chin.
Dorsal and pectoral fins with spines.



BATRACHOIDIDAE, toadfishes

Eggs

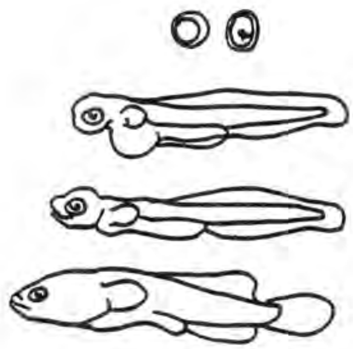
Spherical, very large (4 mm in diameter).
Yolk bright yellow to pinkish-yellow, hard.
Chorion thick, eggs change shape during incubation.
Meroblastic cleavage.
Demersal and adhesive.

Larvae

Body short and chunky.
Anus near thoracic region.
Yolk-sac larval stage attached to substrate.

Juveniles

Body elongate, trunk and tail taper off.
Head large, flat.
Dorsal and anal fins elongate.
Photophores on head and body.



GOBIESOCIDAE, clingfishes

Eggs

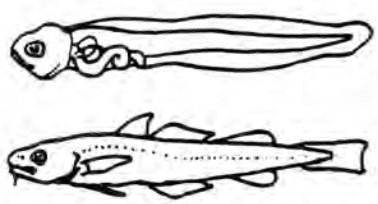
Elliptical.
Oil globules.
Meroblastic cleavage.
Demersal and attached to substrate.

Larvae

Body short and stubby.
Anus midway of total length.
Large stellate melanophores cover trunk.

Juveniles

Body robust, tapers off.
Head big and flat.
Lips thick and fleshy.
Single dorsal fin near caudal region.
Pelvic fin modified into sucking disc.



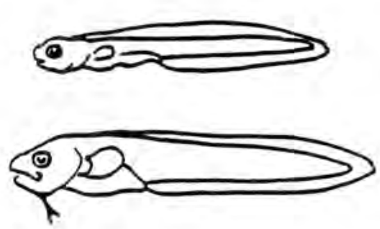
GADIDAE, codfishes

Larvae

Body elongate, laterally compressed.
Anus slightly anterior.
Matching pigmentation pattern in tail region

Juveniles

Body elongate, laterally compressed.
Dorsal fin, 2-3; anal fin, 1-2. No spines in fins.



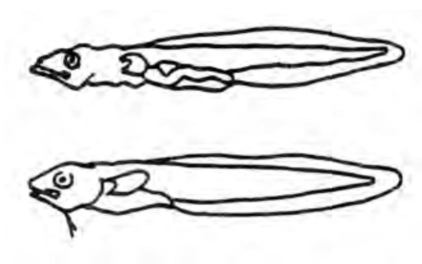
OPHIDIIDAE, cusk-eels

Larvae

Body elongate, laterally compressed.
Anus anterior.
Melanophores concentrate mostly along postanal region in early postlarvae.

Juveniles

Body elongate, laterally compressed.
Pelvic fins modified into filamentous structure in jugular area.
Dorsal and anal fins elongate.



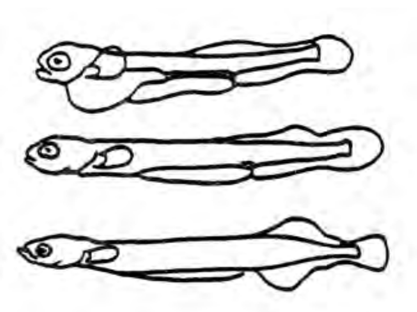
BYTHITIDAE, viviparous brotulas

Larvae (embedded in ovaries of females)

Body elongate.
Anus midway or slightly anterior.
Melanophores along dorsal and postanal regions in alternate pattern.

Juveniles

Body elongate, cylindrical (similar to eels).
Pelvic fin modified into filamentous structure in jugular region.
Dorsal and anal fins elongate.



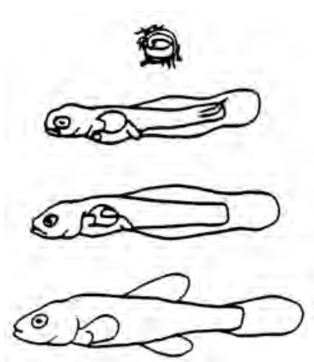
SCOMBERESOCIDAE, sauries

Larvae

Body elongate, laterally compressed, heavily pigmented.
Anus posterior.
Eyes large.

Juveniles

Body very slender.
Snout pointed, upper jaw short.
Dorsal and anal fins very posterior on body, both followed by a few finlets.



CYPRINODONTIDAE, killifishes

Eggs

Spherical.
Yolk yellowish with oil globules.
Fine filaments cover chorion.
Meroblastic cleavage.
Demersal, but suspended on substrate.

Larvae

Body short, stubby, generally heavily pigmented.
Anus slightly anterior.
Caudal rays visible in newly hatched larvae.

Juveniles

Body short, stubby, tapers off, heavily pigmented.
Head large and flat.
Mouth superior.
Dorsal fin anterior to anal fin.
Tail round.

POECILIIDAE, livebearers

Eggs (embedded in ovaries of females)

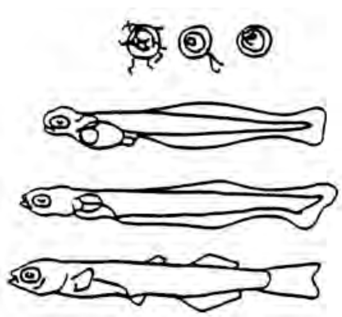
Spherical.
Yolk bright yellow, with many oil globules.
Meroblastic cleavage.

Larvae (embedded in ovaries of females)

Body curled, pigmented.
Anus in thoracic position.
Scales developed.

Juveniles

Body short, stubby, fully scaled.
Head flat.
Mouth superior.
Origin of dorsal fin posterior to origin of anal fin.



ATHERINIDAE, silversides

Eggs

Spherical.
Yolk yellowish, granular, with one or more oil globules.
Various elongate chorion filaments.
Meroblastic cleavage.
Demersal, nonadhesive, suspended on substrate.

Larvae

Body thin, elongate, with single oil globule.
Anus thoracic.
Long tail.

Large stellate melanophores cover top of head, dashed melanophores along lateral line.

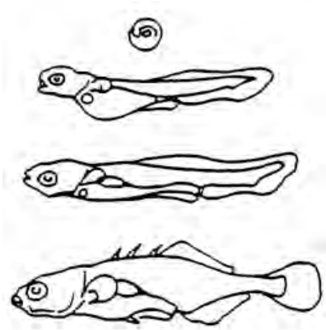
Juveniles

Body elongate.

Head and snout relatively flat.

Two dorsal fins, well separated.

Anus shifts to posterior.



GASTEROSTEIDAE, sticklebacks

Eggs

Spherical.

Yolk yellowish, clear, with oil globules.

Meroblastic cleavage.

Demersal, adhesive, clustered.

Larvae

Body short and stubby, heavily pigmented.

Anus midway.

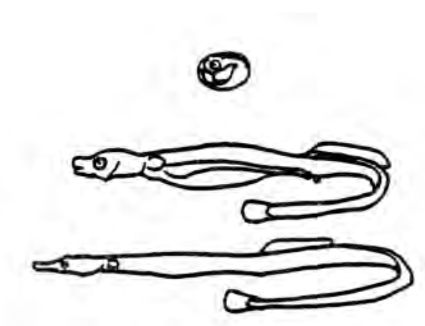
Elongate yolk sac, with single oil globule.

Juveniles

Body short, narrow caudal peduncle.

First spiny dorsal fin develops into separate spines.

Bony plates develop on sides of body.



SYNGNATHIDAE, pipefishes and seahorses

Eggs (embedded in males' pouches)

Spherical to oval.

Yolk bright yellow to orange, with many oil globules.

Meroblastic cleavage.

Demersal and clustered.

Larvae (embedded in males' pouches)

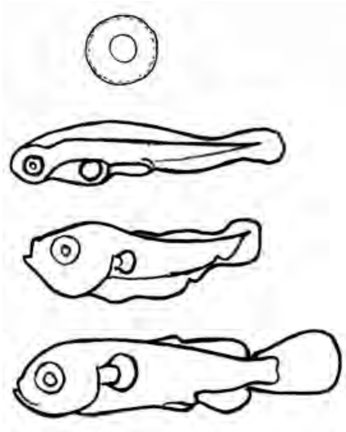
Body curled.

Yolk sac large, spherical, thoracic.

Anus anterior.

Juveniles

Body elongate, covered with bony rings.
Mouth tubular, small.
Head bony.



PERCICHTHYIDAE, temperate basses

Eggs

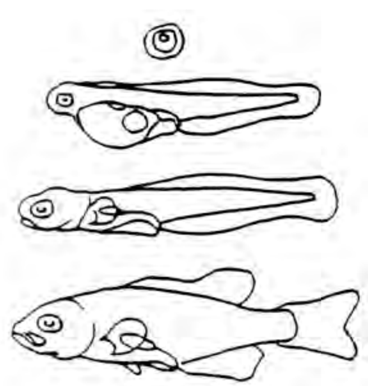
Spherical, large (3 mm in diameter).
Yolk yellowish, with single oil globule.
Large perivitelline space.
Meroblastic cleavage.
Semidemersal.

Larvae

Body elongate, chunky.
Yolk sac large, oval, with a single oil globule.
Anus midway.
Sharp teeth.
Low myomere count (ca. 25).

Juveniles

Body elongate.
Mouth terminal and large, sharp teeth.
Gut straight.
Two dorsal fins.



CENTRARCHIDAE, sunfishes.

Eggs

Spherical.
Yolk yellowish, granular, with single large oil globule.
Meroblastic cleavage.
Demersal, highly adhesive.

Larvae

Body elongate.
Thoracic yolk sac, with single oil globule.
Anus slightly anterior.
Gut coiled or twisted, air bladder distinctive.

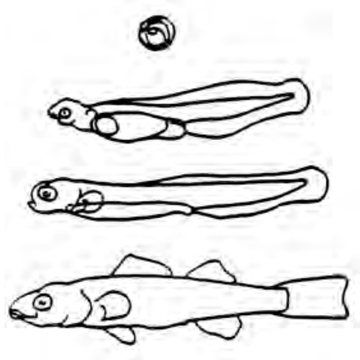
Juveniles

Body deep to elongate, laterally compressed.

Anus midway.

Two connected dorsal fins.

PERCIDAE, perches



Eggs

Spherical.

Yolk yellowish, clear, with single oil globule.

Demersal, adhesive.

Larvae

Body elongate.

Yolk sac elongate, thoracic, with single oil globule.

Anus slightly posterior.

Gut elongate, straight.

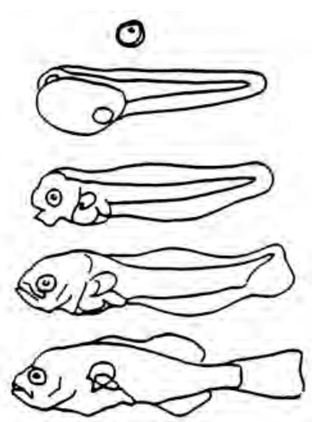
High myomere count (ca. 40).

Juveniles

Body elongate, cylindrical.

Two separated dorsal fins.

SCIAENIDAE, drums



Eggs

Spherical, small (ca. 1 mm in diameter).

Yolk yellowish-whitish, clear, with single oil globule.

Meroblastic cleavage.

Pelagic in coastal waters.

Larvae

Body short, high finfolds.

Head large, body tapers off.

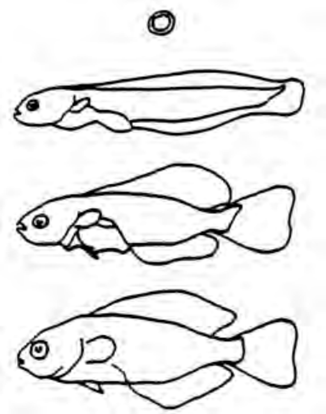
Anus thoracic.

Teeth sharp.

Juveniles

Body deep.

Caudal fin pointed.



EMBIOTOCIDAE, surfperches

Eggs (embedded in ovaries of females)

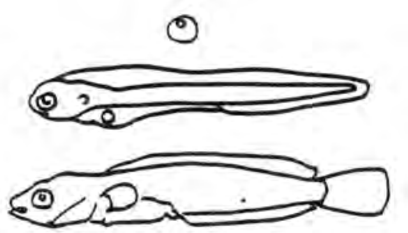
Spherical, small.
An oil globule may be present.
Modified holoblastic or meroblastic cleavage.

Larvae (embedded in ovaries of females).

Body elongate (similar to tadpoles), with elongate unpaired fin rays.
Anus midway or anterior.
Large hind gut.

Juveniles

Body deep, elongate unpaired fin rays.
Two connected dorsal fins.
Body with sparse or no pigmentation.



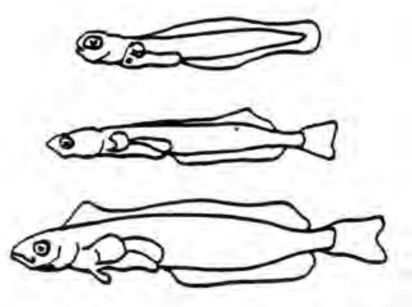
LABRIDAE, wrasses

Larvae

Body elongate.
Anus midway.

Juveniles

Body elongate.
Snout pointed, teeth modified into buckteeth.
Spiny and soft dorsal fins elongate and continuous.



CLINIDAE, clinids

Eggs

Spherical.
Yolk yellowish, with single oil globule.
Chorion attached to substrate by filaments.
Meroblastic cleavage.
Demersal, clustered.

Larvae

Body very elongate.

Anus anterior.

Series of melanophores along postanal region.

High myomere count (ca. 46-58).

Juveniles

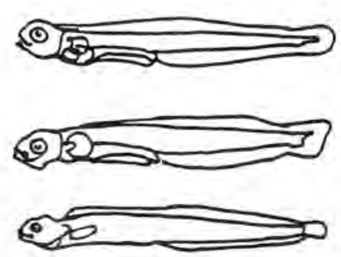
Body elongate, compressed, leaf-like.

Snout pointed.

Pelvics in jugular region.

Dorsal and anal fin elongate.

STICHAEIDAE, pricklebacks



Eggs

Spherical.

Yolk mostly white, yellow to gray, with single oil globule.

Meroblastic cleavage.

Clustered, Demersal.

Larvae

Body elongate.

Anus slightly anterior.

Melanophores mostly along midventral and postanal regions.

High myomere count (ca. 40-80).

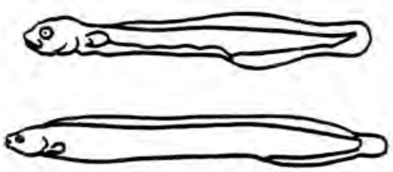
Juveniles

Body elongate, laterally compressed.

Dorsal fin, all spines.

Anal fin elongate, with sharp spine.

PHOLIDAE, gunnels



Eggs

Spherical.

Yolk whitish, granular.

Meroblastic cleavage.

Demersal, clustered.

Larvae

Body elongate.

Anus slightly posterior.

Series of melanophores along postanal region.

Very high myomere count (ca. 80-110).

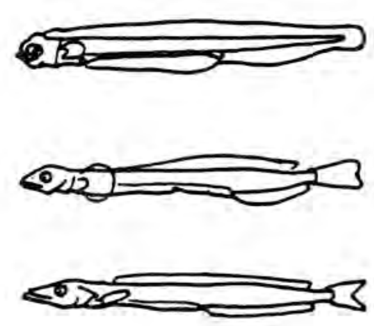
Juveniles

Body elongate, leaf-like.

Pelvic fin absent or with one spine and one ray.

Dorsal fin extends from head to tail, entirely spiny.

Anal fin elongate, with sharp spine.



AMMODYTIDAE, sea lances

Larvae

Body very elongate, with high finfolds.

Anus slightly posterior.

Melanophores along dorsal surface of gut and postanal regions.

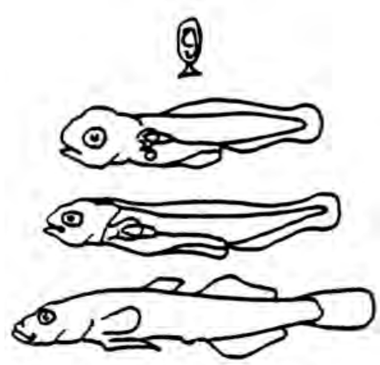
Juveniles

Body elongate, stick-like.

Snout pointed, and lower jaw projected.

Dorsal fin elongate, spines absent.

No pelvic fin.



GOBIIDAE, gobies

Eggs

Elliptical or tear-drop shape.

Yolk yellowish, granular, with oil globules.

Meroblastic cleavage.

Demersal and attached to roof of underground burrow.

Larvae

Body short.

Spherical, thoracic yolk sac, with single oil globule.

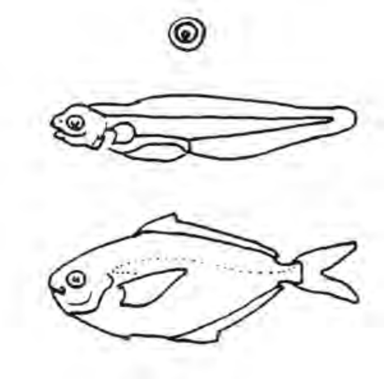
Anus midway.

Melanophores along postanal region.

Mostly pelagic.

Juvenile

Body elongate, cylindrical.
Pelvics modified into sucking disc.
Two separated dorsal fins.
Mostly benthic.



STROMATEIDAE, butterfishes

Eggs

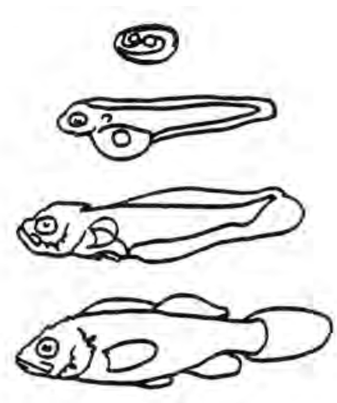
Spherical.
Yolk yellowish.
Meroblastic cleavage.

Larvae

Body elongate, with high finfolds.
Anus slightly anterior.
Lower myomere count (ca. 29-31).

Juveniles

Body deep.
Dorsal and anal fins elongate.
Pelvic fins absent.



SCORPAENIDAE, scorpionfishes

Eggs (embedded in ovaries of females)

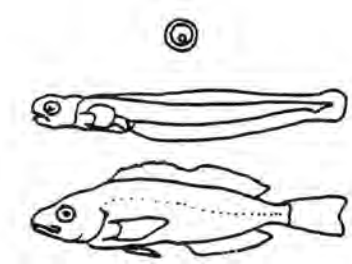
Spherical to elliptical.
Yolk yellowish, with single oil globule.
Meroblastic cleavage.

Larvae (partial development in ovaries of Sebastes spp. females)

Body elongate, with high finfolds.
Spherical, thoracic yolk sac, with single large oil globule.
Anus near thoracic region.
Low myomere count (ca. 26-30).

Juveniles

Body deep.
Eye and head large, numerous spines on head.
Two connected dorsal fins.



HEXAGRAMMIDAE, greenlings

Eggs

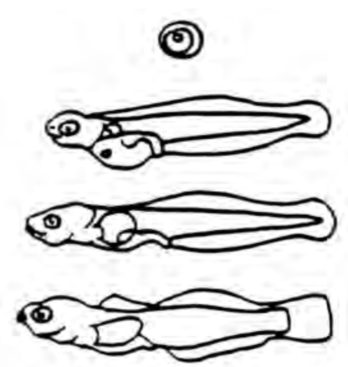
Spherical, large (ca. 2.0 mm in diameter).
Chorion very thick.
Meroblastic cleavage.
Clustered, demersal.

Larvae

Body elongate.
Yolk, yellow to green to blue with single oil globule.
Anus anterior.
Pigmentations heavy, particularly along middorsum.

Juveniles

Body elongate to deep, heavily pigmented.
Snout pointed.
Single to multiple lateral line systems.



COTTIDAE, Sculpins

Eggs

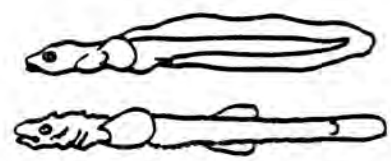
Spherical, large (1.5 mm in diameter).
Yolk yellow to greenish to various colors, with single oil globule
Meroblastic cleavage.
Demersal and clustered.

Larvae

Body elongate.
Large thoracic yolk sac.
Anus in thoracic region.
Long tail.
Gut coiled, air bladder absent.

Juveniles

Body elongate, cylindrical, tapers off.
Head large.
Pelvic fins never form disc.
Two connected dorsal fins.



AGONIDAE, poachers

Eggs

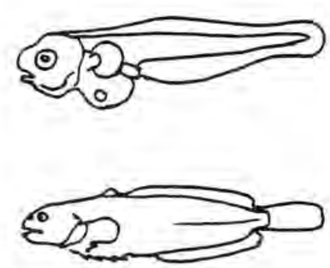
Spherical.
Chorion very thick.
Meroblastic cleavage.
Demersal.
Prolonged incubation period.

Larvae

Body thin, slender, heavily pigmented.
Anus anterior.
Very large pigmented pectorals.

Juveniles

Body elongate, covered with bony plates which do not overlap (resemble alligators).
Snout protrudes.
Two separated dorsal fins.



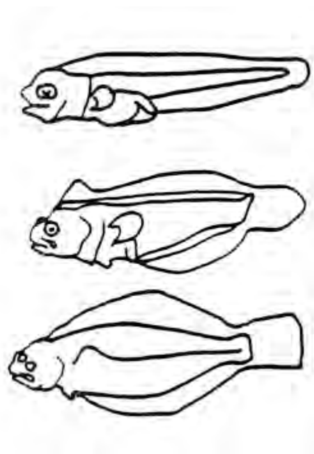
CYCLOPTERIDAE, snailfishes

Larvae

Body short and deep.
Large pectoral fin bud.
Anus anterior.
Scattered melanophores on body, and a series melanophores along postanal region.

Juveniles

Body short, stubby, and cylindrical.
Pelvic fins modified into an adhering disc.
Pectoral fin wide and large.
Scaleless.



BOTHIDAE, lefteye flounders

Eggs

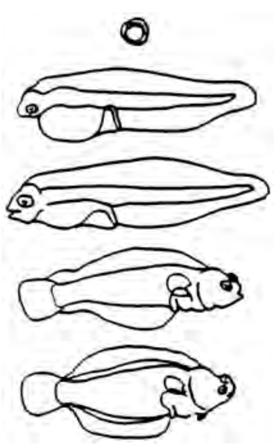
Spherical.
Oil globule present or absent.
Meroblastic cleavage.
Pelagic or demersal.

Larvae

Both thin, slender, bilaterally symmetrical, high finfolds.
Anus near thoracic region.
Long tail.
Gut coiled.

Juveniles

Body deep, flat, asymmetrical.
Eyes usually on left side.
Very elongate dorsal and anal fins, separated form caudal fin.



PLEURONECTIDAE, righteye flounders

Eggs

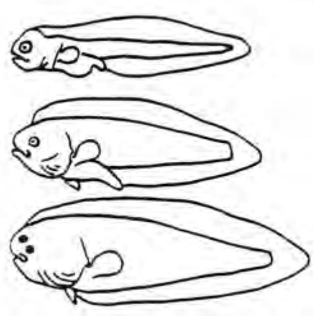
Spherical.
Oil globule may be present.
Meroblastic cleavage.
Pelagic or demersal.

Larvae

Body elongate, bilaterally symmetrical, high finfolds, pigmentation on body and finfolds.
Anus midway or thoracic.
Gut coiled.

Juveniles

Body deep, flat, asymmetrical.
Eyes usually on right side.
Dorsal and anal fins elongated, separated from caudal fin.



CYNOGLOSSIDAE, tonguefishes

Larvae

Body thin, slender, high finfolds, pigmentation.

Anus anterior or thoracic.

Gut coiled.

Juveniles

Body deep, flat, asymmetrical.

Eyes on left side.

Dorsal, caudal, and anal fins connected as one continuous fin.

Gut elongated in early juveniles.

Pectoral fin degenerate.

SPECIES ACCOUNTS

1. Petromyzontidae – Lampreys

Lampreys have no jaws. At least three species of lamprey are found in the Sacramento-San Joaquin River system. Pacific lamprey, *Lampetra tridentata*, is a common parasitic lamprey in Pacific coastal waters; the river lamprey, *Lampetra ayresi*, also a parasitic lamprey, is less common. Ammocoetes of either Pacific brook lamprey or Kern brook lamprey have been collected in upper San Joaquin River in Millerton Lake. Pacific brook lamprey, *Lampetra pacifica*, is a nonparasitic freshwater species, which was described by Vladykov in 1973; Kern brook lamprey, *Lampetra hubbsi*, is also a nonparasitic freshwater lamprey, described by Vladykov and Kott in 1976.

References

Vladykov 1973; Vladykov and Kott 1976.

RIVER LAMPREY, *Lampetra ayresi* (Gunther)

SPAWNING

Location	Small freshwater tributary streams of the Sacramento-San Joaquin River system (Moyle 1976), such as the Sonoma and Napa Rivers.
Season	April and May (Moyle 1976); April.
Temperature	ca. 13.0–13.5°C.
Salinity	Freshwater.
Substrates	Rocks and gravel
Fecundity	11,398–37,288 from specimens measuring 175 and 230 mm long (Scott and Crossman 1973).

CHARACTERISTICS

EGGS

Diameter	0.7 mm (Vladykov and Follett 1958).

AMMOCOETES (Figure 1-1)

Snout to anus length	ca. 84–86% of TL ammocoetes at 15.6–20.6 mm TL, ca. 73–75% of TL of ammocoetes at 128–130 mm.
Gill slits	7, with separate exterior openings.

Mouth	Inferior, disk-like funnel, with lip.
Teeth	None at this stage.
Total myomeres	120 or more from first gill slit to end of caudal region.
Trunk myomeres	65–70 (Vladykov and Follett 1958); average 67 (Moyle 1976); 66–70.
Pigmentation	Snout, head, and dorsum covered with light pigmentation; base of caudal fin surrounded by pigmentation.
Distribution	Free swimming or benthic; in lower Sacramento-San Joaquin River system, Cache Slough, the Delta, Suisun Bay, Montezuma Slough, and Sonoma River.

TRANSFORMING AND NEWLY TRANSFORMED ADULT (Figure 1-2).

Teeth	Supraoral lamina has 2 sharp cusps; infraoral lamina has 7–10 cusps (Vladykov and Follett 1958).
Dorsal fin	2, separated, but toughing with a low membrane.
Distribution	Transforming adults are free-swimming, newly transformed adults are free-swimming or parasitic. In the estuary, distribution of adults is similar to that of ammocoetes.

LIFE HISTORY

The anadromous river lamprey is found in coastal streams from San Francisco Bay to Taku River and Lynn Canal, Alaska (Vladykov and Follett 1958). In the study area, river lamprey have been reported in Mill Creek, Tehama County (Vladykov and Follett 1958), San Pablo Bay (Ganssle 1966), and Carquinez Strait (Messersmith 1966). This species was captured mostly in the upper portion of Sacramento-San Joaquin Estuary and its tributaries.

Vladykov and Follett (1958) stated that river lamprey spawn in small streams in April and May. During their spawning run, adults were observed in Sonoma and Napa Rivers although no eggs were collected.

River lamprey ammocoetes are morphologically similar to those of Pacific lamprey. This, coupled with their overlapping distributions, makes positive identification of ammocoetes very difficult. No information concerning incubation and development time exists. Ammocoetes burrow into sandy or muddy substrates near banks (Scott and Crossman 1973, Hart 1973, this study). Ammocoete stage lasts several years (Hart 1973). Ammocoetes have no teeth and feed on microscopic plants and animals (Scott and Crossman1973, Hart 1973). Ammocoetes, transforming adults, and newly transformed adults apparently spend some time in the water column, since they were collected in plankton nets in Suisun Bay, Montezuma Slough, and Delta sloughs. They were taken in midwater trawls in San Pablo Bay and Suisun Bay by Ganssle (1966) and in Carquinez Strait by Messersmith (1966).

Transformation to the adult form can occur when individuals are as small as 117 mm SL (Scott and Crossman 1973). The presence of river lamprey in collections made above dams, such as upper Sonoma Creek, would indicate that some river lamprey may spend their entire life in freshwater.

River lamprey are of no sport or commercial value (Fry 1973). Adults are parasitic in California rivers (Withler 1955, Kimsey and Fisk 1964, Hart 1973). There is no accurate assessment of damage to fish populations.

References

Fry 1973, Ganssle 1966, Hart 1973, Kimsey and Fisk 1964, Messersmith 1966, Moyle 1976, Scott and Crossman 1973, Vladykov and Follett 1958, Withler 1955.

PACIFIC LAMPREY, *Lampetra tridentata* (Gairdner)

SPAWNING

Location	Upper drainages of Sacramento-San Joaquin River system; below Friant Dam on San Joaquin River (Moyle and Nichols 1974); below Nimbus Dam and above Howe Avenue bridge crossing of American River; below Red Bluff Dam on Sacramento River; Napa River; below Boyes Spring Historical Park Dam on Sonoma Creek; above Concord Avenue bridge crossing of Walnut Creek.
Season	April through July in British Columbia (Pletcher 1963); April through July (Moyle 1976); in spring (Kimsey and Fisk 1964); April through June.
Temperature	15°C (Hart 1973); eggs and ammocoetes were collected at 13.0–18.5°C.
Salinity	Freshwater.
Substrates	Mostly gravel and rocks (Scott and Crossman 1973, Hart 1973, Moyle 1976); occasionally sand.
Fecundity	10,000–106,000, with an average of 34,000 (Pletcher 1963); may produce as high as 20,000–200,000 eggs (Moyle 1976).

CHARACTERISTICS

EGGS

Shape	Oval (Pletcher 1963); slightly elliptical and irregular.
Diameter	Long axis 1.12–1.24 mm; short axis 1.06–1.09 mm (Pletcher 1963); long axis 1.3–1.4 mm; short axis 1.1–1.5 mm.
Yolk	Cream yellow to pale greenish.
Oil globule	None.
Chorion	Clear, thick, rough.
Perivitelline space	Very narrow.
Egg mass	Deposited singly.
Adhesiveness	Adhesive (Scott and Crossman 1973); slightly adhesive.

AMMOCOETES (Figure 1-3)

Length at hatching	ca. 4–5 mm TL (judging by the smallest specimen taken from the nest in this study).
Snout to anus length	ca. 85–90% of TL of ammocoetes at 8.7 to 12.1 mm TL; ca. 82–84% of ammocoetes at 20.5–27.2 mm TL; ca. 70% of TL of ammocoetes at 133 mm TL.
Gill slits	7, open separately to exterior.
Mouth	Inferior, with lip or hood.
Teeth	None at this stage.
Total myomeres	ca. 120 or more, from the last gill slit to the end of the notochord.
Trunk myomeres	64–70 (Moyle 1976); 68–70.
Pigmentation	Melanophores on top of head, middorsum, dorsal area of gut and gill slits.
Distribution	Free-swimming or benthic in Sacramento and San Joaquin Rivers and their tributaries

TRANSFORMING AND NEWLY TRANSFORMED ADULT (Figure 1-4)

Teeth	Supraoral lamina has 3 cusps; infraoral lamina has 5 cusps (Hart 1973, this study); 5–8 cusps (Scott and Crossman 1973).
Trunk myomeres	63–70.
Dorsal fin	2, separated abruptly by a cleft (Hart 1973, Scott and Crossman 1973).

Distribution	Transforming adults are free-swimming. Newly transformed adults are probably free-swimming and become parasitic on fish when they reach the ocean. They range widely in Sacramento-San Joaquin Estuary and River system.

LIFE HISTORY

The Pacific lamprey, a parasitic anadromous species, has been found from Point Canoas, Baja California, to the Bering Sea and Japan (Fry 1973, Hart 1973, Miller and Lea 1972). Along the California coast, they are more abundant from Monterey northward (Moyle 1976). In the study area, Pacific lamprey were reported in the Sacramento-San Joaquin River system by Rutter (1908). In recent years, this species has been taken by trawl in San Francisco Bay (Aplin 1967), San Pablo Bay (Ganssle 1966), and Carquinez Strait (Messersmith 1966). In this study, Pacific lamprey were observed in Cache Slough, Lindsey Slough, Suisun Bay, American River (up to Nimbus Dam), Sacramento River (up to Red Bluff), Napa River, Sonoma Creek, and Walnut Creek.

The life history of this species in the British Columbia area has been reported by Pletcher (1963). The following information is a personal observation at a nesting site in Walnut Creek, unless otherwise noted. Spawning takes place in riffle areas where the current is swift. Both sexes construct the nest in gravel and occasionally use sandy substrates. The depth of water at nest sites is usually less than 1 m. The diameter of the nest is about 54–58 cm (Scott and Crossman 1973) or 40–60 cm (Moyle 1976). The nest is slightly larger than total length of the lampreys. Some nests are higher and piled with more gravel on downstream side than upstream edge. During mating, female attaches to a rock on upstream side of nest and the male attaches to the head of the female (Scott and Crossman 1973), or both attach to rocks and lie close to each other, but are not necessarily parallel to current flow. Both of them “vibrate” rapidly for a few seconds when milt and eggs are released (Scott and Crossman 1973). Eggs are slightly adhesive, and cannot sustain rapid current. As a result, most eggs are washed into crevices of the rocks on the downstream side of nest. Hatching occurs in about 19 days at 15°C (Hart 1973). Males may mate with more than one female in different nests (Pletcher 1963). In the American River, many lamprey nests were found in close proximity. During disturbances, lampreys move between adjacent nests. Adults die after spawning (Scott and Crossman 1973, Moyle 1976, this study). Eggs of California roach and Sacramento sucker were occasionally observed in lamprey nests.

The caudal region of the newly hatched ammocoete is initially bent ventrally, but straightens within a short time. The ammocoetes remain in the crevices of rocks, and then swim up into the current. Ammocoetes are carried to suitable areas of soft mud and sand (Moyle 1976). They are also found in areas of coarse sand. They burrow tail first into substrates or sometimes lie on top of substrates and move from one place to another. Ammocoetes are filter feeders, subsisting on algae and organic matter (Moyle 1976). The ammocoete stage may last 5–6 years (Scott and Crossman 1973, Hart 1973) or

3–7 years (Moyle 1976). They are found in freshwater streams and estuaries as free swimmers. They are more often observed during winter and spring high flow seasons.

McPhail and Lindsey (1970) described the physical changes of transformation of ammocoetes into predatory adults, which occur when they are about 14–16 cm in length. The lip or oral hood becomes an oral sucking disc, flanked by a series of leaflike lamillae on the disc. Horny plate (or teeth) appear in the mouth, the eyes enlarge, and the snout enlongates. When transformation is completed, downstream migration begins, usually in spring (Hart 1973), and lampreys become parasitic when they arrive in the ocean.

The parasitic life lasts about 1–2 years before they return to freshwater (Scott and Crossman 1973, Moyle 1976). In the Trinity River, upstream migration starts in August and September (Moffett and Smith 1950) or July to September (Scott and Crossman 1973). During a wine spill in the Napa River in mid–October 1979, many intoxicated adult lampreys were collected in this study. Apparently they were the prospective 1980 spawners.

The Pacific lamprey during its parasitic life stage causes damage to marine fishes, including striped bass and salmon (Kimsey and Fisk 1964), but the mortality is low. Fry (1973) commented that West Coast fish and lampreys have lived with (and on) each other for many generations and are well adjusted to the relationship. Pacific lampreys are of no sport or commercial value, although they were once eaten by California Indians, and some species in Europe are considered a delicacy (Moyle 1976).

References

Aplin 1967, Fry 1973, Ganssle 1966, Hart 1973, Kimsey and Fisk 1964, McPhail and Lindsey 1970, Messersmith 1966, Miller and Lea 1972, Moffett and Smith 1950, Moyle 1976, Moyle and Nichols 1974, Pletcher 1963, Rutter 1908, Scott and Crossman 1973.

PACIFIC BROOK LAMPREY, *Lampetra pacifica* Vladykov or KERN BROOK LAMPREY, *Lampetra hubbsi* (Vladykov and Kott)

SPAWNING

Location	Upper San Joaquin River between Kerckhoff Dam and its junction with Millerton Lake.
Season	Judging from ammocoetes taken, spawning season is estimated to be from July through September.
Temperature	Ammocoetes were taken at water temperature 15.0–17.5°C.
Salinity	Freshwater.

CHARACTERISTICS

AMMOCOETES (Figure 1-5)

Snout to anus length	ca. 88–90% TL of ammocoetes at 7.3–9.1 mm TL; ca. 84–87% of TL of ammocoetes at 9.2–12.2 mm TL.
Gill slits	7, opening separately to exterior.
Mouth	Inferior, funnel-like, with hood or lip on lateral and dorsal sides.
Gut	Straight, bending ventrally in anal region.
Teeth	None at this stage.
Total myomeres	ca. 80+ for specimens at 8.5–9.1 mm TL; ca. 90+ for specimens at 10.3 mm TL; ca. 100+ for specimens at 12.2 mm TL.
Trunk myomeres	53–58.
Pigmentation	Scattered melanophores on snout, head, middorsum, gill slits, lateral surface of gut, and postanal regions for specimens less than ca. 10 mm TL; pigmentation is much lighter for specimens greater that 10 mm TL.
Distribution	Upper San Joaquin River below Kerckhoff Dam, at its junction with Millerton Lake.

LIFE HISTORY

Between July and September 1979–1982, a total of 87 ammocoetes (range of 7.3–12.2 mm TL) was collected in upper San Joaquin River from below Kerckhoff Dam to the junction with Millerton Lake. The trunk myomere count (53–58) of those specimens fits description for ammocoetes of either the Pacific brook lamprey, a nonparasitic lamprey reported by Rutter (1908) and Dill (1946) to inhabit upper San Joaquin River prior to construction of Friant Dam, or the Kern brook lamprey, also a nonparasitic lamprey, recently discovered in Friant-Kern Canal near Delano (Vladykov and Kott 1976). The Friant-Kern Canal is connected to Millerton Lake and upper drainages of San Joaquin River through extensive irrigation systems. No adult specimens of either species were captured in Millerton Lake, and identification of specimens remains unresolved.

References

Dill 1946, Rutter 1908, Vladykov and Kott 1976.

Characteristic Comparison: Lampreys

			Lampetra spp.	
Characteristic	**River Lamprey**	**Pacific Lamprey**	**Pacific Brook Lamprey**	**Kern Brook Lamprey**
Ammocoetes				
Trunk myomeres	65–70	64–70	52–57	53
Myomeres under 1st dorsal fin	16–18	19	53–58 for Lampetra spp.	
Adults				
Trunk myomeres	60–71	63–70	53–58	54–57
Supraoral lamina (cusps)	2	3	2	2-3
Infraoral lamina (cusps)	7–9	5–8	6–9	5

Figure 1.—Petromyzontidae: Lampreys.

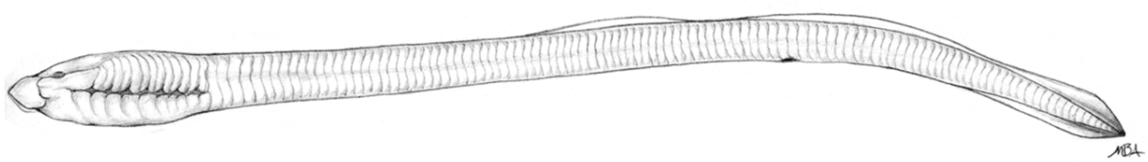


FIGURE 1-1.—River lamprey *Lampetra ayresii* ammocoete, 133 mm TL.

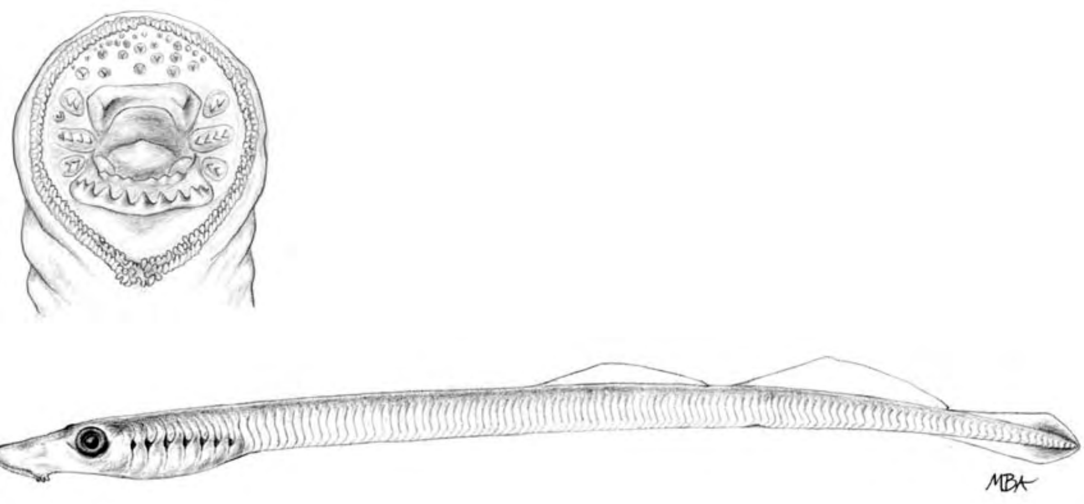


FIGURE 1-2.—River lamprey *Lampetra ayresii* transforming and newly transformed adult, 127 mm TL.

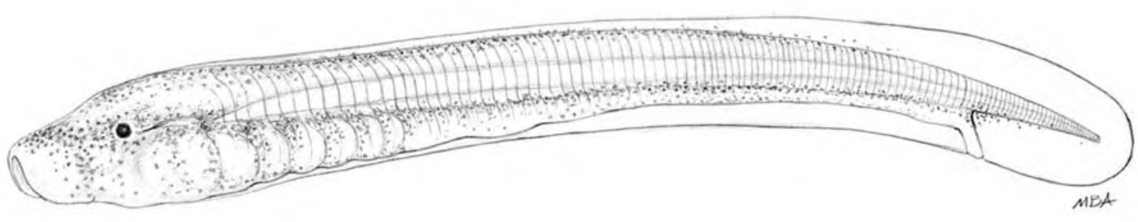


FIGURE 1-3.—Pacific lamprey *Lampetra tridentata* ammocoete, 8.7 mm TL.

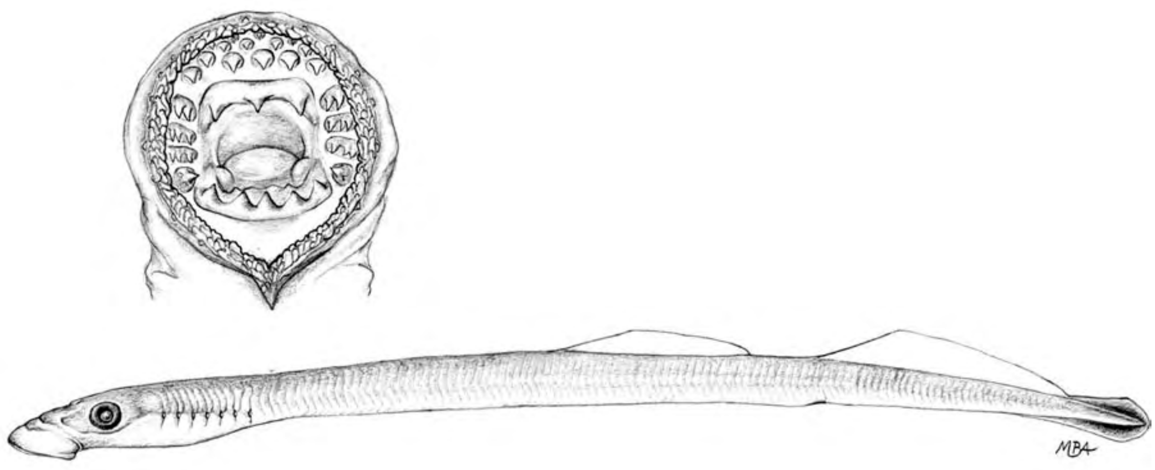


FIGURE 1-4.—Pacific lamprey *Lampetra tridentata* adult, 170 mmTL.

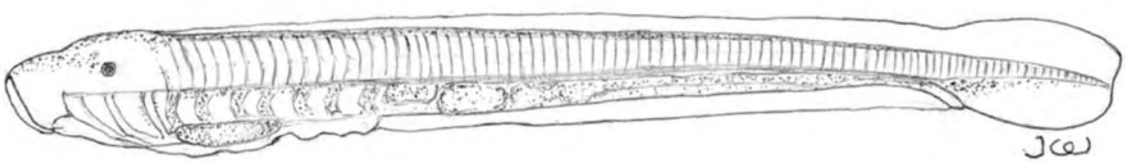


FIGURE 1-5.—Pacific brook lamprey or Kern brook lamprey *Lampetra* spp. ammocoete, 10.4 mm TL.

2. Acipenseridae – Sturgeons

Seven species of sturgeon have been reported in North America, and two of them are found in California water: green sturgeon, *Acipenser medirostris*, and white sturgeon, *Acipenser transmontanus*. Both are anadromous and native to the Sacramento-San Joaquin Estuary (Pycha 1956, Skinner 1962, Moyle 1976, Shapovalov *et al.* 1981). Green sturgeon are not commonly found in the estuary, and its life history is poorly documented; white sturgeon, on the other hand, is common and its life history, particularly the early life history, has been well studied (*e.g.*, Doroshov *et al.* 1983).

References

Doroshov *et al.* 1983, Moyle 1976, Pycha 1956, Shapovalov *et al.* 1981, Skinner 1962.

GREEN STURGEON, *Acipenser medirostris* Ayres

SPAWNING

Location	In upper Klamath River (Fry 1973); just above Orleans on Klamath River (Moyle 1976); upper Sacramento River (Fry 1973); tributaries to Sacramento River such as Feather, Yuba, and American Rivers.
Season	Middle of June to middle of July in Datta River, USSR (Scott and Crossman 1973); spring and early summer in Klamath River (Moyle 1976). Similar season to white sturgeon and may be slightly delayed in cold water streams (S. Doroshov 1982, personal communication).

CHARACTERISTICS

JUVENILES (Figure 2-1)

Dorsal fin	33–42 (Miller and Lea 1972); 33–35 (Scott and Crossman 1973); 33–36 (Hart 1973, Moyle 1976).
Anal fin	22–29 (Miller and Lea 1972); 22–28 (Scott and Crossman 1973, Hart 1973, Moyle 1976).
Pectoral fin	I, 31–34; pectoral spine is fused by 2–3 pectoral rays.
Dorsal bony plate	8–11 (Miller and Lea 1972, Moyle 1976); 9–11 (Scott and Crossman 1973); 7–11 (Hart 1973).
Lateral bony plate	23–30 (Miller and Lea 1972; Scott and Crossman 1973, Hart 1973, Fry 1973, Moyle 1976).

Ventral bony plate	7–10 (Miller and Lea 1972, Scott and Crossman 1973, Moyle 1976); 7–11 (Hart 1973).
Mouth	Ventral, directed down, transverse (Hart 1973); toothless, protruding, and sucker-like, on ventral side beneath eyes (Fry 1973)
Distribution	Delta, Suisun Bay, San Pablo Bay, and San Francisco Bay

LIFE HISTORY

The green sturgeon has been found from Ensenada, Mexico, to the Bering Sea and Japan (Miller and Lea 1972). They are also found along the North Pacific coasts of Korea, China, and the Amur River of the USSR (Berg 1948). In study area, green sturgeon were reported in San Francisco Bay (Aplin 1967), San Pablo Bay (Ganssle 1966, Miller 1972a); and lower San Joaquin River and Delta (Radtke 1966b). They were also recorded in Tomales Bay (Bane and Bane 1971) and Bodega Bay (Standing *et al.* 1975). Green sturgeon juveniles were collected in San Francisco up to lower reaches of Sacramento-San Joaquin Rivers and Delta, including intakes of Tracy Pumping Station (A. Pickard 1982, personal communication).

At present, biologists are unsure of spawning locations of green sturgeon. Spawning has been reported at 1.5 km above Orleans on the Klamath River (Moyle 1976) and in upper inland streams of large rivers such as Sacramento and Klamath Rivers (Fry 1973; Doroshov 1982, personal communication). The early developmental biology of this species is essentially unreported. Stevens and Miller (1970), who collected a total of 85 yolk-sac larvae of Acipenser spp. in the lower reaches of the Sacramento and San Joaquin Rivers and Suisun Bay, believed the majority of them to be white sturgeon (L. Miller 1982, personal communication). The smallest of the fish identified as green sturgeon were 20–22 cm FL and were captured by gill net and trawl from 1963–1964 by Radtke (1966b). The origin of those juveniles was probably the upper Sacramento River (Fry 1973). Diet of juvenile sturgeon consists mostly of amphipods and mysid shrimps in the Delta (Radtke 1966b).

Little is known about age and growth of green sturgeon. The 138 green sturgeons collected in Sacramento and San Joaquin Rivers and Suisun Bay by Radtke (1966b) ranged from 20 to 58 cm FL, with two apparent size groups in this range.

Green sturgeon’s flesh is darker than that of white sturgeon, and it is considered to be of inferior eating quality. Some sport fishing for green sturgeon is observed in the Klamath River (Fry 1973).

References

Aplin 1967; Bane and Bane 1971; Berg 1948; Fry 1973; Ganssle 1966; Standing *et al.* 1975; Hart 1973; Miller 1972a; Miller and Lea 1972; Moyle 1976; Radtke 1966b; Scott and Crossman 1973; Stevens and Miller 1970.

WHITE STURGEON, *Acipenser transmontanus* Richardson

SPAWNING

Location	Upper Sacramento River and Feather River (Stevens and Miller 1970, Moyle 1976); Sacramento River above the Delta (Fry 1973); mostly in Sacramento River between Knights Landing and Colusa (Kohlhorst 1976); eggs were collected in Sacramento River between Freeport and Rio Vista; major spawning occurs between Freeport and Colusa on Sacramento River (P. Lutes 1982UC, personal communication).
Season	Mid-February to late May (Kohlhorst 1976); March through June (Moyle 1976); spring through summer (Dees 1961, Hart 1973); May and June (Scott and Crossman 1973); eggs were collected in April and May.
Temperature	7.8–17.8°C, peaking at 14.4°C (Kohlhorst 1976); 10–22°C (Moyle 1976); 8.9–16.7°C (Scott and Crossman 1973); ambient temperature at hatchery 12–16°C (Beer 1981); hatchery temperature 12–19°C (P. Lutes 1982, personal communication); 14–15°C during the peak of catch of Acipenser spp. larvae (Stevens and Miller 1970).
Salinity	Freshwater.
Substrates	Rocky bottom (Scott and Crossman 1973); over sandy or muddy bottom (S. Doroshov 1980, UC Davis, personal communication, 1980); hard clay and other various substrates (P. Lutes, UC Davis, personal communication, 1982).
Fecundity	3–4 million (Migdalski 1962); 700,000 (Scott and Crossman 1973); ca. 3 million eggs for a 3-m-long 50–year-old female (Dees 1961); 100,000 (Moyle 1976); 3,000–12,000 eggs per kg per batch, and several batches of eggs can be produced by a single female during spawning (P. Lutes, UC Davis, personal communication, 1982).

CHARACTERISTICS

EGGS (Figures 2-2, 2-3)

Shape	Spherical, oval, or slightly irregular; unfertilized eggs ovoid (Beer 1981).

Diameter	Unfertilized eggs, short axis 3.3 mm, long axis 3.6 mm; fertilized eggs with jelly coat, short axis 3.8 mm and long axis 4.0 mm (Beer 1981); fertilized eggs, short axis 3.3–3.5 mm and long axis 3.5–4.0 mm.
Yolk	Overall, slate gray, animal pole whitish (Beer 1981); brown (Scott and Crossman 1973): dark gray brown with light yellow spots at animal pole.
Oil globule	None (Cherr and Clark 1982).
Chorion	Clear, thick with 4 layers (Cherr and Clark 1982).
Perivitelline space	Prominent at animal pole (Beer 1981); overall, narrow
Egg mass	Assumed to be broadcasted singly (P. Lutes 1982, personal communication).
Adhesiveness	Adhesive (Beer 1981); sticky (Scott and Crossman 1973); more substrates attached to vegetable pole.
Buoyancy	Demersal.

LARVAE (Figures 2-4, 2-5)

Length at hatching	Mean length (TL) 11.0 mm (Beer 1981); 10.0–11.1 mm TL.
Snout to anus length	ca. 68–70% of TL of prolarvae at 10.0–11.1 mm TL; ca. 56–59% of late prolarvae at 16.7–17.8 mm TL; ca. 53% of TL of larvae at 31.0 mm TL.
Yolk sac	Ovoid, light pigmentation on ventral surface; dark pigmentation on dorsal and posterior portions (Beer 1981); gray-yellowish, very large, extends from jugular to mid-abdominal region.
Oil globule	None.
Gut	Straight.
Size at completion of yolk-sac stage	ca. 15.5–15.8 mm TL (Beer 1981); 17.6–18.5 mm for Acipenser spp. larvae (Stevens and Miller 1970, Kohlhorst 1976).
Total myomeres	Newly hatched larvae, 55–60 somites (Beer 1981); ca. 60+ to 70+ for larvae less than 31.0 mm TL.
Preanal myomeres	37–40.
Postanal myomeres	ca. 25+ to 30+.
Last fin to complete development	Pelvic.

Pigmentation	Newly hatched larvae, scattered melanophores on side of body and head (Beer 1981); prolarvae, scattered melanophores on head, body, lateral portion of yolk sac; eye is a dark pit; late prolarvae, melanophores on head, body, and finfolds except the ventral side of yolk sac and barbels; in postlarvae, pigment covers entire body.
Distribution	Initially pelagic, becoming demersal when pectoral fins are fully developed (Beer 1981); channels and deeper waters near bottom in lower reaches of Sacramento and San Joaquin River and Delta (Stevens and Miller 1970, this study); near bottom in upper Sacramento River (Kohlhorst 1976).

JUVENILES (Figure 2-6)

Dorsal fin	44–48 (Miller and Lea 1972, Scott and Crossman 1973, Hart 1973, Moyle 1976).
Anal fin	28–31 (Miller and Lea 1972, Hart 1973, Moyle 1976); 28–30 (Scott and Crossman 1973).
Pectoral fin	I, 35–39. The pectoral spine consists of at least 3 fused pectoral rays.
Dorsal bony plate	11–14 (Miller and Lea 1972, Scott and Crossman 1973, Hart 1973).
Lateral bony plate	38–48 (Miller and Lea 1972, Scott and Crossman 1973, Hart 1973, Moyle 1976).
Ventral bony plate	9–12 (Miller and Lea 1972, Scott and Crossman 1973, Hart 1973, Moyle 1976).
Mouth	Ventral, toothless, wide and tranverse (Scott and Crossman 1973, Hart 1973); on ventral side, a short distance behind the eyes (Fry 1973).
Distribution	From San Francisco Bay to Sacramento and San Joaquin Rivers and Delta, most of them concentrating in upper estuary.

LIFE HISTORY

White sturgeon are found from Ensenada, Mexico, northward to the Gulf of Alaska (Miller and Lea 1972), but they are rare south of Monterey (Fry 1973). In the study area, white sturgeon have been reported in San Francisco Bay (Aplin 1967), San Pablo Bay (Pycha 1956, Ganssle 1966), Carquinez Strait (Messersmith 1966), lower reaches of Sacramento and San Joaquin Rivers and Delta (Radtke 1966b, Stevens and Miller 1970, Miller 1972), and at Tracy Pumping Plant (A. Pickard 1982, personal communication). In this study, white sturgeon were observed from the vicinity of Red Bluff on the

Sacramento River to intake areas of Potrero and Hunters Point Powerplants on San Francisco Bay, but most of the specimens were captured by bottom trawl in Suisun Bay and the Delta.

Spawning occurs from February through June (Kohlhorst 1976, Moyle 1976). Suitable water temperatures are 12–15°C (Beer 1981). The major spawning locations are in the Sacramento River between Freeport and Colusa (Kohlhorst 1976; P. Lutes 1982, personal communication). This species may also use Feather River as spawning ground (Moyle 1976, Kohlhorst 1976). In this study, white sturgeon eggs were also collected between Rio Vista and Freeport on Sacramento River in April and May 1978. Water temperatures were 13.0–13.5°C at the bottom at the collecting sites, the depth of the channel was over 10 m, and river had considerable flow.

The eggs are adhesive (Scott and Crossman 1973, Beer 1981). Egg chorion is very thick and has 3–15 micropyles (Cherr and Clark 1982). Sturgeon eggs go through holoblastic (unequal) cleavages. Details of embryonic development and early life stages of white sturgeon are well documented by Beer (1981). Eggs hatch in a little over 4 d at 16°C (Beer 1981) or 8–12 d at 12°C (P. Lutes 1982, personal communication).

Average TL of newly hatched larvae is 11.0 mm, with a large yolk sac and small, underdeveloped eyes (Beer 1981). Larvae swim vertically after hatching, and a few days later swim in a horizontal position (Beer 1981). Initial behavior of vertical swimming is estimated to be the result of downstream drifting (Beer 1981). When pectoral fin is well developed, sturgeon larvae swim near the bottom (S. Doroshov 1980, personal communication; Beer 1981). Yolk sac is absorbed after 7–10 d, depending on water temperature.

The majority of white sturgeon larval population is believed to be in the upper Sacramento River. Stevens and Miller (1970) collected 85 yolk-sac larvae and larvae of Acipenser spp. in the lower reaches of Sacramento River, lower San Joaquin River, Delta, and Suisun Bay during the 1966–1967 sturgeon survey; Kohlhorst (1976) collected 9 eggs and 246 larvae of Acipenser spp. between the mouth of Feather River and Colusa on the Sacramento River in 1973. The bulk of those collections are believed to be white sturgeon (Stevens and Miller 1970, Kohlhorst 1976). In this study, a total of 2 eggs and 11 larvae were collected in Sacramento River below Freeport and downstream to Suisun Bay. Larvae collected in the field are found to be identical to white sturgeon larvae artificially hatched at UC Davis.

Juvenile sturgeon achieve fully developed bony plates at about 40 mm TL. Juvenile sturgeon this size and larger were commonly captured by trawl in Montezuma Slough, in vicinity of Contra Costa and Pittsburg Powerplants, and lower reaches of the Sacramento-San Joaquin Rivers. Pycha (1959) reported that young sturgeon are nonmigratory, but Bajkov (1951) and Scott and Crossman (1973) have suggested that juveniles moved upstream in late summer and fall and moved downriver in spring and summer. The primary purpose of the migration may be for feeding. In the Sacramento-San Joaquin Estuary, Moyle (1976) described young sturgeon living mostly in the upper reaches of the estuary. Movements of this species in the mid-Columbia River were also studied by Haynes *et al.* (1978). Tagged white sturgeon from the Sacramento-San Joaquin Estuary have been recaptured in Oregon (Chadwick 1959); however, their migration patterns in the Pacific Ocean are not well documented.

Juveniles feed on mysid shrimps, amphipods (Schreiber 1962), small clams, polychaetes, and fish eggs (Ganssle 1966). Feeding is concentrated during the night; fish rests during the day (P. Lutes 1982, personal communication). Growth rate of larvae and juveniles on various artificial diets (pellets) have been studied by Monaco *et al.* (1981) and Buddington and Doroshov (1983).

Female white sturgeon generally mature at 11–12 years and 1.1–1.5 m FL; males become mature at a smaller size than females (Semakula and Larkin 1968, Moyle 1976). The most recent study (P. Lutes 1982, personal communication) found that male sturgeon reach sexual maturity as early as 3–4 years and females at 5 years. White sturgeon do not spawn every year; input energy for developing ova is apparently very large. The interval between spawning is about 4 years for young females and 9–11 years for older females (Scott and Crossman 1973). White sturgeon support an important sport fishery in the Sacramento-San Joaquin Estuary. Angler interest is more concerned with the flesh than the use of eggs for caviar. White sturgeon has the potential to be developed into an excellent aquaculture species through artificial propagation.

References

Aplin 1967, Bajkov 1951, Beer 1981, Buddington and Doroshov 1983, Chadwick 1959, Cherr and Clark 1982, Dees 1961, Fry 1973, Ganssle 1966, Hart 1973, Haynes *et al.* 1978, Kohlhorst 1976, Messersmith 1966, Migdalski 1962, Miller 1972, Miller and Lea 1972, Monaco *et al*. 1981, Moyle 1976, Pycha 1956, Radtke 1966b, Schreiber 1962, Scott and Crossman 1973, Semakula and Larkin 1968, Stevens and Miller 1970.

Characteristic Comparison: Sturgeons

Characteristic	**Green Sturgeon**	**White Sturgeon**
Juveniles		
Dorsal fin	1, 33–42	I, 44–48
Anal fin	22–29	28–31
Pectoral fin	I, 35	I, 35
Dorsal bony plate	8–11	11–14
Lateral bony plate	23–30	38–48
Ventral bony plate	7–10	9–12
Gill rakers of the first gill arch	18–20	34–36
Mouth	Inferior	Inferior
Barbels	Closer to mouth than to tip of snout	Closer to tip of snout than to mouth
Distribution	Sacramento-San Joaquin Estuary, occasionally in upper reaches	Sacramento-San Joaquin Estuary, particularly in upper reaches

Figure 2.—Acipenseridae: Sturgeons.

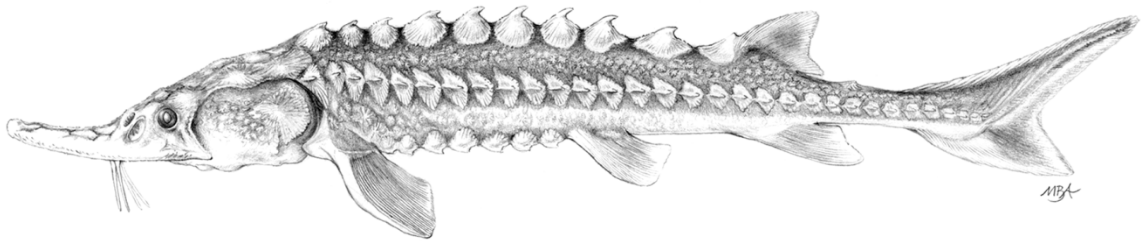


FIGURE 2-1.—*Acipenser medirostris*, green sturgeon juvenile, 275 mm TL.

FIGURE 2-2.—*Acipenser transmontanus*, white sturgeon egg, 4-cell stage, long axis 3.8 mm, short axis 2.6 mm diameter.

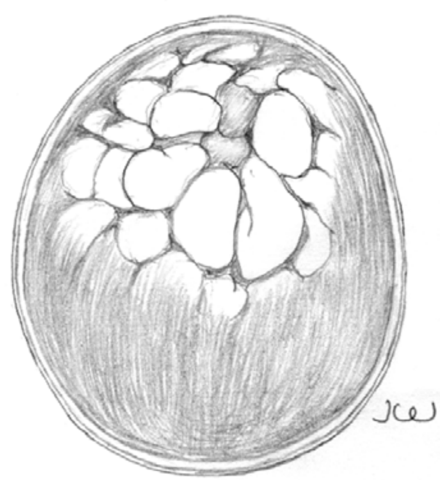


FIGURE 2-3.—*Acipenser transmontanus*, white sturgeon egg, morula, long axis 3.9 mm, short axis 3.3 mm diameter.

Acipenseridae: *Acipenser transmontanus*, white sturgeon.

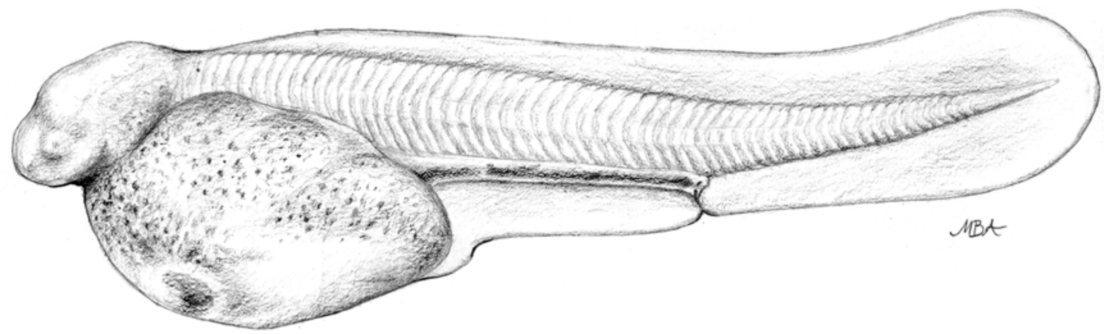


FIGURE 2-4.—Prolarva, 11.6 mm TL.

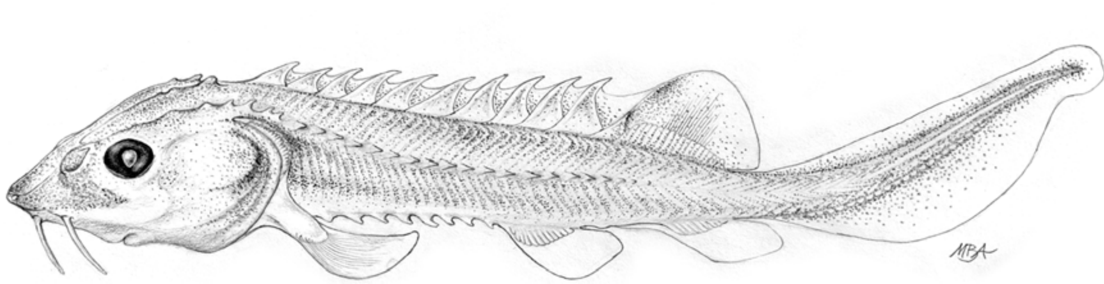


FIGURE 2-5.—Postlarva, 31 mm TL.

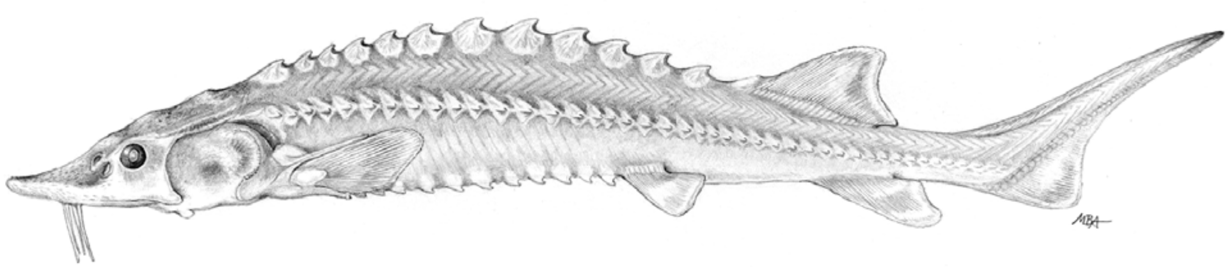


FIGURE 2-6.—Juvenile, 237 mm TL.

3. Clupeidae – Herrings

Three species of herrings are found in the study area: American shad *Alosa sapidissima*, an introduced anadromous fish; Pacific herring *Clupea harengus pallasi*, a native coastal marine fish; and threadfin shad *Dorosoma petenense*, an introduced euryhaline species.

AMERICAN SHAD, *Alosa sapidissima* (Wilson)

SPAWNING

Location	Main channel of Sacramento River, up to Red Bluff (Skinner 1962, Stevens 1972). Some individuals reach Keswick Dam on the Sacramento River (R.E. Painter 1979, personal communication), lower reaches of San Joaquin River and its tributaries, Mokelumne River, and Stanislaus River (Skinner 1962, Moyle 1976); a landlocked population has been found in upper San Joaquin River in Millerton Lake.
Season	Ripe females observed from February through June (Ganssle 1966); May through June (Erkkila *et al.* 1950); March through July (Skinner 1962, Stevens 1972); April through July, peaking in June and July in Sacramento-San Joaquin River system; and as late as September in upper San Joaquin River at Millerton Lake.
Temperature	Water temperatures of 8–26°C (Walburn and Nichols 1967); maximum 15–20°C (Skinner 1962, Stevens 1972); ca. 12–17 in upper San Joaquin River at Millerton Lake.
Salinity	Freshwater, possibly brackish water (Leim 1924).
Substrate	None. Egg survival is apparently higher when deposited over sandy and gravel areas (R.E. Painter 1979, personal communication).
Fecundity	155,000–410,000 (Reintjes and Hettler 1967); 2,000–150,000 (Scott and Crossman 1973); 30,000–300,000 (Moyle 1976).

CHARACTERISTICS

EGGS (Figures 3-1, 3-2, 3-3)

Shape	Spherical (Ryder 1887).

Diameter	2.5–3.8 mm (Marcy and Jacobson 1976); 2.5–4.4 mm.
Yolk	Pale amber to pink (Mansueti 1955), granular yolk (Bigelow and Welsh 1925, Lippson and Moran 1974); pale yellow to yellow, with coarse, granular yolk.
Oil globule	No oil globule (Lippson and Moran 1974, Wang and Kernehan 1979).
Chorion	Transparent (Mansueti 1955); transplant, smooth, and very thin.
Perivitelline space	Very wide, ca. ½ egg radius (Bigelow and Welsh 1925).
Egg mass	Broadcast singly.
Adhesiveness	Initially adhesive (Chittenden 1969); slightly adhesive (Wang and Kernehan 1979); later, non-adhesive (Hildebrand 1963).
Bouyancy	Demersal (Manuseti 1955, Hildebrand 1963); semi-demersal or slightly heavier than freshwater, suspended by water current (Wang and Kernehan 1979).

LARVAE (Figures 3-4, 3-5, 3-6)

Length at hatching	5.7–10 mm TL (Marcy and Jacobson 1976); 7.0–10.0 mm TL (Lippson and Moran 1974); ca. 6.5 mm TL (Wang and Kernehan 1979); ca. 6.5–10.0 mm TL.
Snout to anus length	ca. 80–83% of TL of prolarvae; ca. 73–80% of TL of postlarvae.
Yolk sac	Spherical, head detached from yolk (Ryder 1887); spherical to oval, in thoracic region.
Oil globule	None.
Gut	Straight, elongated, segmented.
Air bladder	Apparent in postlarval stage; shallow, located midway between pectorals and anus.
Teeth	None on jaw, one row develops in middle of tongue in late postlarvae.
Size at completion of yolk-sac stage	9–12 mm TL (Lippson and Moran 1974); ca. 10–12 mm TL.
Total myomeres	55–57 (Lippson and Moran 1974); 53–58.
Preanal myomeres	41–47 (Lippson and Moran 1974); 8–16.

Last fin(s) to complete development	Pectoral.
Pigmentation	Single row of dashed melanophores along jugular to thoracic region; stellate or dotted melanophores in midventral and dorsal gut region; scattered melanophores also found along postanal and caudal regions.
Distribution	Pelagic (Marcy and Jacobson 1976); newly hatched larvae gradually move to the sea (Moyle 1976); pelagic in the lower reaches of Sacramento River, Delta, Mokelumne River, Suisun Bay, and upper San Joaquin River at Millerton Lake.

JUVENILES (Figure 3-7)

Dorsal fin	15–19 (Miller and Lea 1972, Moyle 1976); 17–19 (Hildebrand and Schroeder 1928); 18–19 (R.L. Lavenberg 1980, personal communication).
Anal fin	19–23 (Miller and Lea 1972, Moyle 1976); 18–25 (Hill 1959); 19–21 (R.L. Lavenberg 1980, personal communication).
Pectoral fin	13–18 (Carscadden and Leggett 1975, Hill 1959).
Mouth	Terminal, upper jaw as long as lower jaw (Scott and Crossman 1973, Wang and Kernehan 1979); maxillary reaches midway of eye.
Vertebrae	55–58 for West Coast population (Miller and Lea 1972); 51–60 (Leim 1924, Hill 1959).
Distribution	Inshore as well as open water. Some remain in Delta for several months after hatching (Moyle 1976); some juveniles remain in estuary several months after hatching, and move to sea in fall and early winter.

LIFE HISTORY

American shad are anadromous and native to the Atlantic coast (Walburn and Nichols 1967). They were first introduced into the Sacramento River in 1871 and planted there for the next 10 years (Skinner 1962). Once established, American shad spread quickly along the West Coast. Their current distribution is from Todos Santos Bay, Baja California, to Alaska and Kamchatka, USSR (Miller and Lea 1972, Hart 1973).

In this study, American shad were found in the Sacramento River system, Delta, and San Joaquin River system. A successfully reproducing population was studied in Millerton Lake (C. Toole and M.A. Koeneke, Ecological Analysts, Inc.; D. Mitchell, CDFG; T. Lambert 1980, personal communications).

Prior to spawning, shad begin to enter the estuary as early as fall (Stevens 1972). Spawning runs occur in March. Potential spawners were captured in gill nets near Montezuma Slough and vicinity of Contra Costa and Pittsburg Powerplants. Actual Spawning takes place about 2–4 weeks later in main river channels from April through June (Stevens 1972).

Major spawning grounds in the estuary are above Rio Vista on the Sacramento River and its major tributaries, Feather and American Rivers. In the San Joaquin River system, the lower reaches of the San Joaquin River have not been used extensively for spawning (Hatton 1940) because of poor water quality, sluggish flow, and reverse flow of the river. Minor spawning was observed at the mouth of the Mokelumne River during this study.

Above the estuary, spawning of American shad was observed in the San Joaquin River at Millerton Lake from May through August. Spawning activities were observed from midnight to early morning hours, between the river's influx into Millerton Lake and the "plunge point," and were concentrated near shore and at the surface.

Eggs are semi-demersal (Mansueti 1958). A moderate current, about 1 m/s or less, will keep eggs floating. Eggs hatch in 17 days at 12°C (Ryder 1887) and in 8–12 days at 11–15°C (Scott and Crossman 1973).

Newly hatched larvae are pelagic and most abundant at the surface of water (Marcy and Jacobson 1976). Some larvae move downstream from spawning ground soon after hatching, since larvae were collected in the lower reaches of the Sacramento River and Suisun Bay, but the majority of the larvae remain in the river and Delta for several months (Stevens 1972).

In this study, downstream migration of large juveniles (about 70 mm TL) was reflected in the impingement samples collected at Contra Costa and Pittsburg Powerplants from October through January 1978–1979. Some small juveniles apparently move directly through the estuary in the summer months (Stevens 1972, Moyle 1976). Juvenile shad feed on copepods, related crustaceans, and insect larvae while in freshwater (Scott and Crossman 1973) and on mysid shrimps and amphipods while in the estuary (Stevens 1966).

American shad spend from 3–5 years in the ocean before they return to the river to spawn (Leim 1924, Moyle 1976). In Millerton Lake, individuals reach maturity in 2 or 3 years. In the Sacramento-San Joaquin Estuary a commercial fishery for American shad had developed by 1879, but commercial fishing was banned by the State of California in 1957 (Moyle 1976). A seasonal sport fishery has developed, especially on the American and Feather Rivers.

Life history of Atlantic coast American shad was investigated extensively by Leim (1924) and Leggett (1969, 1973). On the West Coast, substantial amount of information on the early life history of American shad in the Sacramento-San Joaquin Estuary have been compiled by CDFG as part of the Delta Fish and Wildlife Protection Study

(Chadwick 1958, Skinner 1962, Stevens 1966 and 1972). However, the life history of immature shad in the Pacific Ocean is still unclear. Moyle (1976) has suggested that wide distribution of shad in the West Coast may indicate extensive migrations take place similar to those of the Atlantic Ocean population. Some shad may remain in the Sacramento-San Joaquin Estuary throughout their life (R.E. Painter 1979, personal communication).

American shad in Millerton Lake are landlocked (von Geldern 1965), and thus cannot make the ocean-to-river spawning run. Instead, a potadromous migration has been noted between San Joaquin River and Millerton Lake. The shad population is generally found in the lake, but during the spawning run they move up to the narrow canyon portion of the river above (or east of) the lake, where there is a good flow from Kerkhoff Dam and Pacific Gas and Electric (PG&E) hydroelectric power house. Water flow in this area is important to spawning success, just as flow is important in streams above the estuary. All life stages have been collected from Millerton Lake, the only known landlocked American shad population in North America.

References

Bigelow and Welsh 1925; Cascadden and Leggett 1975; Chadwick 1958; Chittenden 1969; Erkkila *et al.* 1950; Ganssle 1966; Hart 1973; Hildebrand 1963; Hildebrand and Schroeder 1928; Hill 1959; Hatton 1940; Leggett 1969, 1973; Leim 1924; Marcy and Jacobson 1976; Lippson and Moran 1974; Mansueti 1955; Marcy and Jacobson 1976; Miller and Lea 1972; Moyle 1976; Reintjes and Hettler 1967; Ryder 1887; Scott and Crossman 1973; Skinner 1962; Stevens 1972; von Geldern 1965; Walburn and Nichols 1967; Wang and Kernehan 1979.

PACIFIC HERRING, *Clupea harengus pallasi* Valenciennes

SPAWNING

Location	Shallow intertidals and subtidals of bays, estuaries, and coastlines (Miller and Schmidtke 1956, Hardwick 1973, Eldridge and Kaill 1973). Particular locations in San Francisco Bay, north end of Golden Gate Bridge, Sausalito, Tiburon, Angel Island, Alcatraz Island, Treasure Island, and Richmond (Miller and Schmidtke 1956, Spratt 1976); minor spawning is also known in vicinity of San Mateo Point of South Bay (Miller and Schmidtke 1956, Spratt 1976); minor spawning is also known in vicinity of San Mateo Point of South Bay (Miller and Schmidtke 1956; M. Hearne and M. McGowan 1979, personal communication). San Pablo Bay and Carquinez Strait have been used for spawning during dry periods (Miller and Schmidtke 1956). In Tomales Bay, spawning occurs mostly on northern half of bay along both shores

	(Miller and Schmidtke 1956, Hardwick 1973); in Moss Landing Harbor and Elkhorn Slough, larvae were taken mostly in Elkhorn Slough (Nybakken *et al*. 1977).
Season	December–June (Miller and Schmidtke 1956); December –March (Hardwick 1973); October –June (Eldridge and Kaill 1973); November–April in San Francisco Bay and Tomales Bay, peaking in January–February; November–July in Moss Landing Harbor and Elkhorn Slough.
Temperature	5–10°C (Alderdice and Velsen 1971); 3–12.3°C (Hart 1973); 6–15°C in San Francisco Bay; 10.0–18.2°C in Moss Landing Harbor-Elkhorn Slough when yolk-sac herring larvae were taken.
Salinity	Range of 8–18 ppt (Alderdice and Velsen 1971); seawater–mesohaline.
Substrate	Mostly on eel grass and seaweeds (Miller and Schmidtke 1956); other substrates include rocks, jetties, sandy beaches, and submerged objects such as pilings (Hardwick 1973, Eldridge and Kaill 1973); *Salicornia* spp. in upper Elkhorn Slough.
Fecundity	19,000–29,500 for 192.5- and 223-mm SL specimens (Hart and Tester 1934); mean fecundity 15,800 (Katz 1948); mean fecundity 18,000–22,000 (Nagasaki 1958); mean fecundity 22,300 (Paulson and Smith 1977); mean fecundity 60,700 (Ambroz 1931).

CHARACTERISTICS

EGGS (Figures 3-8, 3-9, 3-10, 3-11)

Shape	Spherical.
Diameter	1.3–1.8 mm (Miller and Schmidtke 1956); 1.2–1.5mm (Hart 1973); 1.3–1.6 mm.
Yolk	Yellowish, granular.
Oil globule	None.
Chorion	Transparent, thick, and tough.
Perivitelline space	Relatively wide, ca. 0.2–0.3 mm in width.
Egg mass	Broadcast over substrates, where eggs adhere in one to several layers or clusters (Blaxter 1956, Eldridge and Kaill 1973).
Adhesiveness	Highly adhesive (Miller and Schmidtke 1956, Taylor 1964); forming flat attaching disc.

Buoyancy	Demersal.

LARVAE (Figures 3-12, 3-13, 3-14, 3-15)

Length at hatching	6.5–8.8 mm TL (Alderdice and Velsen 1971); average 7.5 mm TL (Hart 1973); 5.6–7.5 mm TL.
Snout to anus length	78–84% of TL of prolarvae and early postlarvae; decreasing to ca. 75–80% in late postlarvae, 20 mm TL.
Gut	Straight and very thin in prolarve; segmental structure apparent in postlarvae.
Teeth	Pointed on premaxillary and hooked on maxillary, conical teeth on lower jaw.
Size at completion of yolk-sac stage	ca. 8–10 mm TL.
Total myomeres	45–55.
Preanal myomeres	37–44.
Postanal myomeres	7–13.
Last fin(s) to complete development	Pectoral.
Pigmentation	Dashed melanophores in middle of jugular to thoracic region; two rows of dashed or dotted melanophores along dorsal gut and midventral regions; some melanophores scattered at tip of notochord.
Distribution	Pelagic, top of water column off coast (Blaxter 1969); in Richardson Bay (Eldridge 1977); in San Francisco Bay, San Pablo Bay. Some ascend to Suisun Bay and Montezuma Slough; they are also known in Tomales Bay and Elkhorn Slough and Moss Landing Harbor (Nybakken *et al.* 1977).

JUVENILES (Figure 3-16)

Dorsal fin	15–21 (Miller and Lea 1972, Hart 1973).
Anal fin	13–20 (Miller and Lea 1972); 14–20 (Hart 1973).
Pectoral fin	17 (Hart 1973).
Mouth	Terminal and upward, maxillary extends to mid-eye (Hart 1973).
Vertebrae	46–55 (Hubbs 1925a, Miller and Lea 1972); 51–53 (Tester 1937).
Distribution	Pelagic, most of them leaving the bay or estuary and returning to the ocean (Eldridge and Kaill 1973); some may remain in bay or estuary.

LIFE HISTORY

The overall distribution of the Pacific herring is from northern Baja California to Toyama Bay, Japan, and westward on the shores of Korea and the Yellow Sea (Suetovidov 1948, Tang 1980). Along the North American continent, Pacific herring have been recorded from northern Baja California to Port Clarence, Alaska (Scattergood *et al*. 1959, Alderdice and Velsen 1971, Hart 1973, Miller and Lea 1972). In this study, Pacific herring were collected seasonally in San Francisco Bay, Tomales Bay, and Moss Landing Harbor-Elkhorn Slough.

Mature fish return to the bays approximately 2 months before they spawn (Eldridge and Kaill 1973). In Tomales Bay, Hardwick (1973) observed Pacific herring entering the bay in late November and early December. Pacific herring spawning activities were observed in the Tiburon area as early as November in 1978 and 1980. Spawning activity was concentrated during or immediately after rainy weather. Peak spawning period in San Francisco Bay and Tomales Bay is from January to March (Miller and Schmidtke 1956). Miller and Schmidtke (1956) also noticed Pacific herring spawning in summer in Monterey Bay and Morro Bay. Similar observations were made in this study; eggs and yolk-sac larvae were collected in Moss Landing Harbor and Elkhorn Slough from November through July in 1978–1979. Major spawning took place in winter, but a small but prominent spawning peak occurred from June to July. At the time larvae were collected, water temperature was 18°C. Alderdice and Velsen (1971) found the maximum observed temperature for herring spawning in British Columbia to be 10°C. Apparently the southern population is able to breed in higher temperature than the northern population. Large schools of mature fish spawn over a period of 1–7 d, occurring mostly at night (Miller and Schmidtke 1956).

The eggs are adhesive, attaching most commonly on eel grass and occasionally on other algae. Eggs are spawned in the intertidal and subtidal areas (Miller and Schmidtke 1956, Hardwick 1973). In San Francisco Bay, eel grass is not as abundant as in Tomales Bay. Pacific herring in San Francisco Bay are known to broadcast their eggs on rocks, rocky jetties, pilings, sandy beaches, and other submerged objects (Eldridge and Kaill 1973). An individual can spawn only once during the season, and the spent female returns to the ocean immediately after spawning (Miller and Schmidtke 1956). However, later spawners will use the same area for spawning as was used by earlier spawners. Consequently, egg masses are deposited in layers up to 5 cm in depth on the substrate (Hardwick 1973, Eldridge and Kaill 1973). Eggs in San Francisco Bay have been reported to hatch in 6–11 d at water temperatures of 8–10°C (Miller and Schmidtke 1956). In this study, eggs in early morula stage collected at Tiburon hatched in the laboratory in 6–7 d at 11.8–13.5°C.

Newly hatched larvae remain on the bottom for a short time. As pigment develops in their eyes, they eventually swim to surface. Eldridge and Kaill (1973) described larvae moving out of the bay soon after hatching. During this study, large numbers of Pacific herring larvae were collected at the Potrero and Hunters Point Powerplants and from Suisun Bay and Montezuma Slough from January to March 1979, providing evidence that not all larvae move directly out to the ocean. Some larvae remain in the estuary for a longer period of time than previously reported.

There is further information to substantiate that even some juvenile Pacific herring, at least those occurring in San Francisco Bay, remain in the estuary. Young-of-the-year Pacific herring have been observed in the vicinity of Port Chicago and Pittsburg (Ganssle 1966) and South Bay. These juveniles appear to be staying in the estuary instead of moving out to sea, a pattern which has also been observed in Canada (Hourston 1958, 1959). Hart (1973) observed larvae and postlarvae in an area of the Strait of Georgia influenced by the Frazer River. He further noted that juveniles remained in coastal waters until fall, when they disappeared into deeper oceanic waters.

The diet of juvenile herring includes copepods, barnacle larvae, molluscan larvae, bryozoans, rotifers, and small fish (Hart 1973).

Pacific herring reach maturity in 1–4 years, depending on individual populations (Paulson and Smith 1977, Miller and Schmidtke 1956, Hart 1973). The maximum lifespan is known to be 9 years for the San Francisco Bay population and 6 years for the Tomales Bay population. Much longer lifespans have been reported for northern populations, depending on their location. Members of each population have a special homing instinct (Rounsefell 1930, Stevenson 1955, Hardwick 1973). Within even as short a distance as that separating Tomales Bay and San Francisco Bay, there are two distinct populations (Hardwick 1973).

The Pacific herring is an important commercial species, particularly along the Alaskan coast. Locally, there is a fishery in San Francisco Bay and Tomales Bay during the spawning season. This fishery is regulated by the State to ensure the resource is not damaged. Most of the catch is exported to Japan, where herring roe is highly valued.

References

Alderdice and Velsen 1971; Ambroz 1931; Blaxter 1969, Eldridge 1977; Eldridge and Kaill 1973; Ganssle 1966; Hardwick 1973; Hart 1973; Hart and Tester 1934; Hourston 1958, 1959; Hubbs 1925a; Katz 1948; Miller and Lea 1972; Miller and Schmidtke 1956; Nagasaki 1958; Nybakken *et al.* 1977; Paulson and Smith 1977; Rounsefell 1930; Scattergood *et al.* 1959; Spratt 1976; Stevenson 1955; Suetovidov 1948; Taylor 1964; Tester 1937.

THREADFIN SHAD, *Dorosoma petenense* (Gunther)

SPAWNING

Location	Shallow water with vegetation just below surface (Taber 1969); shallow sluggish sloughs, ponds, and reservoirs such as most of the sloughs in the Delta and inshore of Suisun Bay; Clifton Court Forebay, Heather Farm Pond, warm water inshore of

	Millerton Lake, Cottonwood Bay of San Luis Reservoir.
Season	From April to end of summer (Johnson 1969, 1971), April–September (Taber 1969); peak in June (Moyle 1976); April through August and peak in June and July.
Temperature	14–18°C (Rawstron 1964); 21°C and higher (Kimsey and Fisk 1964); mostly concentrated at 20–25°C in Millerton Lake and San Luis Reservoir.
Salinity	Freshwater (Burns 1966a).
Substrate	Submerged vegetation, floating debris (Rawstron 1964); bushes, stumps, logs (Lambou 1965); filamentous algae, rocks, sticks, grass, and other submerged vegetation (Taber 1969); submerged vegetation, floating tree branches, sticks, and plant seeds.
Fecundity	6,210–21,000 ova in 126-mm and 168-mm SL specimens (Finucane 1965); mature ova, 920–8,540 (Johnson 1971).

CHARACTERISTICS

EGGS (Figure 3-17)

Shape	Spherical.
Diameter	Fertilized eggs, 0.75 mm (Hubbs and Bryan 1974); 0.9–1.2 mm.
Yolk	Light yellow for mature ova (Finucane 1965); yellowish-whitish, coarse, granular.
Oil globule	Single oil globule, ca. 0.1–0.2 mm in diameter.
Chorion	Transparent.
Perivitelline space	Wide, ca. 0.1–0.2 mm.
Egg mass	Broadcasted on aquatic vegetation and other floating objects.
Adhesivenss	Adhesive (Berry *et al.* 1956); very adhesive throughout incubation.
Buoyancy	Demersal.

LARVAE (Figures 3-18, 3-19, 3-20, 3-21)

Length at hatching	4.1–4.4 mm TL (Taber 1969); 3.2–4.4 mm TL.
Snout to anus length	81–85% of TL in prolarvae and early postlarvae; decreasing to 75–86% of TL in postlarvae at 15 mm TL and larger.

Yolk sac	Spherical to oval, located at the jugular-thoracic region.
Oil globule	Single, small located in posterior of yolk sac.
Gut	Straight, slender in prolarvae, becoming thick and segmented in postlarvae.
Air bladder	Elongate and shallow, above or slightly behind pelvic fins, apparent in postlarval stage; ca. 10 mm TL.
Teeth	Pointed or hooked teeth on maxillary; sharp pointed teeth on lower jaw, teeth lost in early juvenile stage.
Size at completion of yolk-sac stage	ca. 4.5–5.0 mm TL.
Total myomeres	Less than 40 (Kersh 1970); 40–45.
Preanal myomeres	ca. 36 (Taber 1969); 36–40.
Postanal myomeres	4–6.
Last fin(s) to complete development	Pectoral.
Pigmentation	Dashed and dotted melanophores in thoracic region; 2 rows of melanophores on dorsal gut posterior along to pelvic fins; dotted melanophores in postanal region.
Distribution	Planktonic (Taber 1969); in shallow and open water of the Delta, Suisun Bay, San Luis Reservior, and Millerton lake.

JUVENILES (FIGURE 3-22)

Dorsal fin	11–15 (Taber 1969, Miller and Lea 1972); 14–15 (Moyle 1976); 14–17 (R.J. Lavenberg 1980, personal communication).
Anal fin	17–27 (Miller and Lea 1972, Jones *et al.* 1978); 20–23 (Moyle 1976).
Pectoral fin	12–17 (Miller 1963b); mostly 15–16.
Mouth	Terminal (Miller 1963b); terminal, oblique, and small (Moyle 1976).
Vertebrae	43–44 (Miller and Jorgenson 1973); 43–45 (R.J. Lavenberg 1980, personal communication).
Distribution	Shallow and open water of Sacramento-San Joaquin river system; some in estuaries. Also, they are common in reservoirs such as San Luis Reservoir and Millerton Lake; occasionally in Moss Landing Harbor.

LIFE HISTORY

Threadfin shad are native to streams flowing into the Gulf of Mexico from Florida to Mexico and the Gulf of Honduras as far south as Belize (Moyle 1976). In the United States, threadfin shad occur as far north as Oklahoma, Tennessee, and southern Arkansas in the Mississippi River and its tributaries (Moyle 1976).

Threadfin shad were collected from the Tennessee River and first introduced into San Diego County by CDFG in 1953 (Kimsey 1954). Additional threadfin shad were introduced to numerous reservoirs in Northern California and the Sacramento-San Joaquin River system (Kimsey and Fisk 1964). Currently, along the Pacific Coast, they have been recorded from Long Beach to Humboldt Bay (Miller and Lea 1972). Although this species is found in waters of various salinities, they seem to prefer oligohaline to freshwater ranges. This species is particularly abundant in warm-water reservoirs (Burns 1966). In this study threadfin shad was the most abundant clupeid in the Delta and upper estuary. They were also common in San Luis Reservoir and Millerton Lake.

Spawning occurs throughout late spring and summer, with peaks from May to July. During this study, an early spawn was observed in the vicinity of the Contra Costa and Pittsburg Powerplants in April. The latest spawn, observed in Millerton Lake, ended in August.

Female fish deposit their eggs on submerged vegetation in shallow water (Taber 1969). Large schools of threadfin shad congregated in the shallows of Cottonweed Bay of San Luis Reservoir and near boat ramps at Millerton Lake in early May. Eggs were not only observed on submerged substrates, but also on floating debris, logs, sticks, and plant seeds. Deposition of eggs on floating substrates could be an incidental case. However, it could also be an important spawning strategy for the reservoir population since large amounts of freshwater are released daily from the reservoir for irrigation and water level fluctuates. In this case, eggs adhering to floating substrate will have a better chance of survival. Eggs are in single layers on the substrate and remain attached throughout the incubation period. Older fish spawn approximately 2 months earlier than younger fish. Total spawning period can be prolonged, but it is unlikely that an individual fish will breed more than once during the season (Johnson 1971). The incubation period for eggs is 3–6 d (Moyle 1976), about 3 d at 26–37°C (Burns 1966a).

Newly hatched larvae are planktonic and exhibit diel migratory behavior. They are found near the surface during daytime and descend to mid-depths or lower at night (Taber 1969). Larvae were abundant inshore and also in open water in the vicinity of the Pittsburg and Contra Costa Powerplants. They were most numerous in Clifton Court Forebay and Rock Slough. Larvae were also observed in the small Heather Farm Pond.

Threadfin shad larvae differ from American shad larvae in both size and myomere count. Threadfin shad larvae are very short and thin and myomere counts are 40–45, whereas American shad larvae are elongated and have myomere counts of 53–58.

Juvenile threadfin shad typically form schools. Ganssle (1966) observed they were abundant in the Delta and Suisun Bay from September through November. In this study, large schools were noted in Suisun Bay and in the vicinity of the Contra Costa and Pittsburg Powerplants. Thermal plumes from powerplants may attract them in fall when the water turns cold. In Millerton Lake, juvenile threadfin shad, swimming in large schools, frequently cross between the warm lake water and the cool river water (the plunge point) in summer and fall months. In the estuary, Miller (1963b) reported young threadfin shad in 15.5 ppt brackish water, although they prefer oligohaline and freshwater. In this study, juveniles were collected occasionally on intake screens at Moss Landing Powerplant, a seawater cooled powerplant. Juvenile threadfin shad are plankton feeders. Zooplankton, phytoplankton, and detritus are their major food sources (Turner 1966b).

Some threadfin shad mature at the end of their first summer, but the majority reaches maturity in their second year (Johnson 1971). Threadfin shad may live up to 4 years (Johnson 1970). Threadfin shad are an important forage fish for game species such as striped bass, largemouth bass, and other centrarchids (Kimsey and Fisk 1964). No human consumption of this species is reported because of its small size.

References

Berry *et al.* 1956; Burns 1966a; Finucane 1965; Ganssle 1966; Hubbs and Bryan 1974; Johnson 1969, 1970, 1971; Jones *et al.* 1978; Kersh 1970; Kimsey 1954; Kimsey and Fisk 1964; Lambou 1965; Miller and Jorgensen 1973; Miller 1963b; Miller and Lea 1972; Moyle 1976; Rawstron 1964; Taber 1969; Turner 1966b.

Characteristic Comparison: Clupeids

Characteristic	American Shad	Pacific Herring	Threadfin Shad
Spawning Location	Mostly in Sacramento River system, Millerton Lake	San Francisco Bay, Moss Landing	Sacramento and San Joaquin Rivers, Delta
Peak	May–June	January–February	May–July
Eggs			
Diameter (mm)	2.5–4.4	1.2–1.75	0.75–1.2
Oil Globule	None	None	0–2 (usu. 1–2)
Buoyancy	Semi-demersal	Demersal	Demersal
Perivitelline space	Very wide (ca. ½ of egg radius)	Wide	Varies
Adhesiveness	None	Adhesive	Adhesive
Larvae			
Length at hatch (mm)	5.7–10.0	5.6–8.8	3.2–4.4
Oil globule	None	None	1–2
Total myomeres	53–58	45–55	40–45
Preanal myomeres	41–49	37–44	36–40
Postanal myomeres	8–16	7–13	4–6
Myomeres between insertion of dorsal fin and origin of anal fin	10–14	5–6	4–6
Distribution	Suisun Bay to upper Sacramento River	San Francisco Bay to Suisun Bay, Moss Landing Harbor and Elkhorn Slough	Suisun Bay, Delta and its tributaries
Juveniles			
Dorsal fin	15–19	15–21	11–17 (last fin ray elongate)
Anal fin	19–25	13–20	17–27
Suborbital bone	Depth greater than width	Depth less than width	Depth less than width
Distribution	Sacramento-San Joaquin Estuary	Mostly off Pacific Coast	Mostly in Delta; occasionally in Moss Landing Harbor

Figure 3.—Clupeidae: *Alosa sapidissima*, American shad.

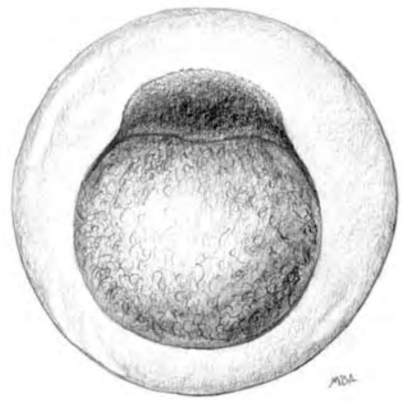


FIGURE 3-1.—Egg, morula, 3.5 mm diameter.

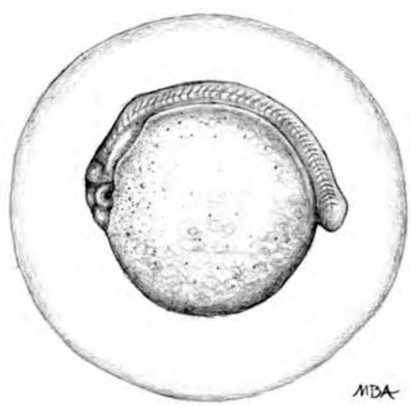


FIGURE 3-2.—Egg, early embryo, 3.2 mm diameter.

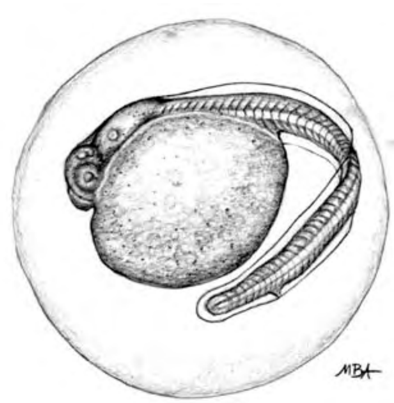


FIGURE 3-3.—Egg, late embryo, 3.5 mm diameter.

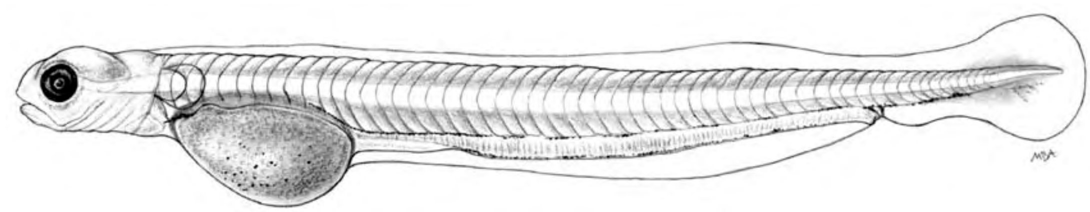


FIGURE 3-4.—Prolarva, 10 mm TL.

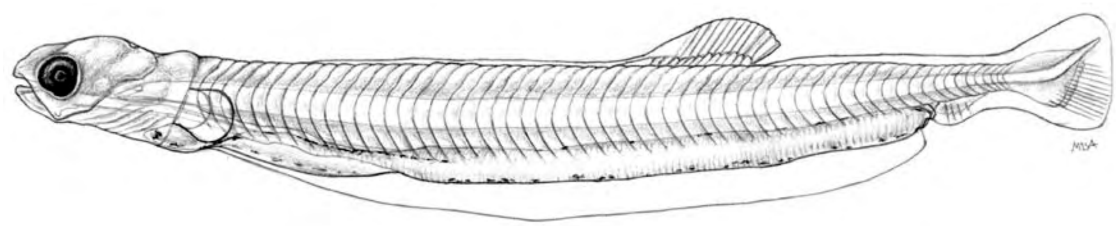


FIGURE 3-5.—Postlarva, 12.2 mm TL.

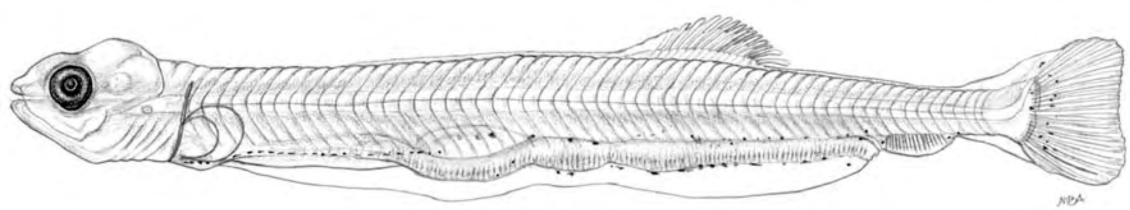


FIGURE 3-6.—Postlarva, 16.5 mm TL.

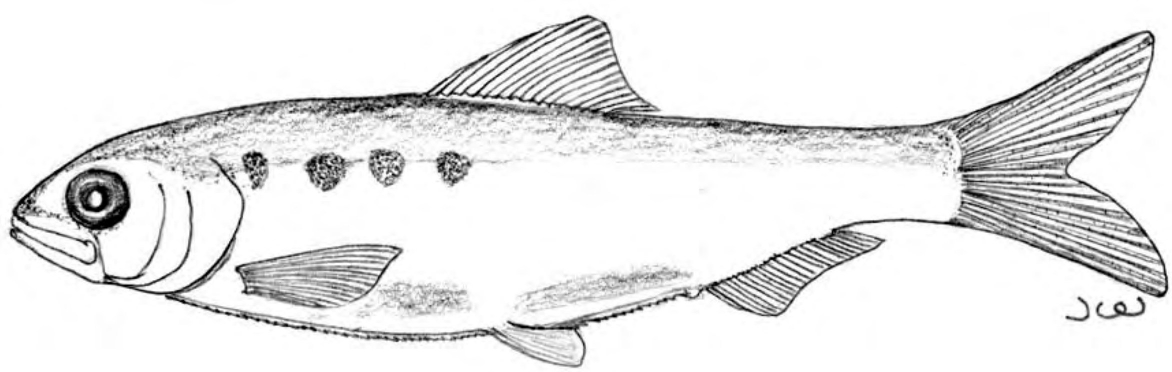


FIGURE 3-7.—Juvenile, 83 mm TL.

Clupeidae: Clupea *harengus pallasi*, Pacific herring.

FIGURE 3-8.—Egg, morula, 1.4 mm diameter.

FIGURE 3-9.—Egg, late morula, 1.4 mm diameter.

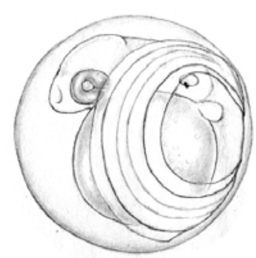


FIGURE 3-10.—Egg, late morula, 1.5 mm diameter.

Figure 3-11.—Egg, late morula, 1.5 mm diameter

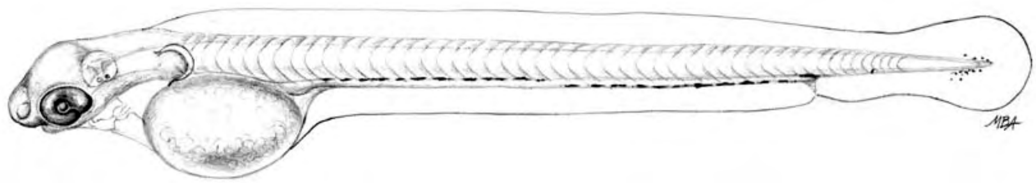


FIGURE 3-12.—Prolarva, 8 mm TL.

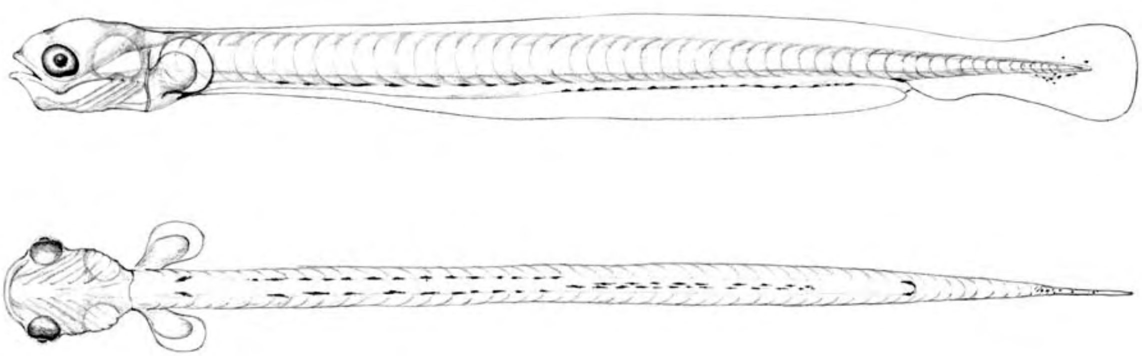


FIGURE 3-13, 3-14.—Postlarva, lateral and ventral views, 10.3 mm TL.

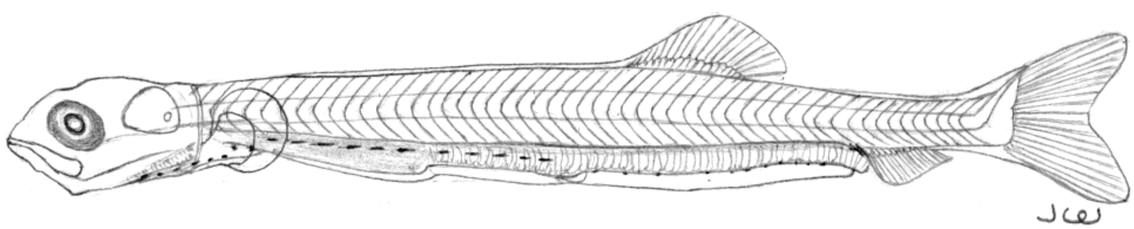


FIGURE 3-15.—Postlarva, 18.8 mm TL.

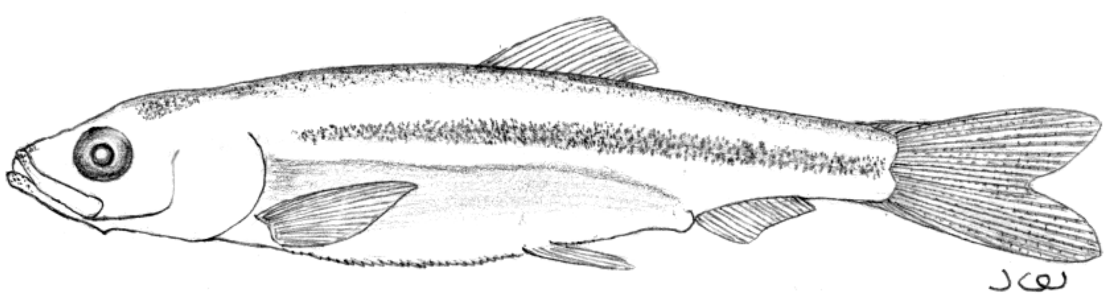


FIGURE 3-16.—Juvenile, 40 mm TL.

Clupeidae: *Dorosoma petenense*, threadfin shad.

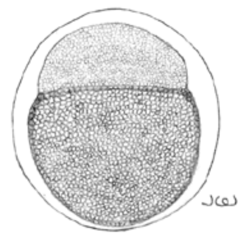


FIGURE 3-17.—Egg, morula, 0.9 mm diameter.

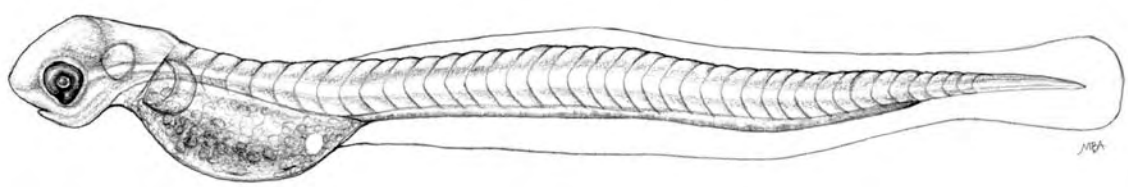


FIGURE 3-18.—Prolarva, 4.7 mm TL.

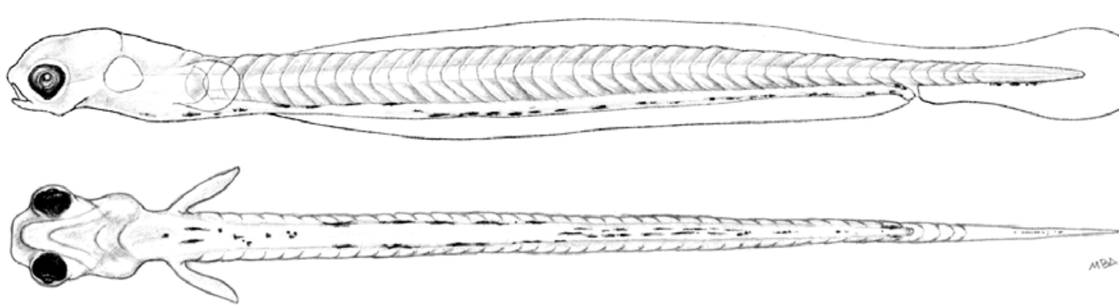


FIGURE 3-19, 3-20.—Postlarva, lateral and ventral views, 5.3 mm TL.

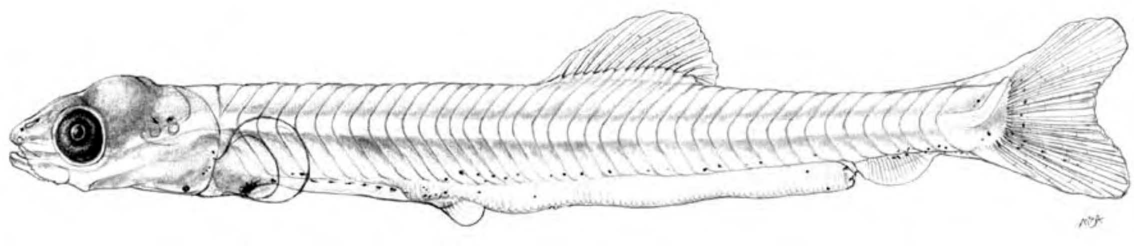


FIGURE 3-21.—Postlarva, 16 mm TL.

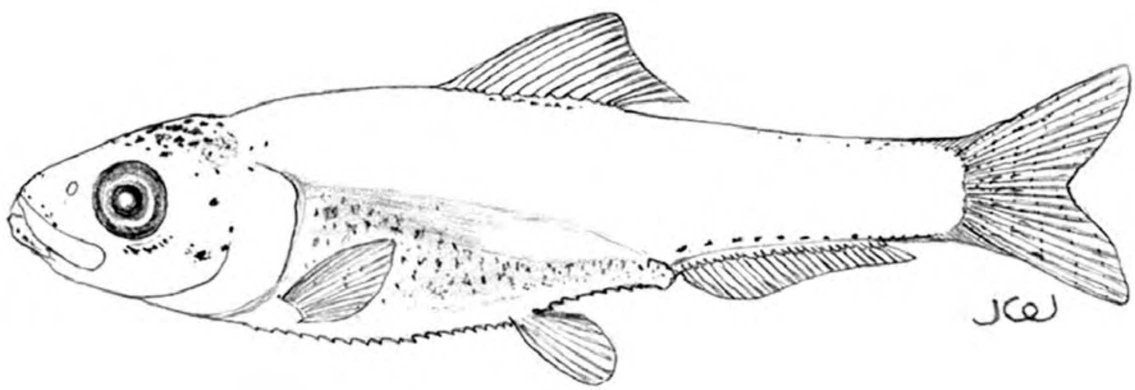


FIGURE 3-22.—Juvenile, 24.5 mm TL.

4. Engraulidae – Anchovies

The northern anchovy, *Engraulis mordax*, is found in the study area. The northern anchovy is widely distributed along the Pacific coast, and three subpopulations were described by McHugh (1951) and supported by Vrooman *et al.* (1981). Hubbs (1925a) identified a separate subspecies, *Engraulis mordax nanus*, in brackish waters of San Francisco Bay. Descriptions contained in this report are based on collections made from San Francisco Bay, San Pablo Bay, and Suisun Bay. Additional specimens in Tomales Bay and Moss Landing Harbor-Elkhorn Slough are included for comparison. There are no distinctive characteristics to separate subspecies, and in fact recent investigations have indicated that the subspecies may not be valid (M. McGowan 1980, personal communication).

The biology and fisheries of the northern anchovy along the California coast have been studied and reviewed extensively.

References

McHugh 1951; Vrooman *et al.* 1981.

NORTHERN ANCHOVY, *Engraulis mordax* Girard

SPAWNING

Location	Open waters of San Francisco Bay and San Pablo Bay, Richardson Bay (Eldridge 1977); Moss Landing Harbor (Nybakken *et al.* 1977, the study); Pacific coast (Ahlstrom 1956); Tomales Bay (Bane and Bane 1971).
Season	Throughout the year (Bolin 1936); 2 peaks, February to April and July to September (this study); July and August offshore, and may spawn throughout the year in southern part of range (Bane and Bane 1971).
Temperature	10–23.3°C, preferring 13.0–17.5°C (Ahlstrom 1956).
Slainity	From seawater to mesohaline, occasionally found in oligohaline, such as Suisun Bay.
Substrates	None.
Fecundity	20,000–30,000 annually (Baxter 1967).

CHARACTERISTICS

EGGS (Figure 4-1)

Shape	Ellipsoid or oval (Bolin 1936, Ahlstrom 1956).

Diameter	Long axis 1.23–1.55 mm; short axis 0.65–0.82 mm (Bolin 1936).
Yolk	Pale yellow whitish, coarse, granular; clean and translucent (Bolin 1936).
Chorion	Transparent, smooth.
Perivitelline space	Very narrow along short axis.
Egg mass	Broadcast in water column.
Adhesiveness	None.
Buoyancy	Pelagic, near surface (Bolin 1936).

LARVAE (Figures 4-2, 4-3, 4-4, 4-5)

Length at hatching	ca. 3.0 mm TL (Bolin 1936); 2.5–3.0 mm TL (Ahlstrom 1956).
Snout to anus length	ca. 70–75% of TL of prolarvae; decreasing to 60–67% of TL of postlarvae.
Yolk sac	Large, teardrop shape, extending from abdominal region past head.
Oil globule	None.
Gut	Straight and thin in prolarvae; thicker with segmentation in postlarvae.
Air bladder	Small, oval, behind pelvic.
Teeth	Sharp, pointed, on both jaws.
Size at completion of yolk-sac stage	ca. 3.5–4.0 mm TL.
Total myomeres	40–46.
Preanal myomeres	27–31.
Postanal myomeres	12–15.
Last fin(s) to complete development	Pectoral.
Pigmentation	No pigmentation in prolarvae; in postlarvae, melanophores along postanal region, dashed melanophores on isthmus, 2 rows of large dotted melanophores in midventral region (on side of gut anterior to pelvic and on dorsal gut posterior to pelvic).
Distribution	Throughout water column in San Francisco Bay and San Pablo Bay, Moss Landing Harbor-Elkhorn Slough, and Tomales Bay.

JUVENILES

Dorsal fin	14 (Clothier 1950); 14–16 (Bane and Bane 1971; Hart 1973); 14–19 (Miller and Lea 1972).
Anal fin	22 (Clothier 1950); 20–23 (Bane and Bane 1971, Hart 1973).
Pectoral fin	13–20 (Miller and Lea 1972); 17 (Hart 1973).
Mouth	Subterminal (Bane and Bane 1971); mouth inferior, very large, maxillary extends behind the eye (Hart 1973).
Vertebrae	44–47 in Southern California (Clothier 1950); average 45 for anchovy in British Columbia area (Taylor 1940); 43–47 (Miller and Lea 1972).
Distribution	Richardson Bay (Green 1975), San Francisco Bay (Aplin 1967, Ganssle 1966); some found in Carquinez Strait (Messersmith 1966) and Suisun Bay (Ganssle 1966); up to Contra Costa Powerplant in lower San Joaquin River; along Pacific coast waters (Ahlstrom 1956); Moss Landing Harbor-Elkhorn Slough (Nybakken *et al.* 1977).

LIFE HISTORY

The northern anchovy ranges from Cape San Lucas, Baja California, to Queen Charlotte Island, British Columbia (Miller and Lea 1972, Hart 1973). It is one of the most prolific fish in terms of numbers and biomass along the northeastern coastal waters of the Pacific Ocean. Based on morphological differences of the dorsal and pectoral fin rays, vertebrae, and gill rakers, the northern anchovy population has been further separated into three subpopulations (McHugh 1951, Frey 1971). The northern subpopulation extends from Vancouver Island, British Columbia, to central California. The central subpopulation ranges from southern California to northern Baja California, and the southern subpopulation is known off central and southern Baja California. Within the Sacramento-San Joaquin Estuary, a subspecies, *Engraulis mordax nanus,* was described by Hubbs (1925a). Aplin (1967) reported that northern anchovy was the most abundant species in San Francisco Bay, constituting 85% of all fish collected in the survey. They were also common in San Pablo Bay and Suisun Bay (Ganssle 1966, Messersmith 1966). In areas near San Francisco Bay, the northern anchovy is also abundant in Tomales Bay (Bane and Bane 1971) and Moss Landing Harbor-Elkhorn Slough (Nybakken *et al.* 1977). In this study, northern anchovy eggs were also observed in Suisun Bay during summer months, as seawater intruded up the river. In the ocean, anchovy eggs have been found up to 300 miles (~480 km) offshore, but are most abundant inshore (Ahlstrom 1967, Mias 1974, Kramer and Ahlstrom 1968). Large numbers of anchovy eggs have been found in Moss Landing Harbor, which has little freshwater input (Nybakken *et al.* 1977). Bolin (1936) described schools of northern anchovy broadcasting their eggs during night hours. A similar situation was observed for the bay anchovy *Anchoa* *mitchilli*, a mid-Atlantic Coast anchovy, in the Indian River Estuary (author's observation). An individual anchovy can spawn two to three times a year (Brewer 1975a, 1975b, 1978).

Northern anchovy eggs are oval in shape. They are found floating near the surface with their major axis perpendicular to the surface. The axis changes to a horizontal position prior to hatching (Bolin 1936). In the same study Bolin commented that eggs hatch in 2–4 d. Ahlstrom (1956) observed northern anchovy eggs hatch in 2–4 d. Ahlstrom (1956) observed northern anchovy eggs in waters of 9.9–23.2°C.

Newly hatched larvae are 2.5–3.0 mm TL, and the yolk sac is absorbed in 36 h (Bolin 1936). Eldridge (1977) reported larval anchovy to be the third (of 39 taxa) most abundant species taken in Richardson Bay. They were the most abundant larvae in Elkhorn Slough (Nybakken *et al.* 1977). Postlarvae swim near the surface and are most abundant in San Francisco Bay and San Pablo Bay. As the salt wedge moves up to the estuary in the summer months, anchovy larvae were found in Suisun Bay and lower Delta, and they were abundant through the fall months.

Juveniles, in schools, are collected from seawater to freshwater in the Sacramento-San Joaquin Estuary, where they are particularly common in July and August. Juveniles use inshore bays and estuaries as their nursery ground, while the offshore waters are adult recruitment areas. Juvenile northern anchovy, with their large inferior mouths, generally consume small crustaceans, such as copepods (Hunter 1976), and other zooplankton. Algae were also reported as part of the anchovy's diet (Bane and Bane 1971). Anchovy are preyed on by Chinook salmon (Merkel 1957), rockfishes, striped bass, white croaker, and surfperches (this study).

Clark and Phillips (1952) reported that a few anchovy are mature at 1–2 years, about half at 2–3 years, and all are mature at 4 years. Collins (1969) reported them mature at 12 months, Hart (1973) 1–3 years, and Bane and Bane (1971) between 2 and 3 years.

They can live and spawn to age 7 (Baxter 1967). In this study, the majority of the anchovy were mature at age 2. Baxter (1967) found adult anchovy to be abundant in the outer continental shelf from 50 to 200 miles (80 to 320 kilometers) offshore. The anchovies have replaced the once-important sardine in both commercial and bait fisheries (Crooke 1969, Messersmith 1969, Bane and Bane 1971, Talbot 1973).

References

Ahlstrom 1956; Aplin 1967; Bane and Bane 1971; Baxter 1967; Bolin 1936; Brewer 1975a, 1975b, 1978; Clark and Phillips 1952; Crooke 1969; Green 1975; Clothier 1950; Collins 1969; Eldridge 1977; Frey 1971; Ganssle 1966; Green 1975; Hart 1973; Hubbs 1925a; Hunter 1976; Kramer and Ahlstrom 1968; McHugh 1951; Merkel 1957; Messersmith 1966; Mias 1974; Miller and Lea 1972; Nybakken *et al.* 1977; Pearcy and Myers 1974; Talbot 1973; Taylor 1940.

Figure 4.—Engraulidae: *Engraulis mordax*, northern anchovy.

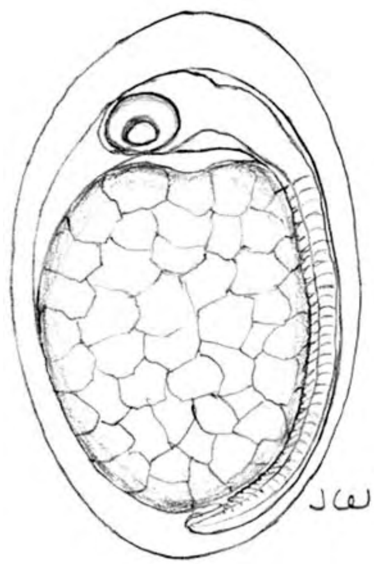


FIGURE 4-1.—Egg, late embryo, long axis 1.4 mm, short axis 0.9 mm diameter.

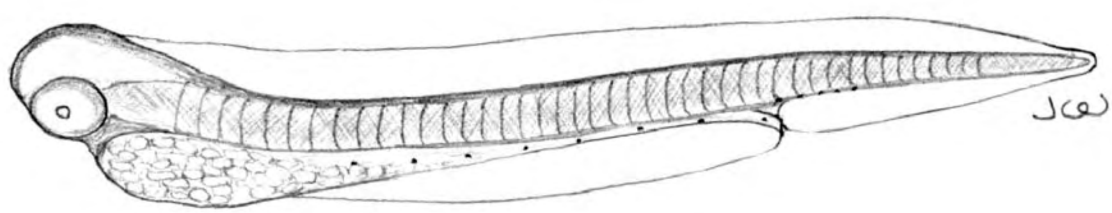


FIGURE 4-2.—Prolarva, 3.6 mm TL.

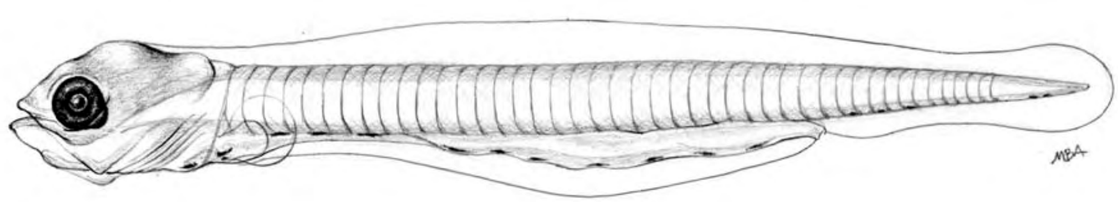


FIGURE 4-3.—Postlarva, 3.9 mm TL.

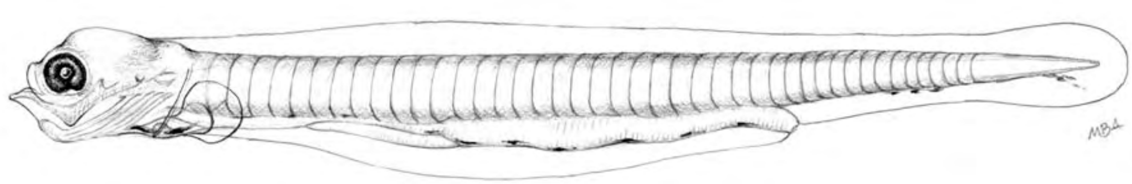


FIGURE 4-4.—Postlarva, 6.0 mm TL.

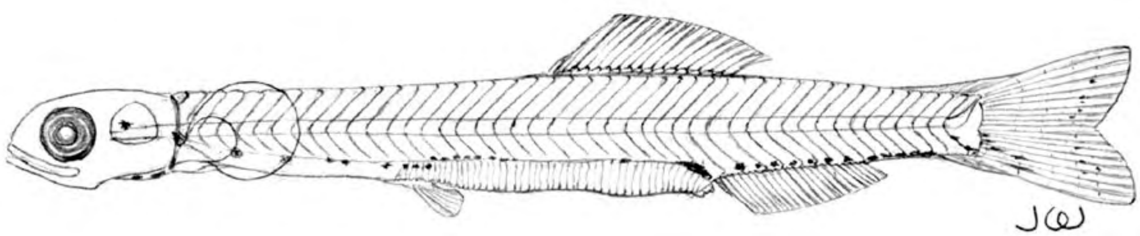


FIGURE 4-5.—Postlarva, 27.5 mm TL.

5. Salmonidae – Trouts

Davidson and Hurchinson (1938) and Hallock and Fry (1967) have recorded five species of salmon, genus *Oncorhynchus*, in the Sacramento-San Joaquin River systems: pink salmon, *O. gorbuscha*, chum salmon, *O. keta*, coho salmon, *O. kisutch*, sockeye salmon, *O. nerka*, and Chinook salmon, *O. tshawytscha*. All are native to the area.

In the genus *Salmo* there are two species, the native steelhead or rainbow trout[1], *Salmo gairdneri* (Hallock *et al.* 1961, McCrimmon 1971), and the brown trout, *Salmo trutta*, introduced to California from Scotland (Staley 1966, Moyle 1976).

The steelhead is the anadromous form of *Salmo gairdneri* and the rainbow trout is the non-migrating form. In the genus *Salvelinus*, there is the brook trout, *Salvelinus fontinalis*, which was introduced from the East Coast to California between 1872 and 1879 (McAfee 1966, Moyle 1976). Both brook and brown trout are common in the middle-to-high elevations of the Sacramento and San Joaquin River systems.

The Chinook salmon and steelhead populations have drastically declined in California in the last century. One of the major reasons for this decline was the construction of many dams in the Sacramento-San Joaquin River system. These fish have been blocked from their historic spawning grounds or their spawning habitat was destroyed. Artificial propagation programs have been established to compensate for some of the losses (Hallock and Fry 1967, Hallock *et al.* 1961).

In this study, the majority of salmonids collected in the estuary were Chinook salmon and steelhead, either en route to upper freshwater tributaries to spawn or migrating to the ocean.

A coho or silver salmon run is occasionally observed at the Nimbus Fish Hatchery (C. Riley 1981, personal communication). The landlocked sockeye salmon, or kokanee, has been stocked by CDFG in Lake Berryessa and Union Valley Reservoir. Natural runs of coho, pink, sockeye, and chum salmon have been observed on rare occasions at the Red Bluff Dam fish ladder facility (R. Hallock 1982, personal communication).

Brown trout are now common in Sierra streams and in higher elevation reservoirs such as Icehouse and Union Valley. They are not found in the valley floor rivers or reservoirs. Brook trout have established populations in many high Sierra streams, but are not found in warm estuarine waters.

Only Chinook salmon and steelhead are discussed in this manual.

1 The native steelhead or rainbow trout, formerly classified in the genus *Salmo*, is now classified as *Oncorhynchus mykiss*.

References

Davidson and Hutchinson 1938; Hallock and Fry 1967; Hallock *et al.* 1961; McCrimmon 1971; McAfee 1966; Staley 1966.

CHINOOK SALMON, *Oncorhynchus tshawytscha* (Walbaum)

SPAWNING

Location	Historically, upper reaches of Sacramento River above Shasta Dam, McCloud River, Pit River, upper reaches of San Joaquin River (Hallock and Fry 1967; Moyle 1976). At present, mostly in upper Sacramento River from Keswick Dam southward. Some tributaries of Sacramento River such as Battle Creek, Mill Creek, the Feather River, Yuba River, and American River are also included. In the San Joaquin River system, spawning is reported in Mokelumne River, Stanislaus River, and Tuolumne River (Hallock and Fry 1967).
Season	Spawning occurs year-round because many races are involved (Hallock and Fry 1967).

Race	**Migratory Run**	**Spawning Period**
Fall	July–December	October–December
Late Fall	Late October–April	January–April
Winter	December–July	April–July
Spring	April–October	August–October

Temperature	10 –15°C; eggs will have maximum survival in water which is less than 14°C (Moyle 1976).
Salinity	Freshwater.
Substrates	Gravel to coarse gravel.
Fecundity	2,000–14,000 (Moyle 1976), 4,800 (Prakash 1958, Rounsefell 1957), 4,200–13,600 for 75- to 100-cm fish in Alaska (Scott and Crossman 1973).

CHARACTERISTICS

EGGS (Figure 5-1)

Shape	Spherical, some slightly irregular.
Diameter	6.0–7.0 mm (Scott and Crossman 1973).

Yolk	Orange-red (Scott and Crossman 1973); bright red (Hart 1973); yellowish to orange-red.
Oil globule	Many oil globules.
Chorion	Transparent to translucent, thick and firm.
Perivitelline space	Very narrow.
Egg mass	Deposited and buried in clusters in gravel.
Adhesiveness	Non-adhesive (Breder and Rosen 1966); adhesive during water hardening.
Buoyancy	Demersal.

LARVAE (Figures 5-2, 5-3)

Length at hatching	ca. 20 mm TL.
Snout to anus ratio	58–61% of TL of prolarvae at 20–29 mm TL.
Yolk sac	Very large, oval-shaped; yellow to orange-red, extending from jugular to abdominal region. The free portion of yolk sac at posterior end actually overhangs near anus.
Oil globules	Many oil globules scattered in the yolk sac.
Gut	Straight.
Air bladder	Large, oval, midway between pectorals and anus.
Teeth	Sharp, conical, developed in late postlarval and early juvenile stage.
Size at completion of yolk-sac stage	30–40 mm TL.
Total myomeres	63–69.
Preanal myomeres	41–44
Postanal myomeres	20–25.
Last fin(s) to complete development	Pectoral and pelvic.
Pigmentation	Dense melanophores on head and dorsum; light melanophores in postanal area; 8–10 parr marks and horizontal stripe in late yolk-sac larval stage.
Distribution	Newly hatched larvae stay in gravel 2–3 weeks until yolk sac is absorbed, then become free swimming, and remain in spawning area or move downstream (Scott and Crossman 1973, Moyle 1976); some remain in the spawning area for several months (T. Richardson 1982, personal communication).

JUVENILES (Figure 5-4)

Dorsal fin	10–14 (Moyle 1976); 10–16 (Miller and Lea 1972); 10–14 (Hart 1983); 11 (Clothier 1950).
Anal fin	14–19 (Moyle 1976); 13–20 (Miller and Lea 1972); 13–19 (Hart 1973); 15–17 (Clothier 1950).
Pectoral fin	14–19 (Moyle 1976); 14–17 (Scott and Crossman 1973).
Teeth	Sharp, conical, developed in late postlarval and early juvenile stage.
Size at completion of yolk-sac	64–72 (Miller and Lea 1972) 64–66 (Clothier 1950).
Distribution	During sea-run migration they are found in both shallow and open waters in the Sacramento-San Joaquin Estuary

LIFE HISTORY

The Chinook salmon, also known as king salmon in California, ranges from San Diego to the Bering Sea and Japan (Miller and Lea 1972). In Asia, this species is found in the Amur River, China, Kamchatka Peninsula, and the Anadyr River, USSR (Hart 1973, Scott and Crossman 1973). In the Sacramento-San Joaquin River systems, four races exist (Hallock and Fry 1967, Hallock and Fry 1967). The Sacramento River is still the most significant southern spawning ground (Fry 1961, 1973; Skinner 1962). The San Joaquin River was once an important spawning area, but construction of Friant Dam in 1946 blocked and subsequently ended that run, except for occasional spawning in years of high runoff (Moyle 1976).

The fall run is the largest in the Sacramento River system. The fish begin their upward migration in September and October. In this study, adults were caught by gillnet in Suisun Bay, near Montezuma Slough, and in the vicinity of the Pittsburg and Contra Costa Powerplants in October. The spawning ground in the Sacramento River system closest to the ocean is the stretch just below Nimbus Dam on the American River.

Large redds (nests) are constructed by females in shallow riffle areas, with gravel or coarse gravel covering the bottom. A dominant male joins the female in the redd and the two engage in the spawning act. The female buries eggs in loose gravel and remains at the nest for about 2 weeks or until she dies (Scott and Crossman 1973). After spawning, dying and dead fish were observed from Sailor’s Park to Big Bend on the American River (this study).

At the Nimbus Fish Hatchery, eggs and sperm of captured Chinook salmon are stripped under controlled conditions. The size of the eggs varies from 6.0 to 8.5 mm, and they are bright orange-red in color. At the hatchery, all eggs hatch in 50–55 d at 10–12.5°C (Nimbus Fish Hatchery Record). In the natural environment, incubation time varies because of temperature fluctuations. Moyle (1976) states that Chinook salmon eggs survive best at water temperatures less than 14°C.

Newly hatched larvae (alevin) have an oversized yolk sac and remain in the interstitial areas of the redd for 2–3 weeks (Scott and Crossman 1973). The larvae emerge into the water column after completely absorbing the yolk sac. At this stage, the larvae soon begin to migrate downstream (Moyle, 1976). In this study, alevins were collected in Suisun Bay in January and February. They were commonly found inshore, in shallow water.

Larger fish, parr-juveniles (ca. 45–75 mm TL), were observed from April to June in this study. Sasaki (1966a) observed parr-juveniles throughout the estuary, the migration peaking from May to June. Richardson (1982, personal communication) stated that some Chinook salmon do not start their downstream migration until their early smolting stage (assuming a silvery color). On the Pacific coast of Canada, Chinook salmon juveniles may remain in freshwater for 1–2 years (Scott and Crossman 1973). Juvenile Chinook salmon are drift feeders, feeding on various aquatic and terrestrial insects, crustaceans, chironomid larvae and pupae, and caddisflies when they are in freshwater. Their diet changes to mainly Neomysis spp., Gammarus spp., and Crangon spp. when they are in more saline waters. Juvenile salmon are prey for many animals, including striped bass, American shad, sculpins, Sacramento squawfish (renamed Sacramento pikeminnow), and sea gulls (P. Moyle 1982, personal communication). Hart (1973) describes juvenile salmon moving far out into the ocean and staying well below the surface. Locally, immature salmon are found offshore from Half Moon Bay to Bodega Bay (information obtained from commercial and sport fisherman).

Pritchard (1940) reports a Chinook salmon maturing anywhere from 2–9 years, though most commonly at 4–5 years, and returning to the stream where they hatched (Hart 1973).

The Chinook salmon has been one of the most important commercial and sport fish species in California. The fish population has declined considerably in the past hundred years (Moyle 1976). The artificial propagation program operated through joint efforts of Federal and California State agencies has compensated for some of the losses, but the future of this native anadromous fish is still uncertain. Future construction of water diversions, dams, and hydroelectric projects may cause additional habitat loss. These man-made factors may cause new restrictions for Chinook salmon spawning and migratory passage and result in further declines in their population.

References

Breder and Rosen 1966; Clothier 1950; Fry 1961, 1973; Hallock and Fry 1967; Hart 1973; Miller and Lea 1972; Moyle 1976; Prakash 1958; Pritchard 1940; Rounsefell 1957; Sasaki 1966a; Scott and Crossman 1973; Skinner 1962.

Specimen Credit

Egg, larvae, and juvenile were obtained from Nimbus Fish Hatchery, California Department of Fish and Game.

ANADROMOUS RAINBOW TROUT OR STEELHEAD, *Salmo gairdneri* Richardson (currently *Oncorhynchus mykiss*)

SPAWNING

Location	Large tributaries of Sacramento-San Joaquin River system such as the American and Feather Rivers (Hallock *et al.* 1961); some coastal creeks such as Waddell Creek (Hallock *et al.* 1961); smaller tributaries within estuary such as Olema Creek, Pine Gulch Creek, and Corte Madera Creek.
Season	December through April (Hallock *et al.* 1961); January through March (Nimbus Fish Hatchery records); spring (Moyle 1976).
Temperature	10–15 °C (Moyle 1976); 10.5 °C (Wales 1941); 10–15.5 °C (Scott and Crossman 1973).
Salinity	Freshwater.
Substrate	Gravel.
Fecundity	200–12,000 (Scott and Crossman 1973, Moyle 1976).

CHARACTERISTICS

EGGS (Figure 5-5)

Shape	Mostly spherical or slightly irregular.
Diameter	4.6–6.2 mm; 3–5 mm (Scott and Crossman 1973).
Yolk	Yellowish, pinkish, or orange-red; granular, pink to orange in color (Scott and Crossman 1973).
Oil globule	Numerous oil globules scattered in the yolk (Knight 1963).
Chorion	Transparent to translucent, thick.
Perivitelline space	Very narrow.
Egg mass	Deposited in loose clusters or piles.
Adhesiveness	None (Breder and Rosen 1966, Knight 1963); eggs are adhesive during water hardening process (Nimbus Fish Hatchery records).
Buoyancy	Demersal (Breder and Rosen 1966, Scott and Crossman 1973).

LARVAE (Figures 5-6, 5-7)

Length at hatching	14.0–15.5 mm TL.
Snout to anus length	63–68% of TL of prolarvae at 14–18 mm TL; ca. 60% for larvae at 23–26 mm TL
Yolk sac	Very large, oval or teardrop shape, extends from jugular to abdominal region.
Oil globule	Oil dispersed in yolk, largest concentration of globules in anterior portion of yolk.
Gut	Straight.
Air bladder	Oval, midway between pectorals and anus.
Teeth	None in prolarvae; canine in postlarvae.
Size at completion of yolk-sac stage	ca. 22–25 mm TL (this study).
Total myomeres	59–66.
Preanal myomeres	37–42.
Postanal myomeres	20–25.
Last fin(s) to be developed	Pectoral and pelvic.
Pigmentation	Pigmentation heavy on head, dorsal, and lateral areas of body; parr marks (ca. 10) in postlarvae; abdominal region has little pigmentation; 8–13 parr marks (Moyle 1976).
Distribution	Newly hatched larvae remain in gravel 2–3 weeks before migrating downstream to shallow, quiet pools in cool streams of Sacramento-San Joaquin River system.

JUVENILES (Figure 5-8)

Dorsal fin	10–12 (Miller and Lea 1972, Moyle 1976, Hart 1973).
Anal fin	8–10 ((Miller and Lea 1972, Moyle 1976); 8–12 (Hart 1973).
Pectoral fin	11–17 (Scott and Crossman 1973, Moyle 1976); about 15 (Hart 1973); 14–15.
Adipose fin	Yes.
Mouth	Terminal, slightly oblique (Scott and Crossman 1973); terminal, large, directed forward (Hart 1973).
Vertebrae	63–65 (Miller and Lea 1972); 60–66 (Scott and Crossman 1973).

Distribution	Remain in the cold freshwater tributaries of the Sacramento-San Joaquin River system and coastal streams for 1–3 years before entering the ocean (Moyle 1976).

LIFE HISTORY

Steelhead, *Oncorhynchus mykiss*, is native to the Pacific coast of North America from the Aleutian Islands to northwestern Mexico (Hart 1973, Moyle 1976). The anadromous steelhead has many different races and populations along the California coast. Specimens described in this manual are from two major stocks: the artificial stocks from the Nimbus Fish Hatchery on the American River and Coleman Fish Hatchery on Battle Creek, and the natural stock from Pine Gulch Creek (which flows into Bolinas Lagoon) and Olema Creek (which flows into Tomales Bay).

In the Sacramento-San Joaquin Estuary, upstream migration of adult steelhead begins in spring and continues through fall, several months before actual spawning (Hallock *et al.* 1961). In the hatcheries, spawning occurs from January through March. In the Sacramento-San Joaquin River system, spawning occurs from December through April (Hallock *et al.* 1961). Spawning habitats range from large rivers to small creeks.

Eggs, orange-red in color, are buried by the females in loose gravel, usually at the lower end of a pool. The female releases some eggs in each batch and the process is repeated until she is spawned out (Shapovalov and Taft 1954). Eggs hatch in 3–4 weeks at water temperatures of 10–15°C (Moyle 1976) or 19 d at 15°C (McAfee 1966). At Nimbus Fish Hatchery, eggs hatch within 4 weeks at 10–12°C (Nimbus Fish Hatchery records).

Newly hatched larvae initially stay in crevices of nesting area until their yolk sac is absorbed (about 2 weeks) and then move into adjacent shallow and quiet pools located below riffles. Larvae are solitary, but a social hierarchy gradually develops within a few weeks after they emerge from the nest (Jenkins 1969).

Juvenile steelhead remain in freshwater streams from 1–3 years before entering the ocean (Moyle 1976). Downstream migration occurs in most months of the year, but peaks occur in fall and spring (Hallock *et al.* 1961). In this study, many juvenile steelhead were observed in inshore, slough, and open waters of the estuary, in rivers, and even in some of the intermittent streams such as Corte Madera Creek, Suisun Creek, Sonoma Creek, Walnut Creek, and Alameda Creek. The hatchery stocks are released mostly during spring by State and Federal agencies near the hatchery, at designated locations in the Sacramento-San Joaquin River system.

Food items eaten by juveniles include terrestrial and aquatic insects. In the estuary, they also eat amphipods, other small crustaceans, and small fish (Sasaki 1966a). Migrating juvenile steelhead are preyed on by Sacramento pikeminnow *Ptychocheilus grandis*, striped bass *Morone saxatilis*, and seagulls (P. Moyle 1982, personal communication). Little is known about the behavior and habits of juvenile steelhead after they enter the ocean (Ganssle 1966). Generally they will return to their natal streams in 1 or 2 years (Scott and Crossman 1973) or 2–3 years (Moyle 1976). Sexual maturity is reached by ages 3–5 years, and males often mature 1 year earlier than females. They can spawn four or more times during their life (Shapovalov and Taft 1954). Steelhead have a life expectancy of 6–8 years (Scott and Crossman 1973). The steelhead is a very important California sport fish.

Moyle (1976) states that the well-known homing behavior of steelhead to particular streams has led to the recognition of many local races and taxonomic variations. Each population returns to its home stream to spawn. This may be the reason why steelhead runs have been declining in recent years. Human activities on these rivers and streams have led to loss of habitat. The future of this anadromous fish is still uncertain in California, although the National Park Service has proposed to restore some of the coastal streams on park lands and provide more spawning habitat (J. Howell 1982, personal communication).

References

Breder and Rosen 1966; Ganssle 1966; Hallock *et al.* 1961; Hart 1973; Jenkins 1969; Knight 1963; McAfee 1966; Miller and Lea 1972; Moyle 1976; Sasaki 1966a; Scott and Crossman 1973; Shapovalov and Taft 1954; Wales 1941.

Specimen Credits

Egg, larvae, and juvenile were obtained from Nimbus Fish Hatchery, California Department of Fish and Game.

Characteristic Comparison: Salmonids

Characteristic	**Chinook Salmon**	**Steelhead Rainbow Trout**
Eggs		
Diameter (mm)	4.6–62.	6.0–7.0
Shape	Spherical, some slightly irregular	Spherical, some slightly irregular
Larvae		
Length at hatch (mm)	Ca. 20	Ca. 15
Snout-anus length	58–61% pf TL of prolarvae and postlarvae	59–68% of TL of prolarvae and postlarvae
Juveniles		
Adipose fin	Upper edge pigmented, base clear	Entire edge of adipose fin pigmented
Dorsal, caudal fin pigmentation	Unpigmented (dorsal fin occasionally with one or more spots)	Pigmented

Figure 5.—Salmonidae: *Oncorhynchus tshawytscha*, Chinook salmon.

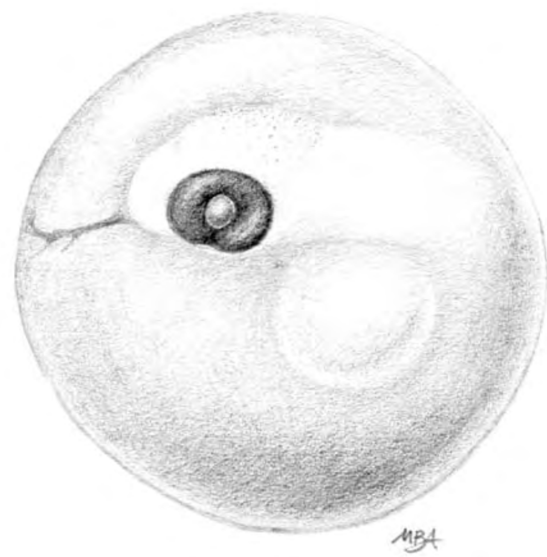


FIGURE 5-1.—Egg, 9 mm diameter

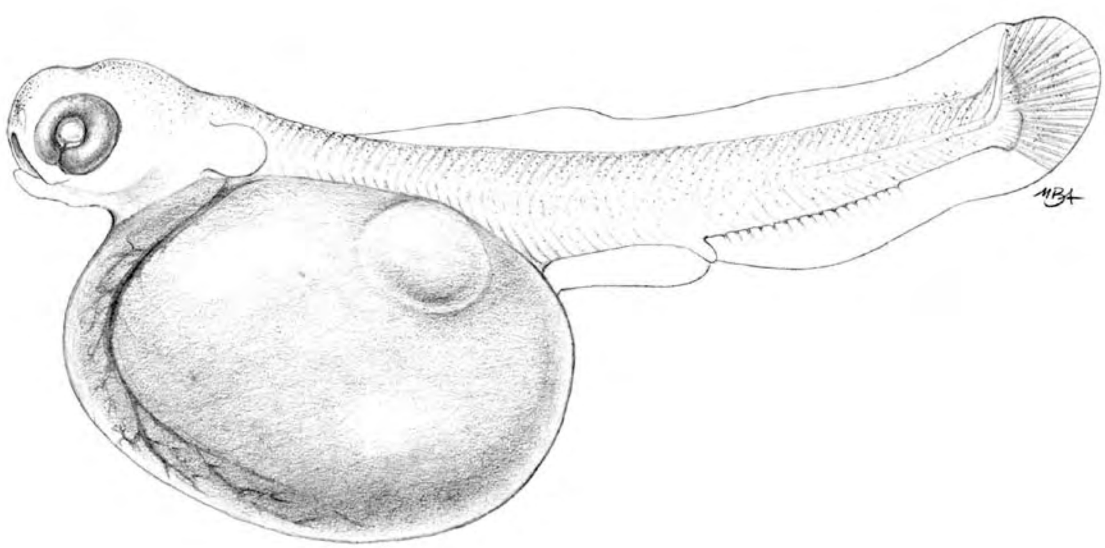


FIGURE 5-2.—Prolarva, 23 mm TL.

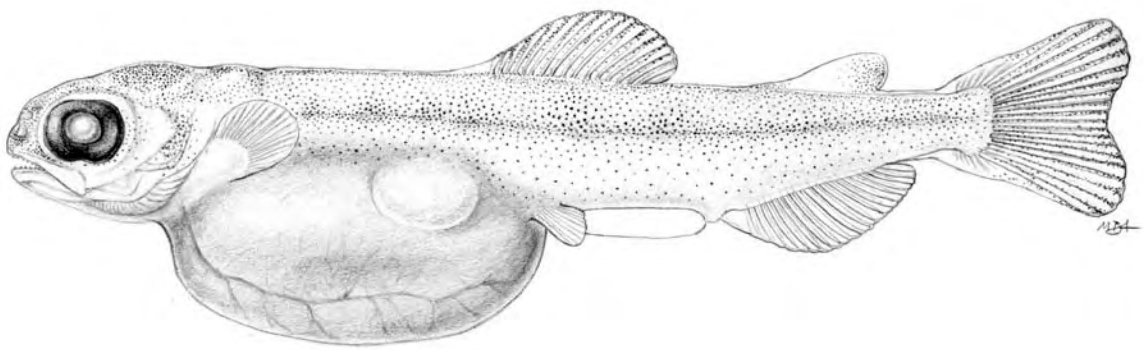


FIGURE 5-3.—Prolarva, 32 mm TL.

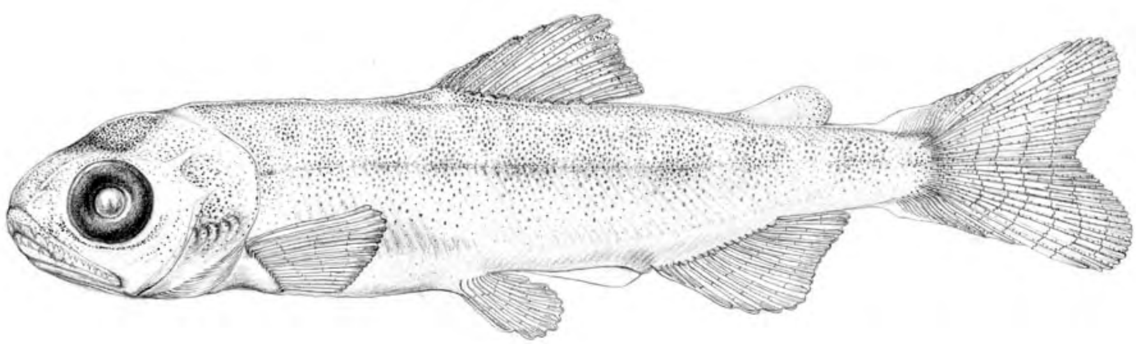


FIGURE 5-4.—Juvenile, 37.5 mm TL.

Salmonidae: *Salmo gairdneri*, rainbow trout.

FIGURE 5-5.—Egg, late embryo, 6 mm diameter.

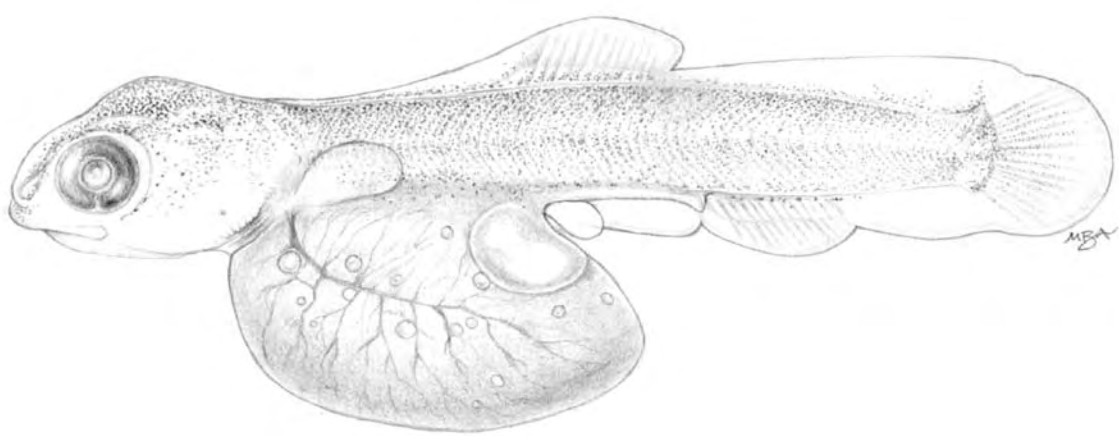


FIGURE 5-6.—Prolarva, 17 mm TL.

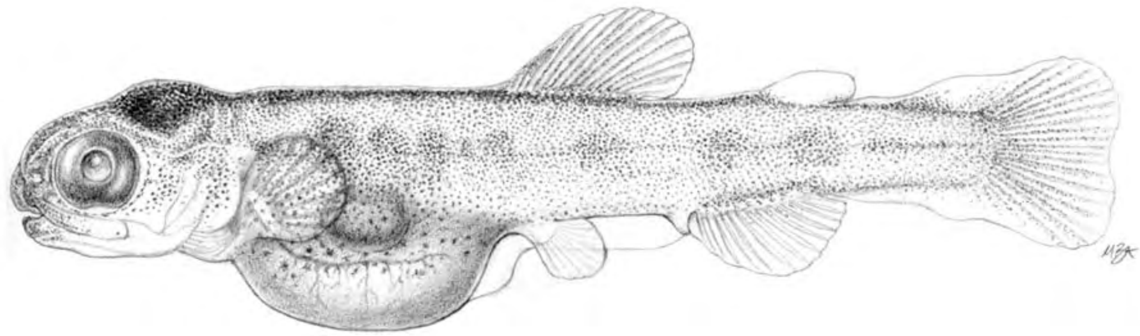


FIGURE 5-7.—Prolarva, 25 mm TL.

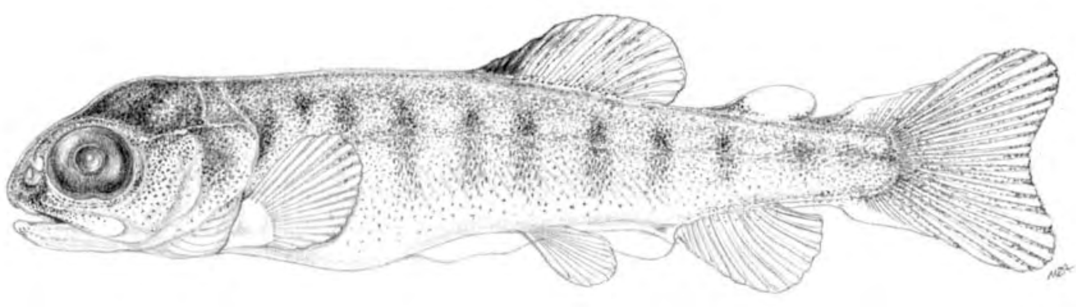


FIGURE 5-8.—Juvenile, 28 mm TL.

6. Osmeridae – Smelts

Ganssle (1966) recorded five species of osmerids in the Sacramento-San Joaquin Estuary. Three of them are marine species: whitebait smelt *Allosmerus elongates*, surf smelt *Hypomesus pretiosus*, and night smelt *Spririnchus starksi*. Delta smelt, *Hypomesus transpacificus*, is a euryhaline fish, native to the Sacramento-San Joaquin Estuary. These smelts spend most of their life in freshwater portions of the estuary (Herald 1961). Longfin smelt, *Spirinchus thaleichthys*, is also a euryhaline fish which has a definite migratory pattern during spawning season (Moyle 1976) as well as in the juvenile stages (Ganssle 1966).

The taxonomy of the family Osmeridae has been reviewed by Hubbs (1925b) and McAllister (1963). The life history work includes Schaefer (1936), Thompson *et al.* (1936), and Yapchiongco (1949) on surf smelt; Dryfoos (1965) and Moulton (1974) on longfin smelt; and Moyle (1976) on Delta smelt. Little study has been done on night smelt and whitebait smelt. Most recently, the early life development of West Coast smelts has been investigated by M. Hearne (1979–1981, personal communication).

References

Aplin 1967; Dryfoos 1965; Ganssle 1966; Herald 1961; Hubbs 1925b; Moulton 1974; Moyle 1976; Schaefer 1936; Thompson *et al.* 1936; Yapchiongco 1949.

WHITEBAIT SMELT, *Allosmerus elongatus* (Ayres)

SPAWNING

Location	Probably spawns in ocean (Hubbs 1925b).
Season	Mature male taken in Humboldt Bay in March (McAllister 1963).

CHARACTERISTICS

JUVENILES (Figure 6-1)

Dorsal fin	9–10 (McAllister 1963, Miller and Lea 1972); 9–11 (Hart 1973).
Anal fin	14–17 (McAllister 1963, Miller and Lea 1972, Hart 1973).
Pectoral fin	12–14 (McAllister 1963, Miller and Lea 1972, Hart 1973); 12.
Adipose fin	Yes.

Mouth	Terminal, large, upper jaw extending just posterior to margin of eye (Hart 1973); large, oblique; lower jaw slightly protruding, snout pointed.
Vertebrae	65–67 (McAllister 1963, Miller and Lea 1972).
Distribution	San Francisco Bay (McAllister 1963, Ganssle 1966, Aplin 1967).

LIFE HISTORY

The whitebait smelt is found from the Strait of Juan de Fuca, British Columbia, southward to San Francisco Bay (McAllister 1963). They have also been reported further south to Monterey Bay (Kukowski 1972b). In San Francisco Bay, this species was collected by Ganssle (1966), Aplin (1967), and this study. Hubbs (1925b) reported that whitebait smelt probably spawn in the ocean and remain there as translucent larvae until they are about 76 mm long.

In December 1982 a total of 53 whitebait juveniles ranging in size from 50 to 78 mm TL were captured in midwater trawls in San Francisco Bay and South San Francisco Bay by the CDFG. Those specimens were still carrying larval pigmentation. The canine teeth (1–3) were developed in the middle of the vomer. All of the juveniles had empty gut cavities.

Life history information for the whitebait smelt is very limited. The largest specimens were reported as 222 mm by Roedel (1953), and a 135-mm TL specimen was captured in this study. Whitebait smelt have been used largely as bait, and only to a minor extent for human consumption (Hart 1973).

References

Aplin 1967, Ganssle 1966, Hart 1973, Hubbs 1925b, Kukowski 1972, McAllister 1963, Miller and Lea 1972, Roedel 1953.

SURF SMELT, *Hypomesus pretiosus* (Girard)

SPAWNING

Location	Beaches at high tide mark and surf zone of Pacific coast (Thompson *et al.* 1936); at the head of sheltered bays with exposed or shaded beaches (Schaefer 1936, Hart and McHugh 1944); sandy to gravel beaches (Yapchiongco 1949).
Season	May–March (Schaefer 1936); May–October (Yapchiongco 1949, McAllister 1963); most months of the year (Hart and McHugh 1944, Hart 1973); fall

	and winter months in the study area.
Temperature	ca. 10°C and higher (Schaefer 1936).
Salinity	Seawater-mesohaline (Thompson *et al.* 1936, Schaefer 1936).
Substrates	Sand, coarse sand, shell, and gravel (Thompson *et al.* 1936, Schaefer 1936, Yapchiongco 1949).
Fecundity	4,020–13,700 (Thompson *et al.* 1936); 2,500–29,300 (Schaefer 1936); 2,500–37,000 per batch (Hart and McHugh 1944); 15,000–20,000 (Leong 1967); 1,500–30,000 (Fitch and Lavenberg 1975).

CHARACTERISTICS

EGGS

Shape	Spherical (Yapchiongco 1949).
Diameter	1–1.12 mm (Thompson *et al.* 1936); 1.02 mm (Schaefer 1936); range 0.93–1.24 mm, and mostly 1.10 mm (Yapchiongco 1949).
Yolk	Paraffin-like in opaqueness (Yapchiongco 1949). Unfertilized egg yolk, granular.
Oil globule	Numerous near periphery of yolk (Yapchiongco 1949).
Chorion	Transparent with many minute pores. With a cap-like accessory structure superimposed on chorion (Yapchiongco 1949); Chorion has two layers, the inner layer is clear and smooth, outer layer will reverse after the egg is released.
Perivitelline space	0.13 mm in width (Schaefer 1936).
Egg mass	Deposited singly, but may appear clustered due to successive broadcast over a certain area of the substrate (Yapchiongco 1949).
Adhesiveness	Adhesive (Thompson *et al.* 1936, Schaefer 1936, Yapchiongco 1949).
Buoyancy	Demersal.

LARVAE (Figures 6-2, 6-3)

Length at hatching	ca. 3.0 mm TL (Schaefer 1936); range 4–6 mm TL (Yapchiongco 1949).
Snout to anus length	71–74% of TL of larvae at 6.1–29.5 mm TL (this study).
Yolk sac	Spherical, slightly behind thoracic region

	(Yapchiongco 1949).
Oil globule	A few large coalesced oil globules, eventually merging into one.
Gut	Straight.
Air bladder	Small oval to large oval, located midway between base of pectoral fin and anus, or slightly anterior and above to pelvic fin bud.
Teeth	Very small, apparent in postlarvae.
Size at completion of yolk-sac stage	6.0–6.2 mm TL (Yapchiongco 1949); ca. 6.5–7.0 mm TL.
Total myomeres	63–67.
Preanal myomeres	47–52.
Postanal myomeres	14–17.
Last fin(s) to complete development	Pectoral.
Pigmentation	Two rows of large melanophores on midventral and postanal regions; a few melanophores on opercles and caudal peduncle; dashed melanophores along lateral line, especially posterior portion of body.
Distribution	Pelagic along Pacific Coast, bays, and estuaries, up to Suisun Bay.

JUVENILES (Figure 6-4)

Dorsal fin	8–11.
Anal fin	12–17.
Pectoral fin	14–17 (McAllister 1963).
Adipose fin	Yes.
Mouth	Terminal and moderate.
Vertebrae	62–70 (McAllister 1963).
Distribution	Along the Pacific coast and in euryhaline waters of the Sacramento-San Joaquin Estuary and adjacent coastal streams and estuaries.

LIFE HISTORY

The surf smelt has been reported to be distributed from Prince William Sound and Chignik Lagoon, Alaska, southward to Long Beach, California (Miller and Lea 1972, Hart 1973). In the Sacramento-San Joaquin Estuary, the surf smelt has been observed in San Francisco Bay, San Pablo Bay, Carquinez Strait, and Suisun Bay (Ganssle 1966, Messersmith 1966, Aplin 1967). During 1978–1980, the surf smelt was common in the

Sacramento-San Joaquin Estuary, Tomales Bay (including Walker Creek), and Moss Landing Harbor-Elkhorn Slough, particularly during fall and winter seasons. Larvae and juveniles can tolerate mesohaline and fresher waters.

Hart (1973) and Hart and McHugh (1944) noted that surf smelt spawn during most months of the year. Contributing to this prolonged spawning season is the fact that females may spawn more than once a season and that each of the many Pacific coast surf smelt populations has its own spawning period. Judging from the size of the larvae collected from Sacramento-San Joaquin Estuary, surf smelt spawn only during fall and winter months in this area. Adult surf smelt have been observed in San Francisco Bay and Suisun Bay during the same period, supporting this hypothesis (Ganssle 1966, Messersmith 1966).

Eggs are deposited in the surf zone on sandy beaches at high tide, usually at the mouth of small bays or inlets (Schaefer 1936, Hart and McHugh 1944, Yapchiongco 1949). A detailed account of spawning behavior has been given by Schaefer (1936). The adhesive eggs become encrusted with sand grains or are anchored to pieces of gravel (Hart and McHugh 1944). The eggs hatch in 10–11 d in the summer and take a longer time in the winter (Hart 1973).

The small numbers of surf smelt larvae collected within the Sacramento-San Joaquin Estuary indicate that most spawning occurs along the Pacific Coast. Follett (1952) collected postlarval stages of surf smelt from the vicinity of the southeast Farallon Islands in 33–44 fathoms of water. The transparent to translucent juveniles (40–50 mm TL) have been collected by trawl, trap net, and beach seine in Suisun Bay and Walker Creek on many occasions during winter months. Larvae were also captured at Tracy Pumping Station. Major food items of juvenile surf smelt include small crustaceans such as copepods, amphipods, and shrimp and crab larvae (Hart 1973). Insect larvae are found in the stomach when they inhabit freshwater (Yapchiongco 1949).

Surf smelt reach maturity in 1–3 years and usually do not live more than 3 years (Yapchiongco 1949). Surf smelt are small but are considered to be a delicacy, and they constitute an important California coastal fishery (Fitch and Lavenberg 1971).

References

Aplin 1967, Fitch and Lavenberg 1971, Follett 1952, Ganssle 1966, Hart 1973, Hart and McHugh 1944, Leong 1967, McAllister 1963, Messersmith 1966, Miller and Lea 1972, Schaefer 1936, Thompson *et al.* 1936, Yapchiongco 1949.

DELTA SMELT, *Hypomesus transpacificus* (McAllister)

SPAWNING

Location	Deadend sloughs (Radtke 1966b); close to inshore of the Delta (Moyle 1976); shallow freshwaters in Delta and Suisun Bay. General locations: Montezuma Slough, vicinity of Pittsburg and Contra Costa Powerplants on Suisun Bay, lower reaches of Sacramento and San Joaquin Rivers and Delta.
Season	Ripe females collected from December to April (Moyle 1976); spawning occurs from February to June.
Temperature	ca. 7–15°C.
Salinity	Freshwater.
Substrates	Aquatic plants (Moyle 1976); submerged and inshore plants; may use sandy and hard-bottom substrates.
Fecundity	1,400–1,800 for 64–80 mm TL specimens (Moyle 1976).

CHARACTERISTICS

EGGS (Figure 6-9)

Shape	Unfertilized mature eggs, spherical.
Diameter	Unfertilized mature eggs, ca. 1.0 mm.
Yolk	Yellowish, granular.
Oil globule	Many small oil globules.
Chorion	Two layers; the outer layer reverses itself and forms an adhesive anchor to the substrates.
Egg mass	Deposited singly on substrates.
Adhesiveness	Attached to plants (Moyle 1976); adhesive outer layer of chorion.
Buoyancy	Demersal.

LARVAE (Figures 6-6, 6-7)

Length at hatching	ca. 5.5–6.0 mm TL.
Snout to anus length	70–75% of TL in both prolarvae and postlarvae.
Yolk sac	Small, spherical to oval, slightly posterior to thoracic region.
Oil globule	Usually single, in front of yolk sac.
Gut	Straight.

Air bladder	Oval, slightly anterior of midway from pectoral to anus or slightly above and anterior of pelvic fin back.
Teeth	In front portion of mandible first; premaxillary and maxillary later in postlarval stage.
Size at completion of yolk-sac stage	ca. 6–7 mm TL.
Total myomeres	51–56.
Preanal myomeres	36–40.
Postanal myomeres	12–18.
Last fin(s) to complete development	Pectoral fin.
Pigmentation	Two rows of dashed melanophores along jugular to thoracic region; then replaced by a single row of dashed melanophores on midventral region, few melanophores along postanal region (near caudal). Pigments also appear on yolk sac.
Distribution	Near surface of water column (Moyle 1976); pelagic, mostly on surface, from Montezuma Slough to upper Suisun Bay to lower Sacramento-San Joaquin river system.

JUVENILES (Figure 6-8)

Dorsal fin	9–10 (McAllister 1963).
Anal fin	15–17 (McAllister 1963).
Pectoral fin	10–12 (McAllister 1963).
Adipose fin	Yes.
Mouth	Small, flexible, maxillary does not extend past the middle of the eye (Moyle 1976); terminal, small, oblique.
Vertebrae	53–56 (McAllister 1963).
Distribution	Pelagic, concentrated in Suisun Bay and Delta; also can be found in San Pablo Bay and lower reaches of Sacramento and San Joaquin Rivers.

LIFE HISTORY

The delta smelt is a euryhaline fish, native to the Sacramento-San Joaquin Estuary (Herald 1961, McAllister 1963) which was formerly identified as the pond smelt, *Hypomesus olidus*. The delta smelt ranges from the lower reaches of the Sacramento and San Joaquin Rivers, through the Delta, and into Suisun Bay (Ganssle 1966, Moyle 1976). Occasionally they are found in Carquinez Strait, San Pablo Bay, and south San Francisco

Bay, but the species is much more abundant in the fresher waters of the Delta and Suisun Bay (Ganssle 1966, Messersmith 1966).

Prior to spawning in the fall, delta smelt congregate in upper Suisun Bay and lower reaches of the Delta (Moyle 1976). They were collected in large numbers by otter trawl near New York Slough and the Antioch Bridge during fall and winter months. Moyle (1976) noted that ripe smelt could be collected from December to April. In this study, larvae were collected from February to mid-July, indicating that the delta smelt spawning period probably extends from January to June. Delta smelt use channels and deadend sloughs of the Delta for spawning (Radtke 1966b). Vegetation is sparse during winter months, so the smelt may deposit their eggs over submerged tree branches and stems or in open water over sandy and rocky substrate. As the eggs descend to the bottom, the outer layer of the chorion peels downward, remaining attached to egg. This adhesive layer then attaches to the substrate.

Newly hatched larvae float near the surface of the water column in both inshore and channel areas. They have been observed in Montezuma Slough and throughout the Delta as far as the lower Sacramento River and San Joaquin River near Tracy Pumping Station.

Small juveniles (ca. 30 mm TL) were collected in plankton tows in Suisun Bay and the Delta on many occasions. Larger juveniles and adults were abundant in the trawl and trap net catches during spring and summer in Suisun Bay and the Delta. Large numbers were observed at times on the intake screens of Pittsburg and Contra Costa Powerplants, indicating that delta smelt swim in large schools. Juvenile smelt move downstream (Radtke 1966b, Moyle 1976) to San Pablo Bay and Carquinez Strait (Ganssle 1966, Messersmith 1966) before turning back to Suisun Bay for spawning. Thus, the seasonal movement occurs within a short section of the upper estuary. Juvenile delta smelt eat planktonic crustaceans, small insect larvae, and mysid shrimp as their major food items (Moyle 1976).

Delta smelt reach maturity after their first year, and most adults die after spawning (Erkkila *et al.* 1950, Moyle 1976). Delta smelt currently have no value as a sport or commercial catch. A fresh delta smelt smells like cucumber.

Reference

Erkkila *et al.* 1950, Ganssle 1966, Herald 1961, McAllister 1963, Messersmith 1966, Moyle 1976, Radtke 1966b.

NIGHT SMELT, *Spirinchus starksi* (Fisk)

SPAWNING

Location	In the surf zone of beaches, from Monterey northward (Fitch and Lavenberg 1971).

Season	In Washington, mature specimens are found in May (McAllister 1963); January–September (Fitch and Lavenberg 1971); in May (Hart 1973).
Salinity	Seawater.
Substrates	Coarse sand and gravel (Fitch and Lavenberg 1971).

CHARACTERISTICS

Length at hatching	ca. 6.0–7.5 mm TL (M. Hearne 1980, personal communication).
Snout to anus length	n/a
Oil globule	Single, large (M. Hearne 1980, personal communication).
Gut	Straight (M. Hearne 1980, personal communication).
Air bladder	Small, oval, midway between the base of pectoral fin and anus or slightly above and anterior of pelvic fin bud (M. Hearne 1980, personal communication).
Total myomeres	61–63.
Preanal myomeres	43–46.
Postanal myomeres	15–18.
Pigmentation	Prolarvae; single row of dashed melanophores along midventral region, ca. 15–16; melanophores also found in postanal, hydeural regions, scattered melanophores at dorsal area of anus, yolk sac, and base of pectorals (M. Hearne 1980, personal communication). In postlarvae, 2 more rows of dashed melanophores along midventral line (M. Hearne 1980, personal communication).
Distribution	Mostly coastal waters, also found in San Francisco Bay, Moss Landing Harbor-Elkhorn Slough.

JUVENILES (Figure 6-11)

Dorsal fin	8–10 (McAllister 1963); 8–11 (Miller and Lea 1972).
Anal fin	15–19 (McAllister 1963); 15–21 (Miller and Lea 1972).

Pectoral fin	10–11 (McAllister 1963); 10–11 (Miller and Lea 1972, Hart 1973).
Adipose fin	Yes.
Mouth	Mouth large, maxillary reaches past posterior margin of the eye (Fitch and Lavenberg 1971); mouth moderate, terminal, and directed upward, maxillary just short of reaching posterior margin of the eye (McAllister 1963); terminal to superior, large.
Distribution	Mostly coastal Pacific; also found in San Francisco Bay up to Carquinez Strait, and in Moss Landing Harbor-Elkhorn Slough.

LIFE HISTORY

Night smelt are found from Point Arguello, California to Shelikof Bay, Alaska, (Dryfoos 1961; McAllister 1963; Hart 1973). However, this species is uncommon in the Sacramento-San Joaquin Estuary (Ganssle 1966, Messersmith 1966). In this study, small numbers of night smelt were observed from San Francisco Bay to San Pablo Bay and in Moss Landing Harbor-Elkhorn Slough, mostly during winter.

Frey (1971) reported that night smelt spawn from Moss Landing Harbor northward starting in March and continuing until fall. Fitch and Lavenberg (1971) recorded the spawning period as January through September. Mature specimens in the Washington area were found in May (McAllister 1963). Judging from the small larvae taken in this study, the spawn may occur during the winter months in ocean waters off San Francisco Bay.

During spawning, schools of fish congregate on shallow beaches with coarse sand and gravel substrates. The adhesive eggs sink to the bottom, become encrusted by sand and gravel, and eventually become completely buried in the substrate in the surf zone. The male fish outnumber the females at the height of the spawn (Fitch and Lavenberg 1971). Adults may spawn more than once during the season. Eggs take about 2 weeks to hatch (Fitch and Lavenberg 1971).

Life history details from the egg to the juvenile stages are not well known. The larval development of night smelt was described by R. Morris and M. Hearne (1980, personal communication). Judging from the catch data made by Ganssle (1966), Messersmith (1966), and Aplin (1967), it appears that the bulk of the population remains along the Pacific coast, and only a few occasionally enter the bays and estuaries. Their diet consists of small crustaceans (Fitch and Lavenberg 1971) and is similar to that of other smelts.

No literature is available on the maturity and lifespan of the night smelt. Night smelt are just as important as surf smelt to commercial and sport fishermen (Frey 1971). Night smelt make excellent fish "chips."

References

Aplin 1967; Dryfoos 1961; Fitch and Lavenberg 1971; Frey 1971; Ganssle 1966; Hart 1973; McAllister 1963; Messersmith 1966; Miller and Lea 1972.

LONGFIN SMELT, *Spirinchus thaleichthys* (Ayres)

SPAWNING

Location	Freshwater section of lower Delta (Moyle 1976); streams near the sea (Hart 1973), tributaries and streams of a land-locked lake (Dryfoos 1965). Sloughs, edge of rivers and bays. General locations: Suisun Bay, Montezuma Slough, lower reaches of Sacramento and San Joaquin rivers, and the Delta. Specific locations: vicinity of Contra Costa and Pittsburg Powerplants, Harris Channel.
Season	December–February (Dryfoos 1965, Moyle 1976); February–April (Moulton 1974); in autumn (Hart and McHugh 1944); October–December (Hart 1973); December–June.
Temperature	7 °C (Dryfoos 1965); 5.6–6.7°C (Moulton 1974); ca. 7–14.5°C.
Salinity	Freshwater (Hart and McHugh 1944, Hart 1973, Moyle 1976).
Substrates	Rocks, aquatic plants (Moyle 1976); submerged plants and probably hard and sand bottoms.
Fecundity	9,621–23,624, with an average of 18,100, in Lake Washington (Dryfoos 1965); 535–1,142 for 2–year olds in Lake Harrison (Hart 1973); 24,000 (Moyle 1976).

CHARACTERISTICS

EGGS (Figures 6-12, 6-13, 6-14)

Shape	Spherical. Diameter 1.2 mm (Dryfoos 1965); 0.9–1.1 mm.
Yolk	Yellowish, granular.
Oil globule	Many oil globules, largest ca. 0.35 mm in diameter.

Chorion	Two layers; inner layer transparent, smooth; the outer layer will reverse and attach to substrate after descending.
Pervitelline space	ca. 0.1–0.15 mm in width.
Egg mass	Deposited singly.
Adhesiveness	Outer layer chorion is adhesive.
Buoyancy	Demersal.

LARVAE (Figures 6-15, 6-16)

Length at hatching	6.9–8.0 mm TL (Dryfoos 1965); 5.3–6.8 mm TL.
Snout to anus length	ca. 68–71% of TL of prolarvae at 5.3–7.5 mm TL and ca. 65% of TL of postlarvae.
Yolk sac	Thoracic.
Oil globule	Usually 2–3 and finally consolidated in one.
Gut	Straight
Teeth	Small, pointed and curled, on both jaws, apparent in postlarval stage.
Size at completion of yolk-sac stage	ca. 8–10 mm TL.
Total myomeres	54–58.
Preanal myomeres	39–44.
Postanal myomeres	11–16.
Last fin(s) to complete development	Pectoral fins.
Pigmentation	In prolarvae, a row of dashed melanophores (ca. 10–12) along midventral region; in postlarvae, 2 rows of melanophores in thoracic and midventral and postanal regions; the single row midventral melanophores gradually fades out.
Distribution	Pelagic, mostly on surface of water column from Carquinez Strait to lower reaches of Sacramento and San Joaquin rivers and theDelta.

JUVENILES (Figure 6-17)

Dorsal fin	8–10 (McAllister 1963).
Anal fin	15–19 (McAllister 1963); 18–21 (Moyle 1976) 15–22 (Miller and Lea 1972).
Pectoral fin	10–12 (McAllister 1963).
Mouth	Slightly superior (this study); maxillary elongate, extends to the posterior margin of the eye (Moyle 1976).

Vertebrae	54–61 for entire distributional range and 55–58 for the California population (McAllister 1963).
Distribution	Middle to bottom of water column (McAllister 1965, Moyle 1976); Suisun Bay, San Pablo Bay, and San Francisco Bay (Ganssle 1966, Messersmith 1966, Aplin 1967).

LIFE HISTORY

The distribution of the longfin smelt is from Prince William Sound, Hinchinbrook Island, Alaska, southward to the Sacramento-San Joaquin Estuary (McAllister 1963, Miller and Lea 1972). According to unpublished data from CDF&G (1980–1982), longfin smelt have been observed from south San Francisco Bay into the Delta. During 1978–1980, most of the smelt were collected between Carquinez Strait and the Delta. One adult longfin smelt was collected in Moss Landing Harbor in March 1980, which indicates a southern range extension for this species.

In the fall, the adults move from San Francisco Bay and San Pablo Bay to the fresher waters of Montezuma Slough, Suisun Bay, and lower reaches of the Sacramento and San Joaquin Rivers, a sign of anadromous behavior. According to Moyle (1976), smelt spawn in the freshwater portions of the Delta from December through February. Judging from the large number of gravid females collected at the Pittsburg and Contra Costa Powerplants from December to June, however, spawning period appears to extend into the spring months. The spawning habits of longfin smelt are similar to those of Delta smelt. During spawning, the anal fin of the male longfin smelt becomes elongated and the body becomes greenish and covered with speckled dark melanophores. Male smelt are larger than females during the breeding season.

Eggs are deposited singly and adhere to the substrate by the reversed outer chorion. Dryfoos (1965) reported the eggs hatched in 37–47 d at 7°C in a landlocked lake. On several occasions during this study attempts were made to fertilize smelt eggs artificially and rear them in the laboratory, but the eggs did not survive the incubation period.

Longfin smelt larvae are pelagic and are usually found in the upper layers of the water column, both inshore and offshore. They school either with other longfin smelt or with Delta smelt, which makes larval identification difficult. During this study, large numbers of longfin smelt larvae were captured in Suisun Bay, particularly from the west side. As larvae become larger, the majority of the population begins to move downbay.

Ganssle (1966) described a downstream movement of juvenile longfin smelt in April and May. The catch of smelt in Carquinez Strait, San Pablo Bay, and San Francisco Bay increases substantially during spring and summer (Messersmith 1966, Aplin 1967). Juveniles remain in the middle to the bottom of the water column (Moyle 1976). They feed on Diaphanosoma, Diaptomus, and Epischura, mysid shrimp (Dryfoos 1965), and other small crustaceans (Moyle 1976). Longfin smelt reach maturity at the end of their second year (Dryfoos 1965). Most die after spawning, but a few females may live and spawn a second time (Moyle 1976). Older smelt spawn later in the season than younger, smaller ones, which explains the prolonged spawning season. No relationship has been found between the length of the fish and fecundity (Moulton 1974).

Longfin smelt are the most abundant osmerids in the Sacramento-San Joaquin Estuary and are seasonally sold in local fish markets.

References

Aplin 1967, Dryfoos 1965, Ganssle 1966, Hart 1973, Hart and McHugh 1944, McAllister 1963, Messersmith 1966, Miller and Lea 1972, Moulton 1974, Moyle 1976.

Characteristic Comparison: Smelts

Characteristic	**Whitebait Smelt**	**Surf Smelt**	**Delta Smelt**	**Night Smelt**	**Longfin Smelt**
Spawning					
Season	Winter	Fall–winter	Winter–spring	Winter	Winter
Location	Pacific Ocean	Pacific Coast	Montezuma Slough to Delta	Pacific Coast	Montezuma Slough to Suisun Bay
Eggs					
Diameter (mm)		0.93–1.24	ca. 1.0		0.9–1.1
Larvae					
Length at hatch (mm)		3.0–6.0	ca. 4.0	ca. 6.0–7.5	5.3–6.8
Total myomeres		63–67	51–56	61–63	54–58
Preanal myomeres		47–52	36–46	43–46	39–44
Postanal myomeres		14–17	12–18	15–18	11–16
Center of adipose vs. center of anal fin		Over–under	Over–under	Adipose posterior	Adipose posterior
Eye size		Large	Large	Large	Small
Juveniles					
Dorsal fin	9–11	8–11	9–10	8–11	8–10
Anal fin	14–17	12–17	15–17	15–21	15–22
Pectoral fin	12–14	14–17	10–12	10–11	10–12
Maxillary	Long, past mid-eye	Short, to mid-eye	Short, to mid-eye	Long, past mid-eye	Past mid-eye
Head	Pointed, long	Pointed, short	Pointed, short	Pointed, long	Wedge-shaped, asymmetrical

Figure 6.—Osmeridae: Smelts.

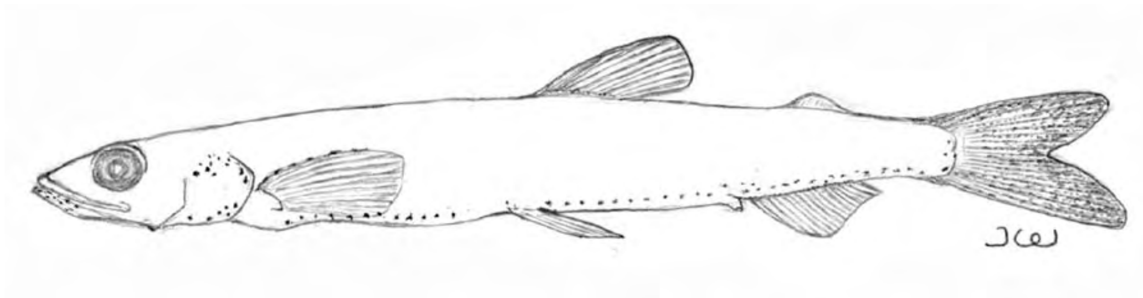


FIGURE 6-1.—*Allosmerus elongatus*, whitebait smelt juvenile, 67 mm TL.

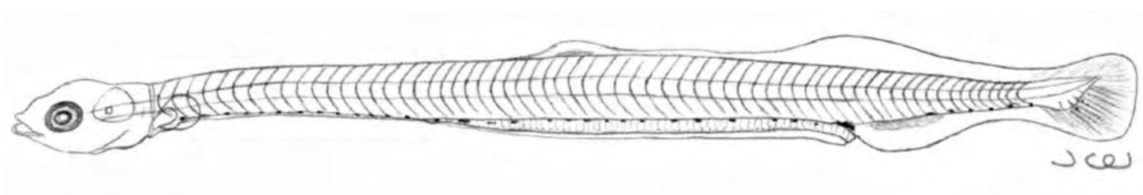


FIGURE 6-2.—*Hypomesus pretiosus*, surf smelt portlarva, 14.7 mm TL.

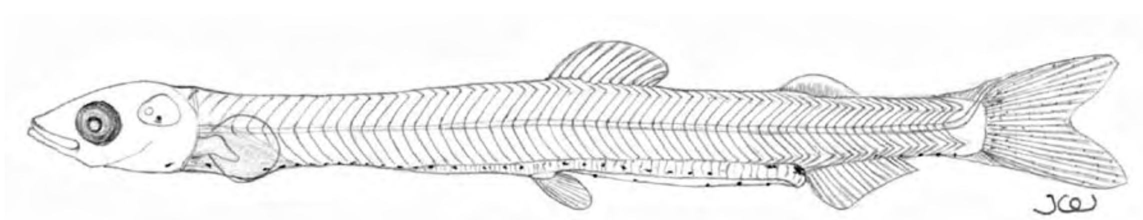


FIGURE 6-3.—*Hyposesus pretiosus*, surf smelt postlarva, 30.5 mm TL.

FIGURE 6-4.—*Hypomesus pretiosus*, surf smelt juvenile, 42.5 mm TL.

Osmeridae: *Spirinchus starksi*, night smelt.

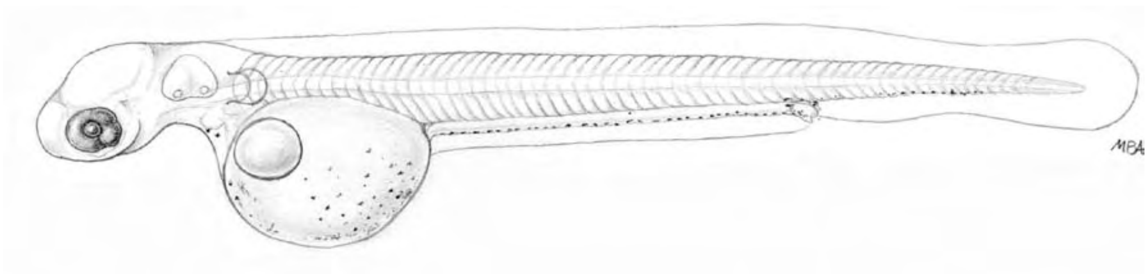


FIGURE 6-5.—Prolarva, 4.3 mm TL.

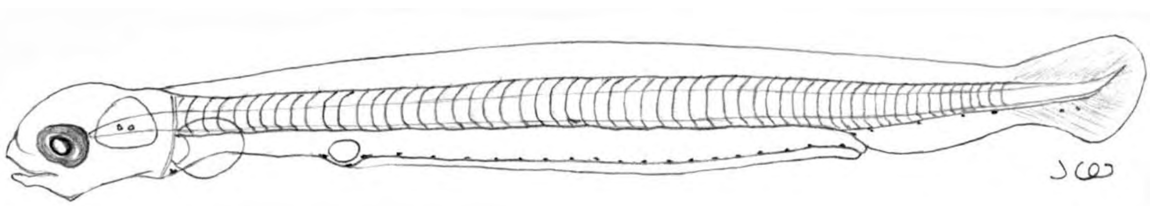


FIGURE 6-6.—Prolarva, 7.2 mm TL.

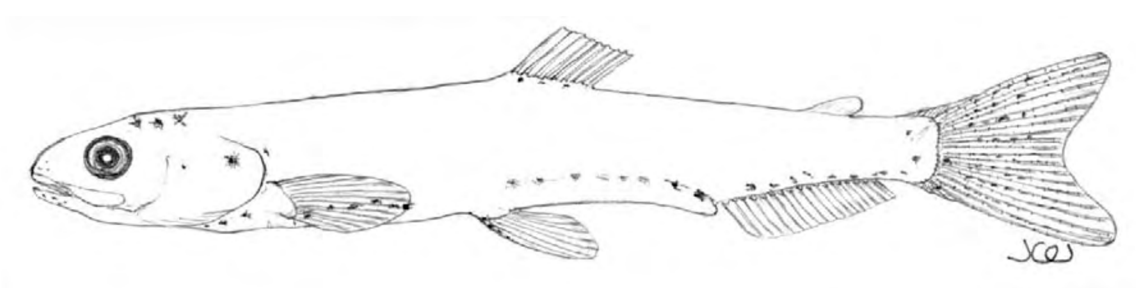


FIGURE 6-7.—Juvenile, 55 mm TL.

Osmeridae: *Hypomesus transpacificus*, Delta smelt.

FIGURE 6-8.—Unfertilized egg, 1.0 mm diameter.

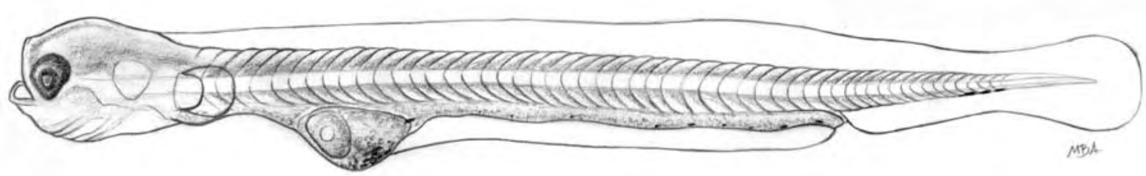


FIGURE 6-9.—Prolarva, 6 mm TL.

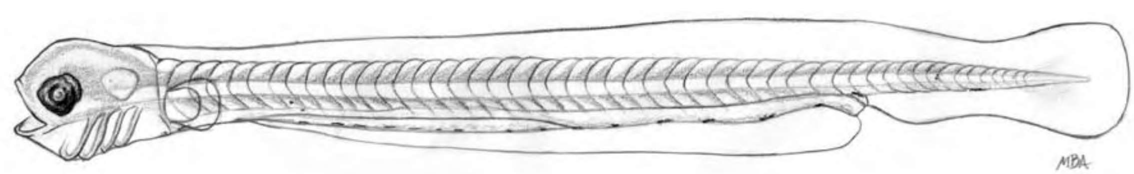


FIGURE 6-10. Postlarva, 8 mm TL.

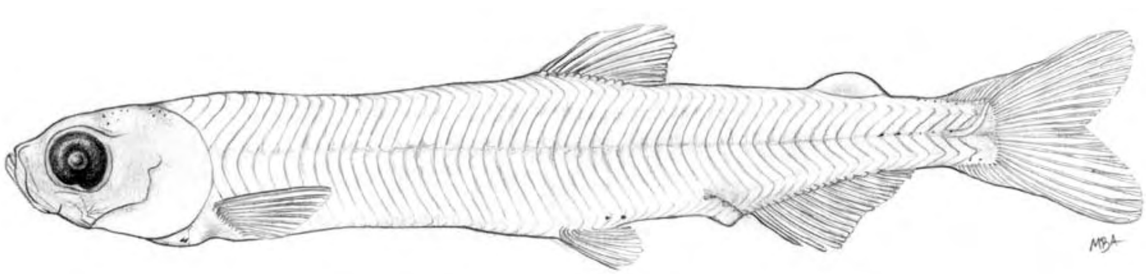


FIGURE 6-11.—Juvenile, 29 mm TL.

Osmeridae: *Spirinchus thaleichthys*, longfin smelt.

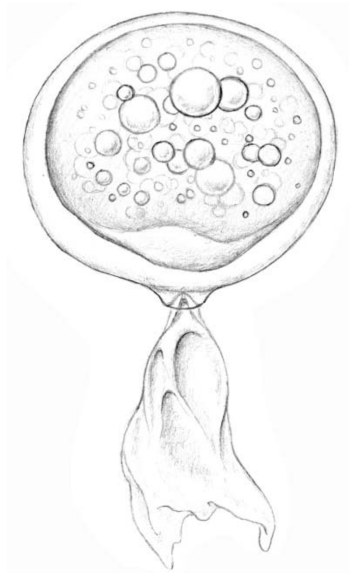


FIGURE 6-12.—Egg, newly fertilized, 1 mm diameter.

FIGURE 6-13.—Egg, 16-cell stage, 1 mm diameter.

FIGURE 6-14.—Egg, morula, 1 mm diameter.

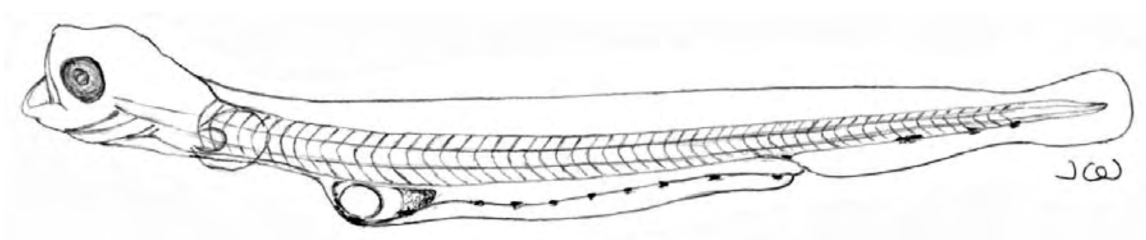


FIGURE 6-15.—Prolarva, 6.2 mm TL.

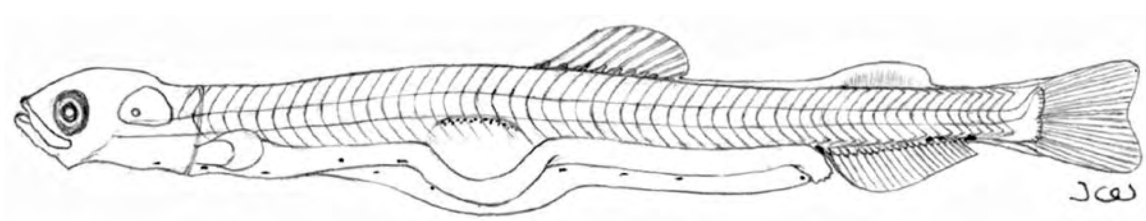


FIGURE 6-16.—Postlarva, 20 mm TL.

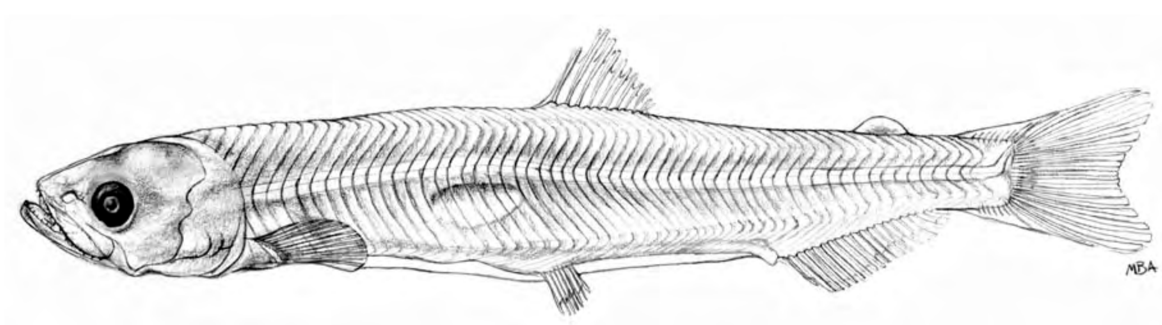


FIGURE 6-17.—Juvenile, 32 mm TL.

7. Bathylagidae – Deepsea Smelts

Two species of deepsea smelts were collected from waters near the Sacramento-San Joaquin Estuary (Moss Landing Harbor): the popeye blacksmelt, *Bathylagus ochotensis*, and the Pacific blacksmelt, *Bathylagus pacificus*. Both species are inhabitants of the deep sea, and probably enter the harbor during coastal upwellings.

POPEYE BLACKSMELT, *Bathylagus ochotensis* (Schmidt)

SPAWNING

Location	Outside of Moss Landing Harbor, probably the Monterey Canyon (this study); Bathypelagic to mesopelagic offshore of the northern Pacific Ocean (Hart 1973). Northern Baja California (Ahlstrom 1965).
Season	Larvae were collected from March through August along Oregon coast (Richardson and Pearcy 1977). Larvae were taken in January and February.
Salinity	Seawater.

CHARACTERISTICS

LARVA (Figure 7-1)

Snout to anus length	ca. 80% of TL of larvae at 12.2–12.7 mm TL.
Gut	Straight.
Air bladder	None.
Total myomeres	47–48.
Preanal myomeres	44.
Postanal myomeres	3–4.
Pigmentation	3–4 large melanophores in thoracic region and ca. 17 large melanophores along entire length of gut and ventral musculature of that section.
Distribution	Mostly in offshore deep water (Ahlstrom 1965).

JUVENILES

Dorsal fin	9–12 (Miller and Lea 1972); 10–12 (Hart 1973).
Anal fin	12–15 (Miller and Lea 1972); 14–16 (Hart 1973).
Pectoral fin	6–10 (Miller and Lea 1972); 10–11 (Hart 1973).
Adipose fin	Yes, slender (Hart 1973).

Mouth	Terminal.
Vertebrae	48 (Miller and Lea 1972).
Distribution	Mesopelagic from northern California to Bering Sea and Sea of Okhotsk (Miller and Lea 1972); bathypelagic in the Northeast Pacific (Hart 1973).

LIFE HISTORY

The popeye blacksmelt or eared blacksmelt, a deep sea fish, ranges from Northern Baja California to the Bering Sea and the Sea of Okhotsk (McAllister 1960, Miller and Lea 1972, Hart 1973). Locally, the larval stages of this species were captured at Moss Landing Harbor, apparently from the Monterey Submarine Canyon.

Ahlstrom (1965) reported popeye blacksmelt larvae in the California Current region. At the larval stage, the eyeball is on an elongated stalk; as larval growth proceeds, the eye stalks gradually shorten, and eventually the eyeball returns to its socket. Larvae were observed in January and February in the study area.

The life history of the popeye blacksmelt is poorly documented.

References

Ahlstrom 1965, Hart 1973, McAllister 1960, Miller and Lea 1972, Richardson and Pearcy 1977.

PACIFIC BLACKSMELT, *Bathylagus pacificus* Gilbert

SPAWNING

Location	Probably outside of San Francisco Bay and Moss Landing Harbor.
Season	Ripe eggs have been noted in ovaries of female fish in spring (Fitch and Lavenberg 1968); larvae were observed from February through May.
Salinity	Seawater.

CHARACTERISTICS

LARVAE (Figure 7-2)

Snout to anus length	ca. 74–75% of TL of larvae at 9.7 to 10.8 mm TL.
Gut	Straight.
Total myomeres	43–45.
Preanal myomeres	35–36.
Postanal myomeres	8–10.

Pigmentation	Two pairs of very large melanophores (one midway between pectorals and anus, the other close to anus) on the sides of body; two pairs of small melanophores at the tip of the tail.
Distribution	Most of the population inhabits deep sea waters outside of the estuaries and harbors of the study area.

JUVENILES

Dorsal fin	8–13 (Miller and Lea 1972); 8–10 (Hart 1973).
Anal fin	15–22 (Miller and Lea 1972); 18–20 (Hart 1973).
Pectoral fin	7–11 (Cohen 1966).
Vertebrae	44–48 (Cohen 1966).
Distribution	Northern Baja California to Gulf of Alaska to the Bering Sea to the Sea of Okhotsk and Kuril-Kamchatka Trench (Grinols 1965; Fitch and Lavenberg 1968; Miller and Lea 1972).

LIFE HISTORY

The distribution of the Pacific blacksmelt is from the deep sea offshore from Northern Baja California, through Oregon, Washington, Gulf of Alaska, Bering Sea, Sea of Okhotsk, and the Kuril-Kamchatka trench (Grinols 1965, Fitch and Lavenberg 1968, Miller and Lea 1972, Hart 1973). Locally, the larval stages of the Pacific blacksmelt were observed at Moss Landing Harbor and in San Francisco Bay near Red Rock. The larval Pacific blacksmelt taken in San Francisco Bay probably constitute the first record for this area.

Ripe eggs were observed in spring by Fitch and Lavenberg (1968). Larvae were collected from February through April. The spawning period of the Pacific blacksmelt is unclear in the literature. Larvae have stalked eyes, as do the larvae of popeye blacksmelt.

Adults feed on crustaceans and make no diurnal migration (Fitch and Lavenberg 1968). This species occurs to depths of at least 230 m (Taylor 1968).

References

Cohen 1966; Fitch and Lavenberg 1968; Grinols 1965; Hart 1973; Miller and Lea 1972; and Taylor 1968.

Characteristic Comparison: Deepsea Smelts

Characteristic	Popeye Blacksmelt	Pacific Blacksmelt
Larvae		
Total myomeres	ca. 48	ca. 45
Pigmentation	A few large melanophores in thoracic region and a series of melanophores along entire length of dorsal gut	Two dark vertical bands (one at midpoint of TL and the other between midpoint of TL and anus); a few melanophores in thoracic region, dorsal gut, and tip of tail.
Juveniles		
Dorsal fin	9–12	8–13
Anal fin	12–15	15–22
Pectoral fin	6–11	7–11
Vertebrae	48	44–48
Base of anal fin	Short	Longer or wider

Figure 7.—Bathylagidae: Deepsea smelts.

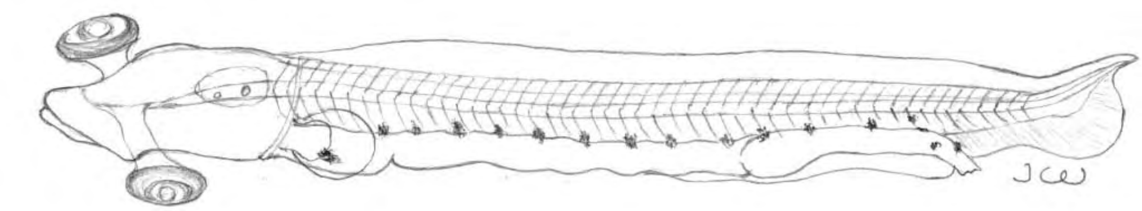


FIGURE 7-1.—*Bathylagus ochotensis*, popeye blacksmelt postlarva, 11.8 mm TL.

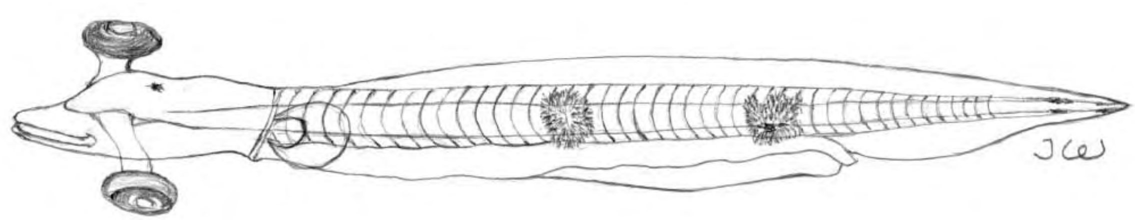


FIGURE 7-2.—*Bathylagus pacificus*, Pacific blacksmelt postlarva, 10.6 mm TL.

8. Synodontidae – Lizardfishes

Only one species of lizardfish is recorded on the Pacific coast of California: the California lizardfish, *Synodus lucioceps*.

CALIFORNIA LIZARDFISH, *Synodus lucioceps*

SPAWNING

Season	June through August (Fitch and Lavenberg 1971); judging by larvae taken in this area, spawning occurs in November and December.
Salinity	Seawater.

CHARACTERISTICS

EGGS

Shape	Spherical for Synodontidae (A. Naplin and Sandy Hook 1980, personal communication).
Diameter	1.20–1.48 mm; average 1.32 mm (Sumida *et al.* 1979).
Chorion	Chorion with hexagonal pattern structure for Synodontidae (A. Naplin and Sandy Hook 1980, personal communication); Sumida *et al.* 1979).

LARVAE (Figure 8-1)

Snout to anus length	ca. 65% of TL of larvae at 27.0 mm TL.
Gut	Straight.
Air bladder	None.
Teeth	Sharp, pointed, apparent in postlarvae.
Total myomeres	60 (based on one specimen).
Preanal myomeres	42 (based on one specimen).
Postanal myomeres	18 (based on one specimen).
Pigmentation	A series of ventrolateral pigments along belly (Fitch and Lavenberg 1971); 7 pairs of dark blotches beneath skin and above gut. Single pairs of blotches in postanal region and 1 pair on caudal peduncle of a 27.0-mm TL specimen.
Distribution	Upper water column over deep offshore water (Fitch and Lavenberg 1971); inshore and embayments.

JUVENILES (Figure 8-2)

Dorsal fin	11–13 (Miller and Lea 1972).
Anal fin	12–14 (Miller and Lea 1972).
Pectoral fin	13.
Mouth	Terminal, very large, maxillary reaches posterior margin of the eye.
Vertebrae	60–63 (Clothier 1950).
Distribution	Early juveniles are pelagic, large juveniles and adults on sandy bottom of coastal waters (Fitch and Lavenberg 1971); in Moss Landing Harbor.

LIFE HISTORY

The California lizardfish is distributed from Cape San Lucas and much of the Gulf of California to San Francisco Bay (Fitch and Lavenberg 1971, Miller and Lea 1972). This species was collected in Moss Landing Harbor-Elkhorn Slough (Kukowski 1972b).

Spawning seems to be concentrated on sandy bottoms from June through August (Fitch and Lavenberg 1971). Judging from the larvae and juvenile collected in this study, spawning may also occur in November and December. Larvae found in the Moss Landing Harbor area may be at or near the northern spawning limit, since there have been no lizardfish observed in San Francisco Bay in recent years.

California lizardfish larvae are pelagic and have transparent bodies with a series of large dark blotches near the surface of their guts and along the postanal and caudal regions. The pigmentation patterns are quite similar to those of synodontid larvae on the Atlantic Coast (Mansueti and Hardy 1967). Large number of Synodus spp. larvae were taken in the California current region by Ahlstrom (1965). A single specimen was collected at Moss Landing Harbor in this study.

Juveniles initially are pelagic but gradually descend to the sandy bottom as they become older. Their major food items are small fish and squid (Fitch and Lavenberg 1971).

Just when the California lizardfish matures, and in fact its life history, is very sketchy in the literature. Lizardfish are of no human food value, but they are the object of a commercial fishery and are made into fish meal (Fitch and Lavenberg 1971).

References

Ahlstrom 1965; Clothier 1950; Fitch and Lavenberg 1971; Kukowski 1972b; Mansueti and Hardy 1967; Miller and Lea 1972; Sumida *et al.* 1979.

Figure 8.—Synodontidae: *Synodus lucioceps*, California lizardfish.

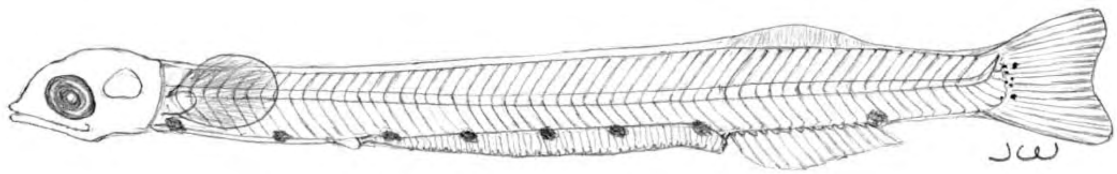


FIGURE 8-1.—Postlarva, 25.5 mm TL.

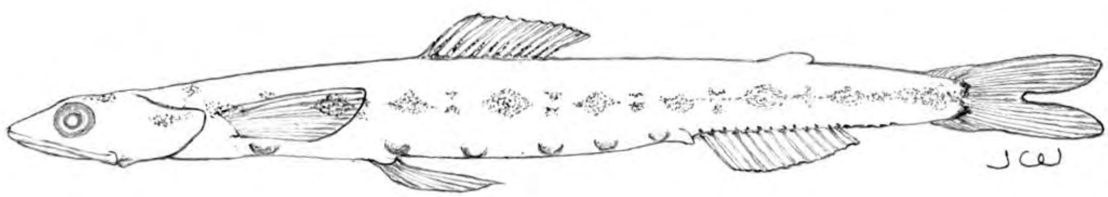


FIGURE 8-2.—Juvenile, 80 mm TL.

9. Myctophidae – Lanternfishes

Two species of deepsea lanternfishes were collected in the study area: the northern lampfish, *Stenobrachius leucopsarus*, and the blue lanternfish, *Tarletonbeania crenularis*. Lanternfish normally inhabit the deep water off the coast, and were probably carried into bays by the coastal current during upwelling.

Many taxonomical studies of the world-wide distributed Myctophidae have been done by such as Bolin (1936, 1939, 1944, 1959) and Nafpaktitis (1968, 1973, 1978); on the early life histories by Fast (1960), Ahlstrom (1965), and Moser and Ahlstrom(1970, 1972, 1974).

References

Ahlstrom 1965; Bolin 1936, 1939, 1944, 1959; Fast 1960; Moser and Ahlstrom 1970, 1972, 1974; Nafpaktitis 1968, 1973, 1978.

NORTHERN LAMPFISH, *Stenobrachius leucopsarus* (Eigenmann and Eigenmann)

SPAWNING

Location	Off the coast of San Francisco Bay and Moss landing Harbor in the Pacific Ocean.
Season	December through August in Monterey area (Fast 1960); December to March (Hart 1973); larvae collected in winter and spring (Ahlstrom 1965); larvae observed from January to May in Humboldt Bay (Eldridge and Bryan 1972); larvae collected from February to October off the Oregon coast (Richardson and Pearcy 1977); larvae collected from December through March (this study).
Salinity	Seawater.

CHARACTERISTICS

LARVAE (Figure 9-1)

Length at hatching	Less than 3.0 mm (Fast 1960).
Snout to anus length	ca. 40–46% of TL of larvae at 3.2–6.2 mm TL.
Gut	Straight or slightly waved, bending ventrally in the anal region (Fast 1960).
Total myomeres	33–37
Preanal myomeres	10–12

Postanal myomeres	23–26
Pigmentation	A series of melanophores (15 or more) along the postanal region; one pair on the lower lateral body wall, two pairs along the gut (Fast 1960, Ahlstrom 1965, this study).
Distribution	San Francisco Bay and Moss Landing Harbor-Elkhorn Slough.

JUVENILES (Figure 9-2)

Dorsal fin	12–15 (Miller and Lea 1972, Hart 1973).
Anal fin	14–16 (Miller and Lea 1972, Hart 1973).
Pectoral fin	8–11 (Miller and Lea 1972); about 11 (Hart 1973).
Adipose fin	Yes.
Mouth	Terminal, very large, maxillary reaches to the middle of the bony orbit (Fast 1960).
Vertebrae	35–38 (Miller and Lea 1972).
Distribution	Mesopelagic (Miller and Lea 1972); bathypelagic (Hart 1973); deep waters outside of San Francisco Bay and Moss Landing Harbor. Specimens were collected occasionally in Moss Landing Harbor.

LIFE HISTORY

The northern lampfish is found in the California Current system from northern Baja California to the Bering Sea and Japan (Miller and Lea 1972). They are also known to the North Pacific Ocean from the Kuril-Kamchatka Trench to Japan (Grinols 1965). In this study, northern lampfish were collected in San Francisco Bay and Moss Landing Harbor.

Larvae were collected from December to August in the Monterey area (Fast 1960). Along the Oregon coast, Richardson and Pearcy (1977) sampled larvae of this species from February to October. The majority of the spawn seems to be in winter months (Ahlstrom 1965, Hart 1973). The early life stages of the northern lampfish were described by Fast (1960) and Ahlstrom (1965). Northern lampfish larvae are among the most abundant fish larvae caught when sampling the California Current system. However, the reproductive strategy of this deep-sea fish is still unclear in the literature, although internal fertilization and hermaphroditism have been suggested as their spawning strategy (Grey 1955, Fast 1960). The eggs of the northern lampfish were never observed. Fast (1960) further suggested that northern lampfish spawn once in their life span.

Larvae were observed in San Francisco Bay and Moss Landing Harbor from 1978–1980. They were also reported in Humboldt Bay by Eldridge and Bryan (1972). Those larvae were carried into the bay and estuary by coastal current during upwelling season. The diets of juvenile and adult northern lampfish include copepods, fish, and euphausiids (Collard 1970).

Age and growth of the northern lampfish and other members of Myctophidae were investigated by Bolin (1956). The majority of the northern lampfish collected by Fast (1960) were in the age classes 1 to 3; however, Smoker and Pearcy (1970) reported that northern lampfish reach maturity at about 4 years. The age at which this species matures is thus still in question. Hart (1973) stated that northern lampfish may live up to 8 years.

Northern lampfish are preyed on by yellowtail rockfish and salmon, among others (Pereyra *et al.* 1969, Hart 1973).

References

Ahlstrom 1965, Bolin 1956, Collard 1970, Eldridge and Bryan 1972, Fast 1960, Grey 1955, Grinols 1965, Hart 1973, Miller and Lea 1972, Pereyra *et al.* 1969, Richardson and Pearcy 1977, Smoker and Pearcy 1970.

BLUE LANTERNFISH, *Tarletonbeania crenularis* (Jordan and Gilbert)

SPAWNING

Location	Deep water outside of San Francisco Bay and Moss Landing Harbor in the Pacific Ocean.
Season	Larvae were taken in winter through spring (Ahlstrom 1965); larvae were found in Humboldt Bay from September to November (Eldridge and Bryan 1972); larvae were captured off the Oregon coast from February through October or December (Richardson and Pearcy 1977); larvae were observed in San Francisco Bay and Moss Landing Harbor from November through March.
Salinity	Seawater.

CHARACTERISTICS

LARVAE (Figure 9-3)

Snout to anus length	ca. 48–53% of TL of larvae at 3.4–4.7 mm TL.
Gut	Straight of slightly waved.
Total myomeres	39–40.
Preanal myomeres	16–17.
Postanal myomeres	23–24.

Last fin(s) to complete development	Pelvic (Moser and Ahlstrom 1970).
Pigmentation	A prominent dark bank in caudal region; large stellate melanophores in three areas; along gut; at thoracic region, midway of gut, and anus.
Distribution	Pelagic and mesopelagic in California Current system (Moser and Ahlstrom 1970); offshore along the Oregon coast (Richardson and Pearcy 1977); occasionally found in bays and estuaries (Eldridge and Bryan 1972; this study).

JUVENILES

Dorsal fin	11–14 (Clothier 1950, Miller and Lea 1972, Hart 1973).
Anal fin	17–19 (Clothier 1950, Miller and Lea 1972, Hart 1973).
Pectoral fin	11–15 (Miller and Lea 1972); ca. 13 (Hart 1973).
Adipose fin	Yes.
Mouth	Terminal, large, directed forward (Hart 1973).
Vertebrae	41 (Clothier 1950); 39–42 (Miller and Lea 1972).
Distribution	Mesopelagic and bathypelagic in California Current system (Miller and Lea 1972); northward to Alaska and west to the Pacific Coast of Japan (Hart 1973).

LIFE HISTORY

The blue lanternfish is found from Baja California to British Columbia (Miller and Lea 1972). They are also known from British Columbia to Alaska and the Pacific coast of Japan (Hart 1973). In this study, the blue lanternfish (larval stages only) were collected in San Francisco Bay and Moss Landing Harbor.

Judging from the larval fish taken, spawning occurs in winter and spring (Ahlstrom 1965) and may extend to most months of the year (Richardson and Pearcy 1977). Details of the reproductive biology of the blue lanternfish are not documented in the literature.

Larvae are distributed mostly offshore in the California Current system (Ahlstrom 1965; Moser and Ahlstrom 1970): most were collected from 37–111 km off the Oregon coast, although a few were found near the coast (Richardson and Pearcy 1977). Eldridge and Bryan (1972) observed larvae of this species in Humboldt Bay, and the author observed them in San Francisco Bay and Moss Landing Harbor. Those larvae could be strays resulting from upwelling and coastal currents and tides.

Blue lanternfish are distributed from mesopelagic to bathypelagic depths (Miller and Lea 1972, Hart 1973). Grinols (1965) noted that blue lanternfish performed diurnal vertical movements, adult fish coming to the surface during the night and returning to as deep as 710 m at daytime. Adult blue lanternfish feed on euphausiids and are preyed by albacore (Hart 1973). Age, growth, and maturity of this species are unclear.

References

Ahlstrom 1965, Clothier 1950, Eldridge and Bryan 1972, Grinols 1965, Hart 1973, Miller and Lea 1972, Moser and Ahlstrom 1970, Richardson and Pearcy 1977.

Characteristic Comparison: Lanternfishes

Characteristic	**Northern Lampfish**	**Blue Lanternfish**
Larvae		
Snout-anus length	ca. 40–46% of 3.2–6.2 mm TL	ca. 48–53% at 3.4–4.7 mm TL
Pigmentation	Series of melanophores along postanal region	Dark band encircling caudal region
Vertebrae	35–38	39–42

Figure 9.—Myctophidae: Lanternfishes.

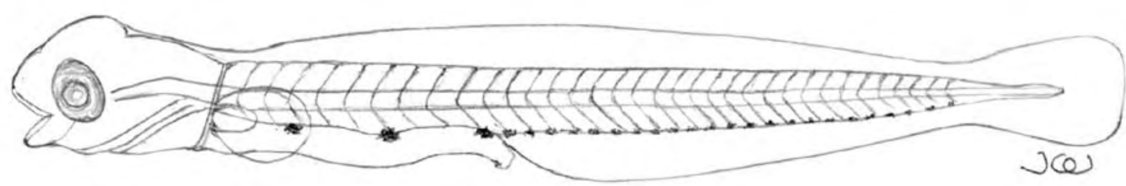


FIGURE 9-1.—*Stenobrachius leucopsarus*, northern lampfish postlarva, 4.3 mm TL.

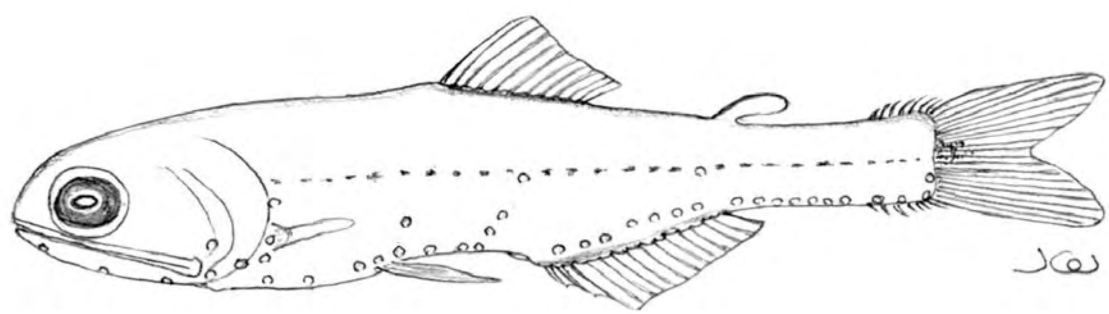


FIGURE 9-2.—*Stenobrachius leucopsarus*, northern lampfish juvenile, 78 mm TL.

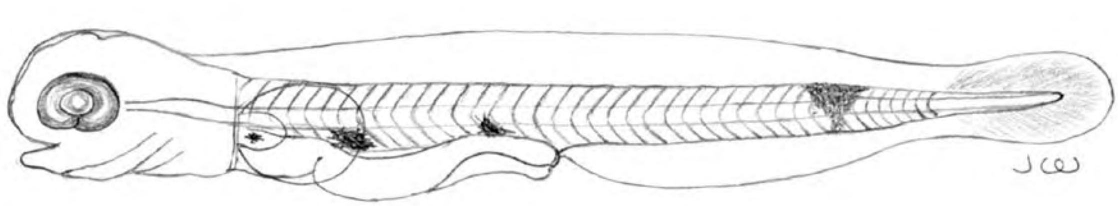


FIGURE 9-3.—*Tarletonbeania crenularis*, blue lanternfish postlarva, 4.5 mm TL.

10. Cyprinidae – Minnows and Carps

At least seventeen species of minnows and carps have been recorded in the Sacramento-San Joaquin River system (Moyle 1976). Twelve species were collected in this study, 6 species of native fish and 6 species of introduced fish:

Species	Native	Introduced
Goldfish, *Carassius auratus*		X
Carp, *Cyprinus carpio*		X
California roach, *Hesperoleucus symmetricus*	X	
Hitch, *Lavinia exilicauda*	X	
Hardhead, *Mylopharodon conocephalus*	X	
Golden shiner, *Notemigonus crysoleucas*		X
Red shiner, *Notropis lutrensis*		X
Sacramento blackfish, *Orthodon microlepidotus*	X	
Fathead minnow, *Pimephales promelas*		X
Splittail, *Pogonichthys macrolepidotus*	X	
Sacramento squawfish, *Ptychocheilus grandis*	X	
Speckled dace, *Rhinichthys osculus*	X	
Lahontan redside, *Richardsonius egregius*		X

All members in this family prefer freshwater, although goldfish, carp, splittail, Sacramento blackfish, and Sacramento squawfish (pikeminnow) are also found in the oligohaline water of the estuary. Golden shiner and hitch are usually observed in freshwater of the Delta, but occasionally descend to Suisun Bay when the salt wedge retreats down this bay. California roach and fathead minnow are mainly restricted to nontidal freshwaters of the system. Hardhead are common in middle and upper drainages of the Sacramento-San Joaquin River system, and a small population is also known in the Napa River (Moyle 1976, this study).

The red shiner is known to Millerton Lake at the present time, but has not been observed in the Delta (this study). Lahontan redside were found in Loon Lake Reservoir in upper drainage of the American River. They were probably introduced by fishermen (Kimsey 1950).

Three more species of minnows have also been recorded in the study area and adjacent waters. The thicktail chub, *Gila crassicauda*, a native minnow, used to be abundant in the Sacramento-San Joaquin River systems (Miller 1963a, Schulz and Simons 1973). Now this species is believed to be extinct (Moyle 1976, Shapovalov *et al.* 1981). The tench, *Tinca tinca*, was introduced into California in 1872 (Shapovalov 1944, Skinner 1972). This species was known in a private pond near Lotitas Creek, San Mateo County (Moyle 1976). This site and its adjacent creeks (Lobitas, Tunitas, and Pilarcitas Creeks) were revisited by author and no specimens were found in those areas. Speckled dace, *Rhinichthys osculus*, were reported in Coyote Creek in recent years (Scoppettone and

Smith 1978), but they were not observed in this study. The thicktail chub, speckled dace, and tench are therefore not described in this manual.

References

Kimsey 1950, Miller 1963a, Moyle 1976, Schulz and Simons 1973, Scoppettone and Smith 1978, Shapovalov 1944, Shapovalov *et al.* 1981, Skinner 1972.

GOLDFISH, *Carassius auratus* (Linnaeus)

SPAWNING

Location	In shallow water among aquatic vegetation in creeks, ditches, ponds, and reservoirs such as Cache, Linsey, and Wilson Sloughs, Coyote Creek, flood control ditch in the Hillcrest Community Park of Concord (in the Walnut Creek system), Concord Golf Pond, Lake Berryessa.
Season	April through July (Moyle 1976).
Temperature	15–23°C (Moyle 1976); 16–23°C (Jones *et al.* 1978); 18.5–29.5°C (Battle 1940); 16–23°C (Lippson and Moran 1974); 16–26°C .
Salinity	Freshwater.
Substrate	Aquatic vegetation, submerged tree branches, roots, and leaves.
Fecundity	2,000 (Smith 1909); up to 400,000 (Slastenenki 1958); average 14,000 (Moyle 1976).

CHARACTERISTICS

EGGS

Shape	Spherical.
Diameter	1.0–1.7 mm (Okada 1959–1960); 1.2–1.5 mm (Wang and Kernehan 1979); 1.4–1.7 mm.
Yolk	Pale yellow, granular (Battle 1940, Jones *et al.* 1978); yellowish, granular.
Oil globule	Many small oil globules (Battle 1940).
Chorion	Transparent, smooth (Smith 1909); transparent, smooth except the adhering area.
Perivitelline space	Narrow.
Egg mass	Deposited on substrates in single form; can be very dense in certain areas because of repeated deposition.

Buoyancy	Demersal.

LARVAE (Figures 10-1, 10-2, 10-3, 10-4)

Length at hatching	3.0 mm TL (Watson 1939); 5.0 mm TL (Okada 1959–1960); mostly 4.0–4.5 mm TL (Wang and Kernehan 1979, this study).
Snout to anus length	Ca. 62–68% of TL of both prolarval and postlarval stages.
Yolk sac	Elongated, enlarged and oval in thoracic region; tapered and cylindrical in abdominal region; it becomes wholly cylindrical as development proceeds (Jones *et al.* 1979, this study).
Oil globule	Minute oil globules, scattered in yolk-sac (Battle 1940).
Gut	Straight.
Air bladder	Elongate, small near thoracic region and developed into two chambers in postlarval stage.
Teeth	None.
Size at completion of yolk-sac stage	Ca. 5.5–6.0 mm TL (Battle 1940, Okada 1959–1960, Nakamura 1969, this study).
Total myomeres	32–34 (Mansueti and Hardy 1967, this study).
Preanal myomeres	21–22 (Mansueti and Hardy 1967, this study).
Postanal myomeres	11–12 (Mansueti and Hardy 1967); 8–10.
Last fin(s) to complete development	Pelvic.
Pigmentation	Large stellate melanophores on snout, cephalic and middorsal regions, in dorsal region of gut (pigment is lighter than that of carp larvae of similar stage), midventral, and postanal regions.
Distribution	Newly hatched larvae remain at bottom (Smith 1909); near surface after yolk sac is absorbed (Fearnow 1925); near or at bottom of shallow water with dense vegetation, such as upper Cache and Lindsey sloughs.

JUVENILES (Figure 10-5)

Dorsal fin	I–II, 14–20 (Scott and Crossman 1973, Nichols 1943); III–V, 14–19 (Lippson and Moran 1976); counting spine of hardened ray, the dorsal fin has 18–19 rays (Moyle 1976); I, 5–6.

Anal fin	I–II, 5–6 (Scott and Crossman 1973, Nichols 1943); II–III, 5–7 (Lippson and Moran 1974); counting spine or hardened rays, the anal fin has 6–7 rays (Moyle 1976); I, 5–6.
Pectoral fin	12–17 (Sterba 1959, Jones *et al.* 1978); 15–17 (Scott and Crossman 1973).
Mouth	Small, terminal, oblique (Scott and Crossman 1973).
Vertebrae	28–32 (Slastenenki 1958, Berg 1964); 28–20 (Scott and Crossman 1973).
Distribution	Scattered in freshwater drainages of the Sacramento-San Joaquin River system, including most landlocked warm-water ponds and reservoirs.

LIFE HISTORY

Goldfish were originally native from China through Eastern Europe, where they were bred domestically as pets in a wide variety of colors, shapes, and sizes. It is uncertain exactly when goldfish were introduced into North America, but it was probably during the late 19th century (Scott and Crossman 1973). This species is now widely distributed throughout the warm waters of California, and large populations exist in some southern California reservoirs and the sloughs of the Central Valley (Moyle 1976). During this study, both wild and domestic goldfish populations were observed in the freshwater portions of the Sacramento-San Joaquin Estuary and in many inland reservoirs and ponds.

Spawning occurs in shallow, weedy coves during spring and summer. During spawning, each female may be pursued by several males, either at her side or close behind her (Scott and Crossman 1973, this study). The highly adhesive eggs are deposited on submerged substrates and remain there throughout the incubation period. The eggs hatch in 5 days at 20°C (Okada 1959–1960) or in 3–4 days at 20–27.5°C (this study). Observations of different sizes and development of ova in individual ovaries indicate that female goldfish are able to spawn more than once each spawning season.

Newly hatched larvae remain near the spawning area. None were collected in open-water plankton tows, and it is assumed that the larvae inhabit mostly the bottom of the shallows.

During this study, large juveniles (35–50 mm TL) were occasionally captured with beach seines in Sweeney Creek, Coyote Creek, in some backwater sloughs of the Delta, and several shallow coves in Millerton Lake in summer and fall. Small juveniles were rarely observed. Juvenile goldfish feed primarily on zooplankton and small insect larvae (Moyle 1976).

Female goldfish reach maturity in 2 or 3 years; males usually mature during their second year (Moyle 1976). Breder and Rosen (1966) reported that goldfish may mature in less than 1 year or in as many as 3–4 years. Goldfish may live as long as 25–30 years in aquaria (Carlander 1969, Moyle 1976). Goldfish have no value as game fish in this country, but the domestic strains have been traded as pets for centuries in the world.

References

Battle 1940, Berg 1964, Breder and Rosen 1966, Carlander 1969, Jones *et al.* 1978, Fearnow 1925, Lippson and Moran 1974, Mansueti and Hardy 1967, Moyle 1976, Okada 1959–1960, Nakamura 1969, Nichols 1943, Scott and Crossman 1973, Slastenenki 1958, Smith 1909, Sterba 1959, Wang and Kernehan 1979, Watson 1939.

COMMON CARP, *Cyprinus carpio* Linnaeus

SPAWNING

Location	Near surface in shallow weedy areas of tidal and nontidal freshwater; spawning was observed in Montezuma Slough, New York Slough, Lindsey Slough, Cache Slough, French Camp Slough, Threemile Slough, Millerton Lake, Lake Berryessa, and Folsom Lake.
Season	Spring to summer (Moyle 1976). March to July; a ripe male (but not ripe females) was observed in November.
Temperature	15–28°C (Swee and McCrimmon 1966, Moyle 1976); optimum 18–22°C (Berg 1964, Mansueti and Hardy 1967); peaking at 22–26°C.
Salinity	Freshwater, may occur in oligohaline; up to 10 ppt mesohaline water in Russia (Berg 1964).
Substrates	Submerged plants, tree roots, and grass roots of undercut banks, dead leaves, and floating plants and logs.
Fecundity	36,000–2,208,000 (Swee and McCrimmon 1966); 50,000–2,000,000 per season (Moyle 1976); minimum 3,950 (Balon 1974).

CHARACTERISTICS

EGGS (Figure 10-6)

Shape	Spherical (Sigle 1955); some slightly oval or irregular.
Diameter	1.5–2.1 mm; as small as 1.0 mm (Slastenenki 1958).
Yolk	Colorless (Okada 1959–1960); pale-yellowish, granular.

Oil globule	None (Hoda and Tsukahari 1971); many minute oil globules (Brinley 1937); some have small oil globules, others do not.
Chorion	Transparent, or translucent because of detritus adhering to chorion.
Perivitelline space	Ca. 1/5 of egg radius (Okada 1959–1960); fairly wide, ca. 15–20% of egg diameter.
Adhesiveness	Highly adhesive throughout incubation period.
Buoyancy	Demersal.

LARVAE (FIGURES 10-7, 10-8, 10-9)

Length at hatching	Minimum 3.0 mm TL (Sigler 1955); 3.0–6.69 mm TL (Jones *et al.* 1978); most average 4.38–5.70 mm TL (Swee and McCrimmon 1966); ca. 4.0–5.0 mm TL from field collection.
Snout to anus length	57–67% of TL of both prolarval and postlarval stages.
Gut	Straight
Air bladder	Shallow, behind pectoral – develops into two chambers in postlarval stages.
Teeth	None on jaws.
Size at completion of yolk-sac stage	Ca. 6.5 TL (Okada 1959–1960); 7.0–9.5 mm TL (Jones *et al.* 1978); ca. 6.0–7.0 mm TL.
Preanal myomeres	24 (Hikita 1956,Okada 1959–1960); 24–26.
Postanal myomeres	10–12.
Last fin(s) to complete development	Pelvic.
Pigmentation	Large stellate melanophores on cephalic and middorsal regions, on ventral side of yolk sac and postanal region, and particularly heavy on dorsal side of gut; pigmentation is similar to that of goldfish but heavier.
Distribution	At bottom or attached to aquatic vegetation immediately after hatching, then gradually in shallow water at bottom among vegetation, occasionally in water column. Common in Montezuma Slough, New York Slough, Lindsey Slough, the Delta, Lake Berryessa, and Millerton Lake.

JUVENILES (Figure 10-10)

Dorsal fin	III–V, 15–23 (Smith 1909); I, 18–20 (Scott and Crossman 1973); I (or a hardened ray), 17–21 (Moyle 1976); I, 20–21.
Anal fin	III, 4–6 (Smith 1909); I, 5 (Scott and Crossman 1973); I (or a hardened ray), 5–6 (Moyle 1976); I, 5.
Pectoral fin	14–17 (Scott and Crossman 1973); 17–18.
Mouth	Terminal or subterminal.
Vertebrae	32–39 (Berg 1964); 35–36 (Scott and Crossman 1973, this study).
Distribution	Mostly shallow weedy waters of both freshwater and oligohaline ranges of the Sacramento-San Joaquin estuarine system; they are also abundant in most warm-water reservoirs and ponds.

LIFE HISTORY

Carp were introduced into California from both Asia and Europe in 1872 and 1877 (Moyle 1976). This species is now well established throughout the state, with the exception of the Klamath River system (Moyle 1976). During this study, carp were observed in the freshwater and oligohaline reaches of the rivers and the estuary. They are particularly abundant in warm-water reservoirs such as Millerton Lake, Folsom Lake, and Lake Berryessa.

Based on the abundance of larvae collected in this study, the peak spawning period for carp is from May through July. Some spawning activity has been observed as early as March near New York Slough, probably due to the elevated water temperature caused by the thermal discharge from an adjacent powerplant. Ripe male carp have been collected in the same area as late as November. Spawning may occur in either fresh or oligohaline waters. Large numbers of carp have been captured in the shallows of Grizzly and Honker Bays during spring months (Ganssle 1966). Carp are also known to spawn in both fresh and oligohaline water of the Delaware estuary along the Atlantic coast (Wang and Kernehan 1979) and up to 10 ppt (mesohaline) in Russia (Berg 1964).

During mating, small groups of carp congregate in shallow weedy waters. Their dorsal fins are frequently exposed above the water surface, and there is much splashing and pursuing from one area to another. The adhesive eggs are deposited on submerged vegetation and hatch in 3–5 days at 20°C (Richardson 1913, Okada 1959–1960). In the laboratory, carp eggs hatched in 4 days at 18–21°C (Wang and Kernehan 1979). Like goldfish, different sizes of ova present in the ovaries at the same time indicate that carp are able to spawn more than once during the breeding season.

In the laboratory observation of this study, newly hatched carp larvae lay on their sides at the bottom of the aquarium. During field sampling, both prolarvae and postlarvae were collected in shallow, weedy, and muddy habitats. Some postlarvae were taken in plankton tows near Montezuma Slough, in the lower reaches of the San Joaquin River. It is apparent that carp postlarvae can be planktonic (Moyle 1976, this study).

Juveniles are also found in areas of dense vegetation that offer protection from predation. As growth proceeds (ca. 10 cm TL and greater), carp move into deeper water and form small schools. Juveniles feed primarily near the bottom on small invertebrates, aquatic plants, and algae (Moyle 1976).

Scott and Crossman (1973) reported that the spawning population of carp in Lake St. Lawrence was composed of fish between the age of 2 and 16 years. The lifespan of this species in North America is approximately 20 years or less (McCrimmon 1968).

Carp have been treated as useful fish and as an important source of protein by Asians for centuries, especially since they are easy to raise in small farm ponds. In Japan, ornamental carp have also been bred for color, shape, and size variations, for use in garden ponds (Migdalski 1962). Although this species was originally introduced into the United States for food and sport purposes, it has not been widely accepted as such. Carp has also been responsible for the destruction of gamefish habitat by increasing turbidity of an area when they feed.

References

Balon 1959, Berg 1964, Brinley 1937, Hikita 1956, Hoda and Tsukahari 1971, Jones *et al.* 1978, Mansueti and Hardy 1967, McCrimmon 1968, Migdalski 1962, Moyle 1976, Okada 1959–1960, Richardson 1913, Slastenenki 1958, Scott and Crossman 1973, Sigler 1955, Smith 1909, Swee and McCrimmon 1966, Wang and Kernehan 1979.

CALIFORNIA ROACH, *Hesperoleucus symmetricus* (Baird and Girard)

SPAWNING

Location	Nontidal tributaries of the Sacramento-San Joaquin River system such as San Ramon Creek, Napa River, San Anselmo Creek, Lagunitas Creek, Olema Creek, Sonoma Creek, Navato Creek, Suisun Creek, and Alameda Creek.
Season	March through June (Fry 1936, Moyle 1976); April through June.
Temperature	12–17.5°C.
Salinity	Freshwater.
Substrate	Gravel (Fry 1936); gravel and lamprey nesting area.
Fecundity	150–900 (Fry 1936); 250–600; average 300 (Barnes 1957).

CHARACTERISTICS

EGGS (Figures 10-11, 10-12)

Shape	Spherical.
Diameter	Ca. 1.5 mm (Barnes 1957); 1.9–2.25 mm.
Yolk	Yellowish, granular.
Oil globule	None.
Chorion	Transparent, smooth, except the adhering area.
Perivitelline space	Ca. 0.1–0.3 mm in width.
Egg mass	Deposited singly or in small clusters (Fry 1936); mostly in single form.
Adhesiveness	Exceedingly adhesive (Fry 1936); adhesive (this study).
Buoyancy	Demersal.

LARVAE (Figures 10-13, 10-14, 10-15, 10-16, 10-17)

Length at hatching	Ca. 5.0 mm TL (Fry 1936); 5.6–6.0 mm TL.
Snout to anus length	Ca. 63–67% of TL of prolarvae, decreasing to ca. 57–63% of TL of postlarvae.
Yolk sac	Elongate, enlarged, and spherical in thoracic region; tapered and cylindrical in abdominal region.
Oil globule	None.
Gut	Straight.
Air bladder	Elongate, near pectorals, developing into two chambers in postlarval stage.
Teeth	None.
Size at completion of yolk-sac stage	Ca. 7.0–7.8 mm TL.
Total myomeres	37–42.
Preanal myomeres	24–29.
Postanal myomeres	12–14.
Last fin(s) to complete development	Pelvic.
Pigmentation	Newly hatched larvae have no pigments. Within 1–2 days, large stellate melanophores show on snout, cephalic, and middorsal regions. Pigments are also found along dorsal surface of gut, jugular, thoracic, and postanal regions; a series of dashed melanophores on lateral line.

Distribution	Prolarvae remain in the crevices of gravels in or near spawning site. After yolk sac is absorbed, postlarvae move into shallow pools or extremely shallow inshore areas.

JUVENILES (Figure 10-18)

Dorsal fin	7–10 (Moyle 1976); 9.
Anal fin	6–9 (Moyle 1976); 8–9.
Pectoral fin	13–16.
Mouth	Terminal or subterminal.
Vertebrae	39–42.
Distribution	Roach are found in low elevation foothill creeks, some are in valley floor waters such as lower reaches of the Napa River and Walnut and Alameda Creeks. No specimens were observed in Delta sloughs and tidal freshwaters of this estuary.

LIFE HISTORY

The California roach, a native freshwater minnow, is found throughout the Sacramento-San Joaquin drainage system (Moyle 1976). Snyder (1913) described five distinct species of them, but other investigators, including Murphy (1943) and Hubbs and Wallis (1948), recognized these five forms only as variants or possibly subspecies of *Hesperoleucus symmetricus*. In this study, California roach were observed often in the nontidal freshwater tributaries of the estuary, particularly in intermittent foothill streams.

According to Fry (1936), spawning occurs from March through June. Spawning activity was observed in this study from April through June. Prior to spawning, the California roach congregate in small pools in groups of 15–50 fish. Both sexes exhibit spawning colors, becoming darker, with rusty orange coloration on the sides of the body and at the base of the pectoral fins. Males also develop minute white breeding tubercles on their snout, head, mouth, and operculum (Fry 1936, Barnes 1957). Eggs are deposited singly or in small clusters in rock crevices or among pieces of coarse gravel (Fry 1936, this study). If gravel substrate is unavailable, roach may deposit their eggs on cattails or tules (Barnes 1957), and abandoned lamprey nests may also be used. The females deposit just a few eggs at a time, and as spawning proceeds the group moves from site to site. No parental care has been observed in the laboratory. The eggs hatched in 5 days at 13.5–17.0°C.

Newly hatched larvae lay on their sides and tended to remain within the rock crevices where the eggs were deposited until the yolk sac was absorbed. They were sometimes observed darting from one hiding place to another before the yolk sac had been completely absorbed. Postlarvae then move into shallow pools or along the shallow edges of streams (this study).

After roach become juveniles they move into the deeper pools and main body of a creek. They often share these areas with juvenile Sacramento sucker, Sacramento squawfish (pikeminnow), and threespine stickleback. The major food items of juvenile roach include diatoms, filamentous algae, crustaceans, and small aquatic insects (Fite 1973).

California roach become mature after 1–3 years (Fry 1926, Barnes 1957). They generally live 3 years, although a few may live 1 or 2 years longer (Moyle 1976). Roach are important forage fish and are often used as bait fish by fishermen (Barnes 1957). California roach are still abundant in the study area, but in the lower portions of some creeks, such as Walnut Creek and the Napa River, the roach populations are gradually being replaced by introduced species such as green sunfish, golden shiner, and yellowfin goby.

References

Barnes 1957, Fite 1973, Fry 1936, Hubbs and Wallis 1948, Moyle 1976, Murphy 1943, Snyder 1913.

HITCH, *Lavinia exilicauda* Baird and Girard

SPAWNING

Location	Nontidal creeks, channelized ditches, irrigation canals, some ponds and reservoirs such as Tassajara Creek, Sweeney Creek, Upper Cache Slough, Flood control ditches in the Hillcrest Community Park in Concord, Walnut Creek, and Lake Hennessy.
Season	March (Murphy 1948b); April (Swift 1965); March through July (Moyle 1976); March through June.
Temperature	14–18°C (Murphy 1948b; Kimsey 1960); 15–22°C.
Salinity	Freshwater.
Substrates	Fine to medium gravels (Murphy 1948b); varies from hard clay bottom to gravel and to emergent vegetation.
Fecundity	Ca. 110,000 (Murphy 1948b); 3,000–26,000 (S. Nicola 1980, personal communication); approximately 10,000–80.000 (R.E. Geary 1981, personal communication).

CHARACTERISTICS

EGGS (Figures 10-19, 10-20, 10-21, 10-22, 10-23)

Shape	Spherical.
Diameter	2.0–2.2 mm (Swift 1965); 1.6–2.4 mm.

Yolk	Light yellow (Swift 1965); pale yellowish, granular.
Chorion	Transparent, smooth.
Perivitelline space	Very wide, ca. 0.3–0.5 mm in width.
Egg mass	Deposited singly.
Adhesiveness	None (Murphy 1948b, Swift 1965, this study).
Buoyancy	Demersal, heavier than water (Murphy 1948b, Swift 1965; demersal, slightly heavier than water, bounces when distributed.

LARVAE (Figures 10-24, 10-25, 10-26, 10-27)

Length at hatching	6.0 mm TL (Swift 1965); 4.2–5.5 mm.
Snout to anus length	61–65% of TL of specimens at 4.4–7.5 mm TL; 56–63% of TL of specimens at 10.3–12.0 mm TL.
Yolk sac	Elongate, almost spherical in thoracic region and cylindrical in abdominal region.
Oil globule	None.
Gut	Thick, straight.
Air bladder	Large and elongate, near and behind pectorals, developing a small anterior chamber and large posterior chamber in postlarval stage.
Teeth	None.
Total myomeres	36–39.
Preanal myomeres	24–28.
Last fin(s) to complete development	Pelvic.
Pigmentation	Newly hatched larvae have no pigments. Within a day or so large stellate melanophores appear scattered on head and middorsum; very large melanophores on dorsal and side areas of gut and on postanal region; dashed melanophores on lateral region. A group of melanophores concentrate at the base of the caudal peduncle and form a dark spot in the late postlarval stage.
Distribution	Shallow weedy areas of nontidal creeks, channelized ditches, ponds, and reservoirs, some in tidal freshwater sloughs of Sacramento-San Joaquin River system.

JUVENILES (Figure 10-28)

Dorsal fin	10–12 (Moyle 1976).

Anal fin	10–14 (Moyle 1976).
Pectoral fin	15–16.
Mouth	Terminal, small, oblique.
Vertebrae	39–41.
Distribution	Shallow weedy areas of nontidal creeks, channelized ditches, ponds, and reservoirs, some in tidal freshwater sloughs of Sacramento-San Joaquin River system in patchy distribution.

LIFE HISTORY

The hitch is a freshwater fish native to California inland waters, and is common throughout the Sacramento-San Joaquin drainage system, in tributaries of San Francisco and Monterey Bays, Clear Lake, and the Russian River (Moyle 1976). Taxonomically, the genus *Lavinia* is represented by only one species, although Miller (1945) and Hopkirk (1973) divided this species into three subspecies based upon their long period of geographical isolation.

Moyle (1976) noted that the hitch population in the Delta is much less abundant than it once was. Observation from this study indicated that hitch have a patchy distribution in warm waters of the Sacramento-San Joaquin drainage system and that local populations may be very dense.

Spawning takes place in streams, intermittent streams, ponds, and reservoirs from March through June. During spawning activity, four or five males will often attend each female (Murphy 1948b). Male hitch exhibit a rusty color on their paired fins during spawning. Large spherical eggs (ca. 1.6–2.4 mm in diameter) are nonadhesive, which is unusual for cyprinids, and they are also semidemersal and will float with any slight disturbance. Hitch eggs are deposited on hard clay bottoms and are also found on gravels and among submerged vegetation. The incubation period was reported to be 7 days at 16–17°C (Swift 1965); during this study freshly laid eggs in the morula stage, collected from the field, hatched out in 3–5 days in the laboratory at 15–22°C .

Newly hatched larvae have large yolk sacs and remain on the bottom for several more days before becoming free-swimming (Murphy 1948b, Swift 1965, this study). Postlarvae form schools in vegetated areas and shaded pools, which they use as nursery grounds and shelters.

Juveniles usually remain in the same habitat as the larvae, particularly among populations which live in a confined environment such as a channelized ditch. Murphy (1948b) described juvenile hitch in the tributaries of Clear Lake that were able to swim to the lake before the streams dried up in summer. Apparently not all hitch are able to avoid this loss of habitat, since many dead juveniles have been observed in dry creekbeds of intermittent streams (such as Marsh Creek and Tassajara Creek) in the summer. Those that are able to find a deep pool to spend the summer in are later subject to predation by birds and raccoons as pools become shallower. Juvenile hitch have been observed near the shoreline of Suisun Bay, probably having come from adjacent tributaries. The major food items for juveniles are phytoplankton, algae, crustaceans, and gnats and other insects (Lindquist *et al.* 1943, Murphy 1948b, Moyle 1976, this study).

Sexual maturity of male fish occurs at 1–3 years; of females at 2–3 years (Kimsey 1960; Moyle 1976). Hitch have been used as fish bait, and have also been sold, along with Sacramento blackfish, in San Francisco Chinatown fish markets as human food, Hitch have wide adaptabilities in terms of spawning, habitat, and food items. They have a good potential to be a fish farming species.

References

Hopkirk 1973; Kimsey 1960; Lindquist *et al*. 1943; Miller 1945; Moyle 1976; Murphy 1948b; Nicola 1980, personal communication; Swift 1965.

HARDHEAD, *Mylopharodon conocephalus* (Baird and Girard)

SPAWNING

Location	Pools and side pools of rivers and creeks, *e.g.*, the Napa River near Yountville, Sacramento River near Red Bluff, and upper San Joaquin River both above and below Kerckhoff Dam.
Season	April and May (Moyle 1976); May through August in the upper San Joaquin River.
Temperature	Ca. 15–18°C.
Salinity	Freshwater.
Substrates	Grave (Moyle 1976), sand, gravel, and decomposed granite and rocky areas.
Fecundity	21,800 (Burns 1966c).

CHARACTERISTICS

EGGS

Shape	Unfertilized eggs, spherical.

LARVAE (Figures 10-29, 10-30)

Snout to anus length	Ca. 60–65% of TL of postlarvae at 11.3–16.5 mm TL.
Gut	Straight.
Teeth	None.
Total myomeres	46–50.

Preanal myomeres	29–34.
Postanal myomeres	14–18.
Last fin(s) to complete development	Pelvic.
Pigmentation	In postlarvae, large and heavy stellate melanophores on snout and cephalic regions; 2 rows of melanophores on mid-dorsum; large melanophores are also found on side and dorsal surfaces of gut and postanal regions. Dashed melanophores on lateral region; 2 groups of melanophores concentrate at urostyle and hypleural regions, and form blotches at base of caudal peduncle.
Distribution	Near surface of pools and side pools of creeks and rivers; near inshore weedy areas of reservoirs and lakes.

JUVENILES (Figures 10-31, 10-32)

Dorsal fin	8 (Moyle 1976); this study).
Anal fin	8–9 (Moyle 1976); 8.
Pectoral fin	15–16.
Mouth	Terminal, large; with a frenum on upper jaw (Moyle 1976).
Vertebrae	45–48.
Distribution	Pools of rivers and creeks, shallow to deeper water of lakes and reservoirs.

LIFE HISTORY

The hardhead is a freshwater fish native to California, with a distribution limited to the Sacramento-San Joaquin River system and the Russian River system (Moyle 1976). In this study, a small number of hardhead was observed in the middle reach of the Napa River. This species was common in the Sacramento River near Red Bluff and near Kerckhoff Dam on the upper San Joaquin River.

Moyle (1976) stated that spawning of hardhead has never been observed, and it was not observed during this study. This may be the result of the spawning habitats in large river and foothill gorges, where the fish are difficult to observe. Judging from the larvae and small juveniles that were captured during this study, spawning occurs as early as May and June in the valley and may extend to August in the foothill regions of the upper San Joaquin River. Spawning substrate may include sand, gravel, and decomposed granite areas since most of the larvae were found there.

Juvenile hardhead inhabit both shallow regions and deeper lakes and reservoirs, and may be also be found in various temperature gradients such as Millerton Lake. Juvenile hardhead feed on plankton and cladocerans (Wales 1946) and on insects and small snails (Reeves 1964). They also take filamentous algae in the intermittent pools of upper San Joaquin River, particularly in the fall months.

Hardhead reach maturity at the end of their second year (Moyle 1976). Much of the spawning behavior and life history are still unclear in the literature. Hardhead may have some foraging value for other predators. In terms of the ecological status of this native fish, Moyle and Nichols (1973) have reported that the overall population has been declining rapidly in their original ranges. In this study, hardhead, particularly the adults, were found to be common below Kerckhoff Dam in the San Joaquin River (T. Lambert and J. Handley 1979, personal communication). Juveniles were taken by beach seine at several places at Millerton Lake in summer and fall months. In 1979–1981 (this study) large adults were observed below Red Bluff Diversion Dam on many occasions (S. Moock 1981, personal communication). However, this species showed signs of decline in the Napa River.

References

Burns 1966c; Moyle 1976; Moyle and Nichols 1973; Reeves 1964; Wales 1946.

GOLDEN SHINER, *Notemigonus crysoleucas* (Mitchill)

SPAWNING

Location	Shallow inshore waters of creeks, ponds, lakes, reservoirs, and sloughs, such as lower reaches of the Petaluma River, Napa River, Lake Herman, Lake Anza, Upper Rodeo Lagoon, Heather Farm Pond, Folsom Lake, some back sloughs in the Delta, Millerton Lake, Ice House Reservoir, Union Valley Reservoir, and Loon Lake.
Season	March through October (Swingle 1946); April through July (Wang and Kernehan 1979); March through August (Moyle 1976); April through July in the Delta and valley; and May through August in mid-elevations of the Sierra Nevada.
Temperature	18°C and greater (Wang and Kernehan 1979); started about 15–20°C (Moyle 1976); 17–21°C .
Salinity	Freshwater.
Substrates	Among aquatic vegetation (Wright and Allen 1913); submerged vegetation and bottom debris (Moyle 1976); in nesting materials of other fish, gravel, sand,

	and aquatic vegetation (Lippson and Moran 1974, Wang and Kernehan 1979, this study).

CHARACTERISTICS

EGGS (Figure 10-33)

Yolk	Yellowish (Wang and Kernehan 1979); pale yellow.
Oil Globule	None (Slastenenki 1958, Forbes and Richardson 1908, Wang and Kernehan 1979).
Chorion	Transparent, smooth.
Perivitelline space	Ca. 0.1–0.2 mm in width.
Egg mass	Deposited singly or in small clusters.
Adhesiveness	Very adhesive (Hubbs and Cooper 1936, Schwartz 1963, Lippson and Moran 1974, Wang and Kernehan 1979, this study).
Buoyancy	Demersal (Lippson and Moran 1974, Wang and Kernehan 1979, this study).

LARVAE (Figures 10-34, 10-35, 10-36)

Length at hatching	Ca. 4.5 mm TL or less (Lippson and Moran 1974); ca. 2.7 mm TL (Snyder *et al.* 1977); 3.8–4.0 mm TL (Wang and Kernehan 1979); 3.4–4.0 mm.
Snout to anus length	Ca. 57–62% of TL for protolarvae and mesolarvae (Snyder *et al.* 1977); ca. 66–72% of newly hatched prolvarvae and ca. 60–66% of late prolarvae and postlarvae.
Yolk sac	Elongate, large and almost spherical in thoracic region, becoming cylindrical in abdominal region.
Oil globule	None.
Gut	Straight.
Air bladder	Very elongate, midway between pectorals and anus, developing two chambers in postlarval stage.
Teeth	None.
Size at completion of yolk-sac stage	Ca. 5.7–6.8 mm TL (Snyder *et al.* 1977); 4.5–5.2 mm TL (Wang and Kernehan 1979); ca. 5.0 mm TL.
Total myomeres	35–39 (Snyder *et al.* 1977); 36–38 (Jones *et al.* 1978); 35–40 (mostly 36–37).
Preanal myomeres	23–24.
Postanal myomeres	11–17 (Snyder *et al.* 1977); 11–15.
Last fin to complete development	Pelvic.

Pigmentation	Newly hatched larvae have no pigments, then large stellate melanophores develop on head, brachiostegal, mid-dorsum, side and dorsal surface of gut, midventrum and postanal regions; dashed and dotted melanophores along lateral region, a group of melanophores concentrate at tip of notochard or urostyle.
Distribution	Near surface of shallow weedy creeks, ponds, sloughs, lakes and reservoirs, occasionally in open water.

JUVENILES (Figure 10-37)

Dorsal fin	7–9 (Frey 1951, Scott and Crossman 1973); 8 (Moyle 1976, this study).
Anal fin	8–19 (Schultz 1927); 11–15 (Moyle 1976); 13–15 (mostly 14).
Pectoral fin	15 (Moyle 1976); 16–18 (Jones *et al.* 1978); 15–16.
Mouth	Upward pointed mouth (Moyle 1976); terminal or slightly superior, oblique.
Vertebrae	37–39 (Scott and Crossman 1973).
Distribution	In both shallow and open warm waters of pools, creeks, ponds, ditches, sloughs, lakes, and reservoirs.

LIFE HISTORY

The golden shiner is a freshwater fish native to the East Coast and inland to the Mississippi River drainage (Scott and Crossman 1973). This species was introduced into southern California as a bait fish in 1891 (Moyle 1976). The golden shiner has now spread into most of the suitable warm water in this state, including the Sacramento-San Joaquin River system (McKechnie 1966, Moyle and Nichols 1973). In this study, the golden shiner was observed in the oligohaline portion of the Sacramento-San Joaquin Estuary, and in the foothill lakes and reservoirs such as Millerton Lake, Ice House Reservoir, Union Valley Reservoir, and Loon Lake. Only a few small streams, such as Pine Gulch, Corte Madera, and Olema Creeks, currently have not been invaded by this species (this study).

Spawning takes place from March through August (Moyle 1976). In this study, spawning activity was observed in sluggish or still waters from March through July in the low elevation Delta and its tributaries and from May through August in foothill and mid-elevation waters of the Sierra Nevada. During the breeding season, the male exhibits a brilliant golden glow on his body and fins. Eggs are deposited over and adhere to aquatic vegetation (Wright and Allen 1913, Webster 1942). Eggs have been wrapped in sand particles. Golden shiner exhibit no parental care for their eggs, but they sometimes deposit eggs into the nest of a largemouth bass or some other centrarchid while the male centrarchid is still guarding the nest (Kramer and Smith 1960, this study). This special behavior assures greater hatching success for the golden shiner eggs. The results of laboratory rearing from this study indicate that golden shiner eggs hatch in 3–4 days at 17–21°C.

Newly hatched larvae remain on the bottom of the nesting area until the yolk sac is absorbed. Once the larvae are able to swim, they are found near the surface or periphery of the littoral zone. Golden shiner larvae school with their own species or with centrarchid larvae. Consequently, during an introduction of largemouth bass larvae to a new pond or reservoir, golden shiner larvae may be transported along with them, and thus the distribution of golden shiner is expanded.

Juveniles form large schools and cruise in the warm water lakes and reservoirs. In small ponds and pools, the golden shiner juveniles are sometimes associated with centrarchids and other minnows. Major food items of juvenile golden whiner include small insects, cladocerans, and zooplankton (Moyle 1976).

Golden shiner mature at 2–3 years of age (Scott and Crossman 1973). The maximum life span of this species has been recorded as 9 years (Carlander 1969). Golden shiner is one of the most popular bait fish in California (Moyle 1976). It is an important forage fish, especially for such predators as bass and trout. However, some reservoirs, such as Ice House and Union Valley, seem to be overpopulated with golden shiner because of the fewness of competitors and predators.

References

Carlander 1969, Forbes and Richardson 1908, Frey 1951, Hubbs and Cooper 1936, Jones *et al.* 1978; Kramer and Smith 1960, Lippson and Moran 1974, McKechnie 1966, Moyle 1976, Moyle and Nichols 1973, Schultz 1927, Schwartz 1963, Scott and Crossman 1973, Slastenenki 1958, Snyder *et al.* 1977, Swingle 1946, Wang and Kernehan 1979, Webster 1942, Wright and Allen 1913.

RED SHINER, *Nortropis lutrensis* (Baird and Girard)

SPAWNING

Location	Near McKenzie Point and Madera Boat Ramp areas of Millerton Lake.
Season	May through October, mostly in June and July in Kansas (Cross 1967); March through June in Arizona (Minckley 1973); June and July in Colorado (Beckman 1970); estimated in June and July in Millerton Lake, California.
Temperature	15–30°C (Moyle 1976).
Salinity	Freshwater.

Substrates	Aquatic plants, gravel, sand, and mud (Cross 1967); nests of centrarchids (Minckley 1959, 1972; Pflieger 1975); spawning adults were collected from sand, decomposed granite, and gravel areas.
Fecundity	Ca. 1,200 mature ova, with numerous immature ova in a female of 65 mm TL.

CHARACTERISTICS

EGGs

Shape	Spherical.
Diameter	Mature eggs 1.3–1.7 mm.
Yolk	Whitish to pale yellow.
Oil globule	None.
Chorion	Transparent, smooth.
Egg mass	Deposited singly or in small clusters.
Adhesiveness	Adhesive (Cross 1967).

LARVAE

Total myomeres	30–35 (Taber 1969); 31–33 in early juveniles.
Preanal myomeres	20–23 (Taber 1969); 17–19 in early juveniles.
Postanal myomeres	10–13 (Taber 1969); 13–15 in early juveniles.
Last fin(s) to complete development	Pelvic.

JUVENILES (Figure 10-38)

Dorsal fin	8 (Cross 1967, Moyle 1976, this study).
Anal fin	8–10 (Cross 1967); 9.
Pectoral fin	Usually 14 (Cross 1967; Minckley 1972, 1973).
Vertebrae	34–36 (Cross 1967); 33.
Distribution	Shallow waters of Millerton Lake.

LIFE HISTORY

The red shiner is native in freshwater, from Wyoming to Minnesota and southward to Mexico; its range covers most of the drainages of the Mississippi and Rio Grande Rivers (Eddy 1957, 1969, Hubbs and Lagler 1958, Pflieger 1975). They have been introduced into the Colorado River (Hubbs 1954) and the Delta in California (Hubbs and Lagler 1958). However, Kimsey and Fisk (1964) did not observe this species in northern California. Moyle (1976) reported the red shiner in the freshwater drainages of the

Salton Sea. The Millerton Lake red shiner population could be the only existing distribution in northern California.

Cross (1967) described red shiner as spawning mostly in calm water with substrates ranging from aquatic vegetation to gravel, sand, and mud, in May through October in Kansas. The red shiner, like the golden shiner, sometimes deposits its eggs into the nests of centrarchids (Cross 1967, Pflieger 1975). At Millerton Lake, spawning adults were collected at McKenzie Point and Madera Boat Ramp, where there are sand, decomposed granite, and gravel bottoms in June and July. The male has breeding tubercles on its snout and head and brilliant orange-red coloration on its fins (except the dorsal fin), head, and the sides of its body (Cross 1967). In this study, different sizes of ova were found in the ovaries of red shiner, indicating that this species spawns more than once during the breeding season.

Saksena (1962) and Taber (1969) have described the larval development of red shiner. However, larvae were not collected in this study, and early life behavior has not been described in the literature.

Juveniles swim in small schools in the shallow inshore and sheltered cove waters of Millerton Lake. Juvenile red shiner feed on small crustaceans, aquatic insects, larvae, and algae (Hardwood 1972). In addition to small crustaceans and insects, plant leaves and detritus were also observed in the stomachs of juvenile red shiner.

Red shiner reach maturity as yearlings and their maximum lifespan is 3 years (Carlander 1969). The largest specimen taken at Millerton Lake was 70 mm long and had two annuli on its scales. Red shiner have been used as bait fish, and Millerton Lake has been incidentally stocked by fishermen tossing unwanted bait into the lake.

References

Beckman 1970; Carlander 1969; Cross 1967; Eddy 1957, 1969; Hardwood 1972; Hubbs 1954; Hubbs and Lagler 1958; Kimsey and Fisk 1964; Minckley 1959, 1972, 1973; Moyle 1976; Pflieger 1975; Saksena 1962; Taber 1969.

SACRAMENTO BLACKFISH, *Orthodon microlepidotus* (Ayres)

SPAWNING

Location	Shallow water with dense vegetation, mostly in reservoirs, and some sloughs and ponds such as San Luis Reservoir, Lindsey Slough, Concord Gold Course pond, Heather Farm pond in Walnut Creek, and a farm pond near Sonoma Mountain Road near Glen Ellen.

Season	April through June (Murphy 1950, this study; April through July (Moyle 1976).
Temperature	12–24°C (Murphy 1950); prolarvae were collected at 14.0–23.2°C.
Salinity	Freshwater.
Substrates	Over beds of aquatic vegetation (Murphy 1950); over rocks (Cook *et al.* 1966); algae and other rooted aquatic vegetation.
Fecundity	Ca. 350,000 (Murphy 1950).

CHARACTERISTICS

EGGS (unfertilized mature eggs)

Shape	Spherical.
Diameter	Ca. 1.0–1.2 mm.
Yolk	Pale yellow, granular.
Oil globule	None.
Chorion	Transparent.
Egg mass	Judging by the loose eggs found in the ovary, the eggs are probably deposited singly.
Adhesiveness	Adhesive.
Buoyancy	Demersal.

LARVAE (Figures 10-39, 10-40)

Length at hatching	Ca. 4.0–5.0 mm TL.
Snout to anus length	Ca. 60–68% of TL of larvae at 6.5–15.2 mm TL.
Yolk Sac	Yellowish, enlarged in thoracic region, and cylindrical in abdominal region.
Oil globule	None.
Gut	Straight.
Air bladder	Shallow, behind pectorals, develops into two chambers in late postlarval stage.
Teeth	None.
Size at completion of yolk-sac stage	Ca. 6.0–7.0 mm TL.
Total myomeres	36–42.
Preanal myomeres	26–29.
Postanal myomeres	11–15.
Last fin(s) to complete	Pelvic.

development	
Pigmentation	Heavy pigmentation on head, middorsal, thoracic, dorsal gut, and postanal regions; dashed and dotted melanophores on lateral line; melanophores cover entire body and base of fins in late postlarval stage.
Distribution	Mostly in shallow waters, ponds, lades, reservoirs, scattered in the sloughs of the Delta, and some in oligohaline waters of Suisun Bay.

JUVENILES (Figures 10-41, 10-42)

Dorsal fin	9–11 (Moyle 1976); 9–10.
Anal fin	8–9 (Moyle 1976); 8.
Pectoral fin	16–18; mostly 16.
Mouth	Slightly upturned (Moyle 1976); terminal, small, oblique.
Vertebrae	39–42.
Distribution	Mostly in shallow water with or without vegetation, landlocked ponds, lakes, reservoirs, and sloughs of the Delta and Suisun Bay such as Harris Slough and Montezuma Slough.

LIFE HISTORY

The Sacramento blackfish is a native inland California freshwater species abundant in the Sacramento-San Joaquin River systems, Clear Lake, Pajaro River, and Salinas River (Murphy 1950, Moyle 1976). In this study, Sacramento blackfish were found to be abundant in small and large impoundments and were also scattered throughout the freshwaters and some of the oligohaline waters of the Sacramento-San Joaquin Estuary. Specimens were also taken by gill net and otter trawl in Honker Bay, Grizzly Bay, and near Martinez (Ganssle 1966). The species was captured by midwater trawl in Carquinez Strait (Messersmith 1966).

Spawning of the Sacramento blackfish takes place from April through July, when small groups congregate over emergent vegetation or rocks in water usually less than 1 m deep (Murphy 1950; Cook *et al.* 1966). In this study, spawning was found in some very small ponds, such as Concord Golf Course pond, as well as in very large bodies of water, such as San Luis Reservoir, from April through June. The male fish bears breeding tubercles during the spawning period (Moyle 1976), and the male is apparently darker than the female (Murphy 1950). The Sacramento blackfish, like other cyprinids, deposits adhesive eggs on the vegetation near or at the bottom of shallow coves (S. Benin 1982, personal communication).

Most larvae were collected in shallow water and were associated with vegetation. They can be locally abundant, particularly when there are limited numbers of other fish species in the same pond. Larvae were also found in the open water of the Delta and Suisun Bay, all apparently planktonic.

Juveniles school in large numbers in shallows during the warm months. They are seldom observed in the same area when the water temperature drops in winter. It is possible that they might move to deeper, open water. Juvenile blackfish feed primarily on phytoplankton, green algae, diatoms, midges, cladocerans, and other bottom-suspended detritus (Murphy 1950; Cook *et al.* 1964, 1966; Moyle 1976). An elongate and coiled intestine indicates that Sacramento blackfish is an herbivorous fish.

Sacramento blackfish reach maturity by the second or third year; they are prolific but have relatively short lives because of spawning stress (Murphy 1950). This species is commercially valuable to Chinatown and other Asian fish markets in San Francisco, Los Angeles, and other cities on the West Coast. Fish are sold alive at the market to ensure freshness. The major supply of Sacramento blackfish is now from San Luis Reservoir and not from Clear Lake, because of parasite infestation.

Moyle (1976) has stated that Sacramento blackfish still predominate in the Sacramento-San Joaquin River system because of their herbivorous feeding habit, which means they face less feeding competition than carnivorous fish.

The Sacramento blackfish can inhabit a small, confined environment and reproduce there (this study); it also can tolerate wide ranges of water quality without apparent stress (C. Carothers 1982, personal communication). They are known to be phytoplankton feeders and their flesh is tasty, and they grow rapidly in warm water. The Sacramento blackfish has the potential to be developed into a species that can be pond-reared.

References

Cook *et al.* 1964, 1966; Ganssle 1966; Messersmith 1966; Moyle 1976; Murphy 1950.

FATHEAD MINNOW, *Pimephales promelas* Rafinesque

SPAWNING

Location	Shallow water with vegetation; in creeks, channelized ditches, and deadend sloughs such as Wilson Slough, Coyote Creek, and Sweeney Creek.
Season	Throughout the summer (Moyle 1976); June through August (Scott and Crossman 1973); March through July.
Temperature	Temperatures exceeding 17.8°C (Dobie *et al.* 1956); minimum 15.6°C (Scott and Crossman 1973); males

	show spawning color at 12°C and actual spawning starts at 15°C .
Salinity	Freshwater.
Substrates	Stone, boards, branches (Moyle 1976); logs, branches, rock, boards, lily pads (Wynne-Edwards 1932); vertical stalks of plants (Cross 1967); cattail, plastic tubing, stone, ceramic products.
Fecundity	4,100 eggs spawned by single female 12 times in 11 weeks (Dobie *et al.* 1956).

CHARACTERISTICS

EGGS (Figures 10-43, 10-44, 10-45)

Shape	Spherical.
Diameter	1.3 mm (Wynne-Edwards 1932); 1.15 mm (Markus 1934); 1.4–1.6 mm (Snyder *et al.* 1977); 1.3–1.45 mm.
Yolk	Whitish to pale yellow, granular.
Oil globule	None.
Chorion	Transparent, smooth.
Perivitelline space	Narrow, ca. 0.05–0.2 mm in width.
Egg mass	Deposited in small clusters or singly.
Adhesiveness	Adhesive (Wynne-Edwards 1932, Scott and Crossman 1973); adhesive throughout incubation.
Buoyancy	Demersal.

LARVAE (Figures 10-46, 10-47, 10-48)

Length at hatching	Ca. 5.0 mm TL (Scott and Crossman 1973); ca. 4.6–5.2 mm TL.
Snout to anus length	Ca.57–61% of TL of protolarvae and mesolarvae (Snyder *et al.* 1977); ca. 55–60% TL of prolarvae and postlarvae.
Yolk sac	Elongate, enlarged, and almost spherical in thoracic region, becoming cylindrical in abdominal region.
Gut	Straight.
Air bladder	Elongate, near pectorals, developing into 2 chambers in postlarval stage.
Teeth	None.
Size at completion of yolk-sac stage	5.7–6.4 mm TL (Snyder *et al.* 1977); ca. 5.0–5.6 mm TL.

Total myomeres	34–37 (Snyder *et al.* 1977); 33–36.
Preanal myomeres	20–22.
Postanal myomeres	14–15 (Snyder *et al.* 1977); 12–15.
Last fin(s) to complete development	Pelvic.
Pigmentation	Large stellate melanophores on snout, head, and middorsal regions; dense melanophores on dorsal surface, side of gut, and postanal regions; dotted and dashed melanophores along lateral line.
Distribution	Newly hatched larvae remain on bottom near nesting area until yolk sac is absorbed, and then disperse into shallow or open water.

JUVENILES (Figure 10-49)

Dorsal fin	8 (Moyle 1976, Scott and Crossman 1973, this study).
Anal fin	7 (Moyle 1976, Scott and Crossman 1973, this study).
Pectoral fin	14–18 (Scott and Crossman 1973); 15–16.
Mouth	Small, near terminal (Scott and Crossman 1973); small, terminal, and oblique.
Vertebrae	35–38 (Scott and Crossman 1973).
Distribution	Shallow creeks, ditches, and sloughs, in patchy patterns.

LIFE HISTORY

The fathead minnow is a freshwater fish native to the central portion of North America (Scott and Crossman 1973). They were introduced into California as bait fish in the early 1950s (Shapovalov *et al.* 1959). Currently, fathead minnows are found in some streams in the Sacramento-San Joaquin Valley (Moyle 1976). In this study, fathead minnows were collected from Lindsey Slough, Sweeney Creek, Coyote Creek, and Wilson Slough. The distribution is patchy but they are locally abundant.

In the Sacramento-San Joaquin River system fathead minnows spawn as early as March. Males become rusty brown with several dark vertical bands. Whitish breeding tubercles become prominent on the snout and top of head. In the laboratory, only the most dominant male could mate, and the other, less dominant males showed little breeding color in a small aquarium. If this dominant male is removed from the aquarium, the second most dominant male assumes breeding color in a very short time. The male establishes a territory and cleans up the nesting area, which is usually the underside of a flat rock or the vertical stalk of a plant (Wynne-Edwards 1932, Cross 1967). After engaging in courtship, the female deposits eggs into the nest or nesting spot and, after fertilization, the male takes over and guards it. Laboratory observation from this study showed that the male fish uses a wrinkled pad modified from the dorsal fin as a cleaning device to sweep eggs gently back and forth; this behavior has also been observed by Wynne-Edwards (1932). Since the ripe female deposits only a few eggs at any one time, spawning can last several days. The incubation period was reported to be 5 days at 25°C (Dobie *et al.* 1956). In this study, fathead minnow eggs hatched in 5 days at 19–21°C.

Newly hatched larvae remain in the nesting area for several more days until the yolk material is absorbed. Prolarvae initially lie on their sides on the bottom; then move to a dorsal-ventral vertical position as late prolarvae. After yolk sac is absorbed, the postlarvae swim freely in the water column, and most of them prefer the shallows, although some have been collected in open water sloughs.

Juveniles inhabit shallow weedy areas where they may be very abundant in one area. Young fathead minnows feed on filamentous algae, diatoms, detritus, and small invertebrates (Moyle 1976).

Fathead minnows have short lifespans, seldom living more than two years (Scott and Crossman 1973). Maturity is reached within 2 years (Carlander 1969). Fathead minnows are commonly used as bait fish in California and are utilized as a forage species by other predators (Shapovalov *et al.* 1959). The patchy distribution of this species in the study area of the Sacramento-San Joaquin River system could be a result of live bait releases by sport fisherman.

References

Carlander 1969, Cross 1967, Dobie *et al.* 1956, Markus 1934, Moyle 1976, Scott and Crossman 1973, Shapovalov *et al.* 1959, Snyder *et al.* 1977, Wynne-Edwards 1932.

SPLITTAIL, *Pogonichthys macrolepidotus* (Ayres)

SPAWNING

Location	Sloughs, flooded rivers and streams in the Delta (Caywood 1974); freshwater from lower Sacramento and San Joaquin Rivers down to Montezuma Slough (may extend to the mouth of Napa River at San Pablo Bay).
Season	March through June (Caywood 1974); January through July.
Temperature	9–20˚C (Caywood 1974); ca. 20˚C during the end of the spawning period.
Salinity	Freshwater (Caywood 1974); may also occur in oligohaline water.

Substrates	Aquatic vegetation, stream or riverbeds and banks (Caywood 1974); marsh and slough vegetation.
Fecundity	5,000–100,800 (Caywood 1974).

CHARACTERISTICS

EGGS

Shape	Mature eggs are spherical.
Diameter	Mature eggs, 1.3–1.6 mm.
Yolk	Yellowish, granular.
Oil globule	Mature eggs, no oil globule.
Chorion	Mature eggs, transparent, thick, smooth except at adhering point.
Egg mass	Assumed that eggs are deposited on substrates in single or small clusters.
Adhesiveness	Adhesive (Caywood 1974).
Buoyancy	Demersal, suspended on substrates (Caywood 1974).

LARVAE (Figures 10-50, 10-51, 10-52, 10-53, 10-54, 10-55)

Length at hatching	Less than 6.5 mm TL.
Snout to anus length	Ca. 62–70% of TL of prolarvae and postlarvae.
Yolk sac	Elongate, enlarged in thoracic region and slender in abdominal region.
Oil globule	None.
Gut	Slightly curved in thoracic region.
Air bladder	Shallow, behind pectorals, developed into 2 chambers in late postlarval stage, with much larger posterior chamber.
Teeth	None.
Total myomeres	39–43.
Preanal myomeres	25–31.
Postanal myomeres	10–15.
Last fin(s) to complete development	Pelvic.
Pigmentation	Large melanophores on head. Scattered melanophores on middorsal region, gradually forming 2 rows; heavy melanophores in jugular, on dorsal surface of gut and postanal regions; dotted to dashed melanophores on lateral line region; scattered melanophores in thoracic region.

Distribution	Planktonic larvae were found from freshwater to oligohaline portions of this estuary, such as the Delta in the vicinity of Pittsburg Powerplant and Montezuma Slough of Suisun Bay. They are occasionally found in water of higher salinity such as San Pablo Bay.

JUVENILES (Figures 10-56, 10-57)

Dorsal fin	9–10 (Moyle 1976); 10.
Anal fin	7–9 (Moyle 1976); 9.
Pectoral fin	16–19 (Moyle 1976); 16.
Mouth	Subterminal (Moyle 1976); terminal to subterminal.
Vertebrae	39–43, mostly 40.
Distribution	In shallow and open water from Delta to San Pablo Bay. They are particularly abundant in Montezuma Slough and Suisun Marsh.

LIFE HISTORY

The splittail is a native freshwater fish of California, formerly common in the lakes and rivers of the Central Valley. Currently splittail are limited to the Sacramento River as far as Knights Landing in Yolo County, and to the lower reaches of all river tributaries to the Delta (Caywood 1974). No information is available as to how far upstream splittail occur in the San Joaquin reaches of the Sacramento River, and throughout the Delta. No specimens were collected from South San Francisco Bay or its tributaries. Splittail there were last reported in 1905, when Snyder collected them from Coyote Creek (Snyder 1905, Aceituno *et al.* 1976).

On the basis of data collected during this study, splittail spawn in the tidal freshwater and oligohaline portions of this estuary from late January or early February to July. Flooded riverbeds and areas with submerged vegetation such as Montezuma and New York Soughs seem to be commonly used as spawning grounds (Caywood 1974, this study). During the spawning season, males bear breeding tubercles and exhibit brilliant orange-red coloration in their pectoral fins. The eggs are demersal and adhesive. During this study, eggs stripped from adult splittail were found to be in several sizes and stages of development, indicating that the female may have a prolonged spawning season.

Larvae were not collected in great abundance in open waters of Suisun Bay or the Delta during this study. However, they are commonly found in the vicinity of Pittsburg Powerplant at New York Slough, and apparently the bulk of the larval population remains in the shallow, weedy areas where spawning occurs. Larvae were also collected near Berkeley Marina of San Francisco Bay in April 1982 (K. Hieb 1982, personal communication). This shows that splittail larvae are euryhaline.

Juvenile splittail were collected by beach seine in Suisun Bay (they were particularly abundant in the vicinity of Montezuma Slough) and most of the Delta sloughs in late winter and spring months. The number of juveniles collected in shallow waters gradually declined as the summer progressed. Larvae probably moved to deep waters of Suisun Bay and San Pablo Bay, since they were often captured by trawl in those areas. Juvenile splittail feed primarily on algae, pelecypods, and amphipods (Caywood 1974). In turn, these juveniles are preyed upon by large squawfish (pikeminnow) and striped bass (S. Moock 1979, personal communication).

Male splittail reach sexual maturity in 1 year, females in 1 or 2 years. The lifespan of this species is approximately 5 years (Caywood 1974).

Moyle (1976) reported that a small sport fishery exists for splittail, and they also have value as forage for large predators.

Judging from the relative abundance of this species collected during this study, the population of splittail appears to be thriving in Suisun Bay and San Pablo Bay of the Sacramento-San Joaquin Estuary. Their ability to tolerate brackish water and exploit suitable habitat such as Suisun Marsh could be the main reasons for this success locally.

References

Aceituno *et al.* 1976, Caywood 1974, Ganssle 1966, Messersmith 1966, Moyle 1976, Snyder 1905.

SACRAMENTO SQUAWFISH, *Ptychocheilus grandis* (Ayres)

SPAWNING

Location	In gravel riffle streams (Taft and Murphy 1950, Moyle 1976); small foothill streams as well as most of the tributaries of Sacramento and San Joaquin Rivers such as American River, Bear Creek, Sonoma Creek, Suisun Creek, Napa River, Alameda Creek, Walnut Creek, Consumnes River, upper San Joaquin River at Millerton Lake, Capell Creek of Lake Berryessa.
Season	April through May (Taft and Murphy 1950); April through July.
Temperature	Exceeds 14˚C (Moyle 1976); larvae were taken from 16–19˚C.
Salinity	Freshwater.
Substrates	Rocks and gravel (Moyle 1976, this study).
Fecundity	17,700 eggs from a single specimen of 50 cm TL (Burns 1966c).

CHARACTERISTICS

EGGS (Figures 10-58, 10-59)

Shape	Mature eggs spherical.
Diameter	Mature eggs, ca. 22–24 mm.
Yolk	Mature eggs, yellowish, granular.
Oil globule	Many small oil globules dispersed in the yolk.
Chorion	Transparent, smooth.
Adhesiveness	Adhesive (Taft and Murphy 1950).
Buoyancy	Demersal (Taft and Murphy 1950).

LARVAE (Figures 10-60, 10-61)

Snout to anus length	Ca. 60–66% of TL of larvae at 9.7–12.5 mm TL.
Yolk sac	Elongate, enlarged in thoracic and cylindrical in abdominal region.
Gut	Straight.
Air bladder	Elongate, behind pectorals, develops into 2 chambers in postlarval stage.
Teeth	None.
Size at completion of yolk-sac stage	Ca. 8.5–9.0 mm TL.
Total myomeres	45–49.
Preanal myomeres	32–34.
Postanal myomeres	13–16.
Last fin(s) to complete development	Pelvic.
Pigmentation	Large stellate melanophores on cephalic, middorsal, jugular, side and dorsal surface of gut, and postanal regions. Dashed melanophores along lateral line region. Pigments are also concentrated in urostyle and hypleural regions and form a dark blotch at base of caudal peduncle in late postlarval stage. This blotch diminishes in juveniles.
Distribution	Shallow water, small pools, and side pools of streams and rivers; some were found in freshwater portion of the estuary.

JUVENILES (Figures 10-62, 10-63)

Dorsal fin	8 (Moyle 1976, this study).
Anal fin	8 (Moyle 1976; this study).

Pectoral fin	16–18.
Mouth	Large (Moyle 1976; this study).
Vertebrae	47–50.
Distribution	Sacramento squawfish (pikeminnow) are mostly found in the tributaries of the Sacramento-San Joaquin Estuary; some are also observed in the tidal portions of the estuary, such as the Delta and Suisun Bay.

LIFE HISTORY

The Sacramento squawfish (renamed Sacramento pikeminnow) is one of the largest freshwater minnows native to California. The largest recorded was 115 cm long (TL) and weighed 14.5 kg, from Avocado Lake, Fresno County (Moyle 1976). This species is distributed throughout the Sacramento-San Joaquin River system and is also found in the Pajaro, Salinas, Russian, and upper Pit Rivers (Taft and Murphy 1950, Moyle and Nichols 1973, Moyle 1976). They are also common in the tidal Carquinez Strait and Suisun Bay (Messersmith 1966, Ganssle 1966). In this study it was observed that large squawfish are common in the open waters of San Pablo Bay, Suisun Bay, Delta sloughs, the American River, and the Sacramento River below Red Bluff Dam; larvae and juveniles are more abundant in lower elevation tributaries. Squawfish are also found in some large lakes and reservoirs such as Folsom Lake, Millerton Lake, and Lake Berryessa.

Taft and Murphy (1950) observed the spawning migration of squawfish from the Russian River to a tributary, Sulphur Creek, in March and April. In this study, mature squawfish were observed at the fish ladder of Red Bluff Dam during their upstream migration in May and June in 1982. Judging by the larvae taken in the upper section of tributaries such as Suisun Creek and Sonoma Creek, and in Capell Creek of Lake Berryessa, spawning occurs in creeks and the fish may not reproduce in the Delta sloughs. Squawfish nests are usually built downstream of a pool with running water; eggs are demersal and adhesive and the male bears breeding tubercles during spawning period (Taft and Murphy 1950).

Newly hatched larvae remain in the crevices of the nesting area for a short period until yolk sac is absorbed, and then they move into side and shallow pools of a stream. As larval growth proceeds, larvae swim in deeper pools. Some larvae can be washed downstream into lakes, reservoirs, or estuaries during the flood.

Juveniles school in shallow waters of large stream pools or reservoirs (Moyle 1976). In this study, juvenile squawfish inhabited streams until October or November, then migrated into deeper portions of large water bodies. In streams the juvenile squawfish often share the same habitat with Sacramento sucker, juvenile rainbow trout, and California roach.

Diet of juvenile squawfish in tributaries includes insect larvae, small insects, small minnows, and salmonid juveniles (Taft and Murphy 1950). In the estuary, in addition to crustaceans, small striped bass and splittail are common food items of large juvenile squawfish (S. Moock 1979, personal communication). Generally, Sacramento squawfish less than 30 cm TL feed mainly on invertebrates.

Sacramento squawfish mature in their third or fourth summer (Moyle 1976). Individuals can live to 9 years (Taft and Murphy 1950). The Sacramento squawfish has not been used as food commonly by fishermen, although Indian middens contain bones of this species (Moyle 1976).

References

Burns 1966c, Ganssle 1966, Messersmith 1966, Moyle 1976, Moyle and Nichols 1973, Taft and Murphy 1950.

LAHONTAN REDSIDE, *Richardsonius egregius* (Girard)

SPAWNING

Location	Inshore of Loon Lake of the upper American River system.
Season	May through August (Evans 1969); June through August.
Temperature	13–24˚C (Evans 1969); ca. 15–19˚C when larvae taken.
Salinity	Freshwater.
Substrates	Rocks and gravel (Miller 1951).
Fecundity	Average 1,125 (Evans 1969).

CHARACTERISTICS

EGGS

Shape	Mature eggs are spherical.
Yolk	Yellowish.
Oil globule	Mature eggs, none.
Adhesiveness	Adhesive (Miller 1951).
Buoyancy	Demersal (Miller 1951).

LARVAE (Figures 10-64, 10-65)

Snout to anus length	58–63% of TL of larvae at 9.8–12.1 mm TL.
Oil globule	None.

Gut	Straight.
Air bladder	Shallow, behind pectorals; developed into two chambers in late postlarval stage.
Teeth	None.
Total myomeres	36–39.
Preanal myomeres	24–26.
Postanal myomeres	12–14.
Last fin(s) to complete development	Pelvic.
Pigmentation	In postlarvae, heavy melanophores on snout and head; 2–3 major rows of heavy melanophores along middorsal region; scattered melanophores on side of gut region, dense melanophores along postanal region; dotted and dashed type melanophores along lateral line. A dark blotch is found in hypleural region in postlarvae which moves up to the base of the caudal peduncle in the postlarval stage.
Distribution	Inshore, coves, and mouth of tributary of Loon Lake.

JUVENILES (Figures 10-66, 10-67)

Dorsal fin	7–8 (Moyle 1976); 9.
Anal fin	8–10 (Moyle 1976); 9–10.
Pectoral fin	13–14.
Mouth	Subterminal for small juveniles and inferior for large juveniles (this study).
Vertebrae	37–39.
Distribution	Shallow area of quiet water (Moyle 1976); shallow inshore and open waters.

LIFE HISTORY

The Lahontan redside is known to be distributed in western Nevada and southeastern California (Snyder 1917, Miller 1951, Evans 1969). Kimsey (1950) reported this species in Mill Creek at the headwaters of the Rubicon River; Moyle (1976) has suggested that the Lahontan redside population in the Rubicon River drainage was introduced by fishermen, since redside has often been used as a bait fish. In this study the Lahontan redside was observed in Loon Lake of the upper American River system. However, no specimens were taken in Ice House Reservoir or Union Valley Reservoir, which are adjacent to Loon Lake (Nicola and Borgeson 1970).

Spawning occurs from June through August in Lake Tahoe (Evans 1969). In this study, judging from the small larvae taken, spawning appears to be from June through August in

Loon Lake. During spawning, groups of spawners congregate in a tight swirling school, and adhesive eggs are deposited into the crevices of rocks and gravel (Miller 1951). This spawning behavior is very similar to that of the California roach. Evans (1969) reported that spawning takes place inshore of the lake as well as in tributaries of a lake. In Loon Lake, the resident population must use inshore areas as their breeding ground, since all tributaries to Loon Lake were dried up in the summer months.

Eggs and newly hatched larvae were not collected in this study, which suggests that they remain in the crevices of the nesting area until yolk absorption of yolk-sac larvae is completed. Larvae move into quiet water after hatching (Moyle 1976). Larvae may school in the area adjacent to spawning sites because of limitation of suitable habitats for the larvae in Loon Lake.

Juveniles were found inshore as well as in open water near the surface, in schools. Major dietary items for juvenile redside are small insects, planktonic crustaceans, and benthic organisms (Miller 1951). Large juveniles and adults captured by gill net at depths of 5–10 m in Loon Lake demonstrate that they can move into deeper waters.

Maturity is generally reached at 3–4 years, although some mature in 2 years (Evans 1969). The largest specimen collected in this study was 163 mm TL and had five annuli on the scale. Lahontan redside is a popular bait fish in the Lake Tahoe area.

References

Evans 1969, Kimsey 1950, Miller 1951, Moyle 1976, Nicola and Borgeson 1970, Snyder 1917.

Characteristic Comparison: Carps and Minnows

Characteristic	Goldfish	Carp	California Roach	Hitch
Spawning				
Season	April–July	March–July	March–June	April–June
Location	Freshwater (tidal, nontidal) ditches, ponds, sloughs	Freshwater (tidal, nontidal) ditches, ponds, sloughs; may spawn in oligohaline	Freshwater (nontidal) creeks and streams	Freshwater (mostly nontidal) chan- nelized ditches, ponds, creeks
Larvae				
Total myomeres	29–34	34–36	37–42	36–39
Preanal myomeres	21–22	24–26	24–29	24–28
Postanal myomeres	8–12	10–12	12–14	11–13
Pigmentation	Large stellate melanophores on snout, cephalic, middorsal portion of gut, midventral, and postanal regions	Pigmentation similar to or much heavier than goldfish, particularly on dorsal gut	Newly hatched larvae: no pigment; in 1–2 days, large melanophores show on snout, cephalic, and middorsal regions; pigments also along dorsal surface of gut, jugular, thoracic, and postanal regions; series of melanophores on lateral line	Large stellate melanophores on snout, cephalic, and middorsal regions; very large melanophores on dorsal and lateral surface of gut; dashed melanophores on lateral line; dark spot on base of caudal peduncle
Juveniles				
Dorsal fin	I–V, 14–20	I–V, 15–23	7–10	10–13
Anal fin	I–III, 5–7	I–III, 4–6	6–9	10–14
Pectoral fin	13–17	14–18	13–16	15–16
Caudal fin	Symmetrical, forked	Symmetrical, forked	Symmetrical, forked	Symmetrical, deep fork
Position of dorsal vs. pelvic fin	Over-under	Dorsal anterior, or over-under	Dorsal posterior	Dorsal posterior
Head shape	Large, pointed	Large, pointed	Large, pointed	Small, pointed
Barbels	None	One pair	None	None
Mouth	Small	Small	Small	Small

Characteristic	Goldfish	Carp	California Roach	Hitch
Body shape	Compressed, heavy	Compressed, heavy	Cylindrical, chunky	Compressed, heavy
Lateral line and its scales	Slight dip, 28–31 large scales	Straight or slight dip, 32–39 large scales	Dip in thoracic, abdominal regions, 47–63 small scales	Ventral dip, 54–62 medium scales

Characteristic Comparison: Carps and Minnows

Characteristic	**Hardhead**	**Golden Shiner**	**Red Shiner**	**Sacramento Blackfish**
Spawning				
Season	April–August	March–October	May–October	April–June
Location	Freshwater (nontidal) rivers, creeks, streams	Freshwater (mostly nontidal) sloughs, ponds, reservoirs, creeks	Freshwater (nontidal) ponds and reservoirs	Freshwater (mostly nontidal) ponds, sloughs
Larvae				
Total myomeres	46–50	35–40	30–35	36–42
Preanal myomeres	29–34	23–24	20–23	26–29
Postanal myomeres	14–18	11–17	10–13	11–15
Pigmentation	Large stellate melanophores on snout and cephalic regions, 2 rows of pigments on middorsum, large melanophores on side and dorsal surface of gut and postanal region; dark blotch at base of caudal peduncle; dashed melanophores in lateral line region	Newly hatched larvae have no pigments, then large stellate melanophores develop on head, branchiostegal, middorsal, side and dorsal surface of gut, midventral, and postanal regions; dashed melanophores along lateral region; a dark blotch at tip of notochord or urostyle		Very large melanophores on cephalic, thoracic, and dorsal gut regions; large melanophores on snout, middorsal, midventral, and postanal regions; dashed melanophores on lateral line
Juveniles				
Dorsal fin	8	7–9	8	9–11
Anal fin	8–9	8–19	8–10	8–9
Pectoral fin	15–16	15–16	13–14	16–18
Caudal fin	Symmetrical, deep fork	Symmetrical, deep fork	Symmetrical, deep fork	Symmetrical, deep fork
Position of dorsal vs. pelvic fin	Dorsal posterior	Dorsal posterior	Over-under	Over-under or dorsal posterior
Head shape	Long, cone-shaped	Small, pointed, conical	Medium, pointed	Medium, conical
Barbels	None	None	None	None
Mouth	Medium	Small	Small	Small

Characteristic	**Hardhead**	**Golden Shiner**	**Red Shiner**	**Sacramento Blackfish**
Body shape	Cylindrical, elongate	Highly compressed	Compressed	Highly compressed
Lateral line and its scales	Slight dip, 70–80 small scales	Dips deeply, 47–54 large scales	Slight dip, 33–36 large scales	Slight dip, up to 105 tiny scales

Characteristic Comparison: Carps and Minnows

Characteristic	Fathead Minnow	Splittail	Sacramento Squawfish	Lahontan Redside
Spawning				
Season	April–July	December–May	April–July	May–August
Location	Freshwater (tidal, nontidal) sloughs, ponds, ditches, creeks	Freshwater (tidal, nontidal), possibly to oligohaline, sloughs, creeks	Freshwater (nontidal) rivers, tributaries, creeks	Freshwater (nontidal) Sierra reservoirs
Larvae				
Total myomeres	33–37	39–43	45–49	36–39
Preanal myomeres	20–22	26–31	32–34	24–26
Postanal myomeres	12–15	10–15	13–16	12–14
Pigmentation	Large stellate melanophores on snout, head, and middorsal regions; dense melanophores on dorsal surface, side of gut, and postanal regions; dotted and dashed melanophores along lateral line	Light and scattered melanophores on cephalic, middorsal, thoracic, dorsal surface of gut, and postanal regions; middorsal melanophores form 2 distinct rows in postlarval stage; dotted melanophores more distinct in lateral line region	Large stellate melanophores on cephalic, middorsal, jugular, side and dorsal surface of gut, and postanal regions; dashed melanophores in lateral line region; dark blotch at base of caudal peduncle	Heavy melanophores on snout and head, 2–3 rows of large melanophores along middorsal region; scattered melanophores on side of gut, dense melanophores along post-anal region; dotted and dashed melanophores along lateral line; dark blotch at base of caudal peduncle
Juveniles				
Dorsal fin	8	9–10	8	7–8
Anal fin	7	7–9	8	8–10
Pectoral fin	14–18	16–19	16–18	13–14
Caudal fin	Symmetrical, forked	Asymmetrical, deep fork, dorsal lobe larger, longer than ventral	Symmetrical, deep fork	Symmetrical, deep fork
Position of dorsal vs. pelvic fin	Over-under	Dorsal posterior	Dorsal posterior	Dorsal posterior
Head shape	Large, blunt	Small, short	Large, elongate, flat	Medium, pointed
Barbels	None	One pair	None	None
Mouth	Small	Small	Large	Medium
Body shape	Cylindrical, chunky	Cylindrical, chunky	Cylindrical, elongate	Cylindrical

Characteristic	Fathead Minnow	Splittail	Sacramento Squawfish	Lahontan Redside
Lateral line and its scales	Slight dip, lateral line incomplete, 44–48 small scales	Slight dip, 57–64 medium scales	Slight dip, 73–86 small scales	Slight dip, 52–63 small scales

Figure 10.—Cyprinidae: *Carassius auratus*, goldfish.

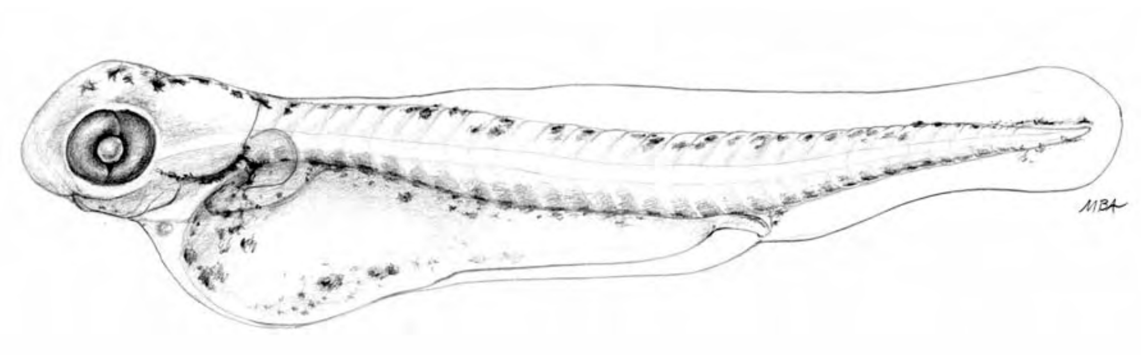


FIGURE 10-1—Prolarva, 4.8 mm TL.

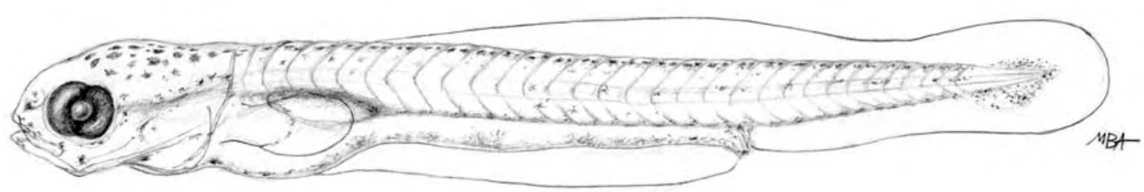


FIGURE 10-2.—Postlarva, 5.8 mm TL.

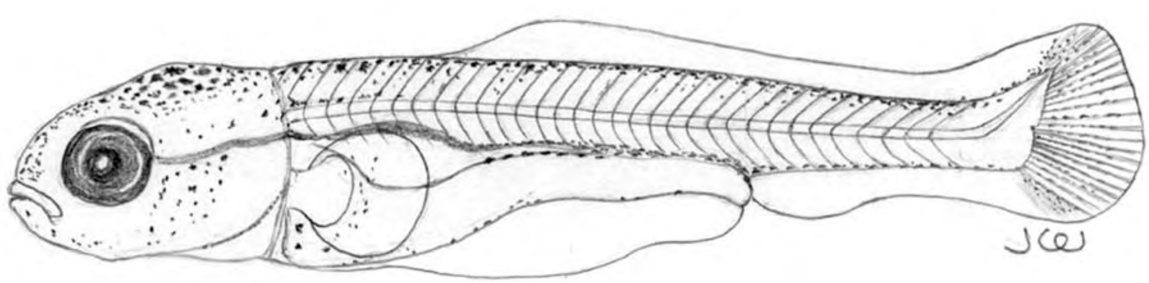


FIGURE 10-3—Postlarva, 9.5 TL.

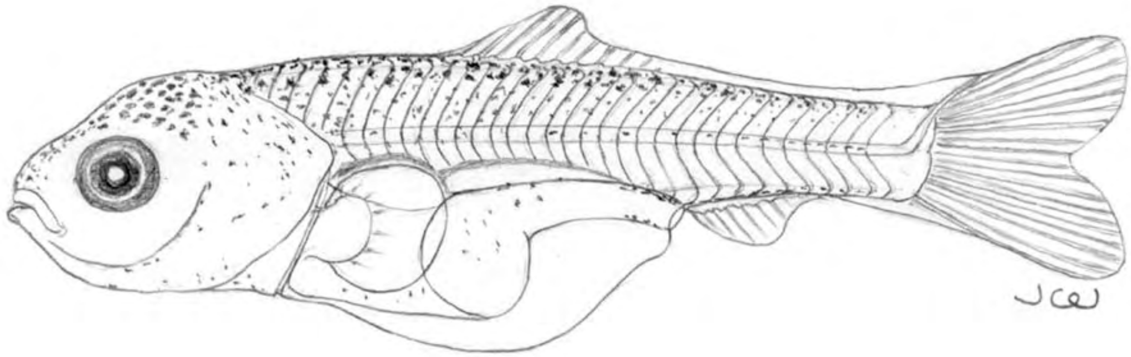


FIGURE 10-4.—Postlarva, 13.8 mm TL.

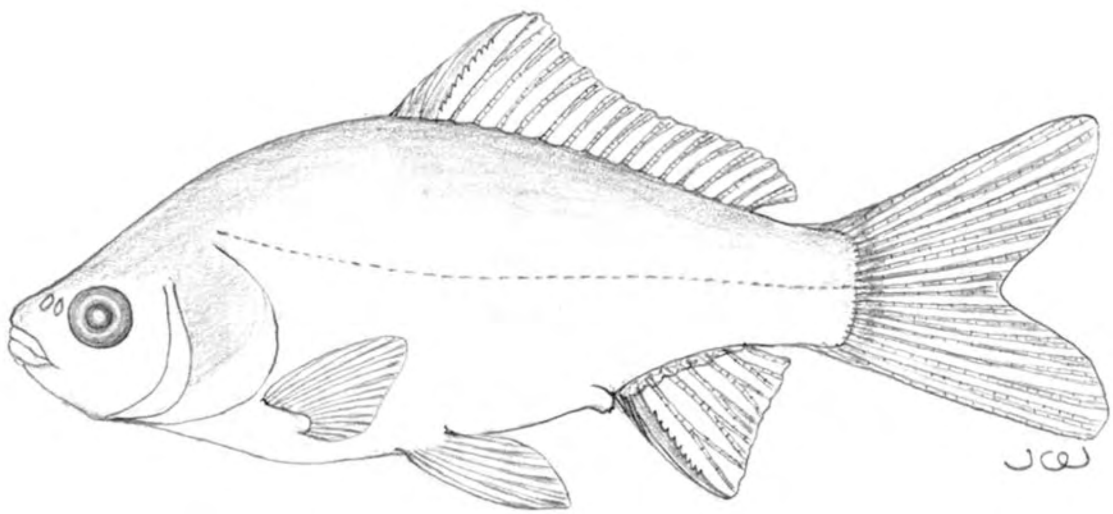


FIGURE 10-5—Juvenile, 48 mm TL.

Cyprinidae: *Cyprinus carpio*, common carp.

FIGURE 10-6.—Egg, late embryo, 1.7 mm diameter.

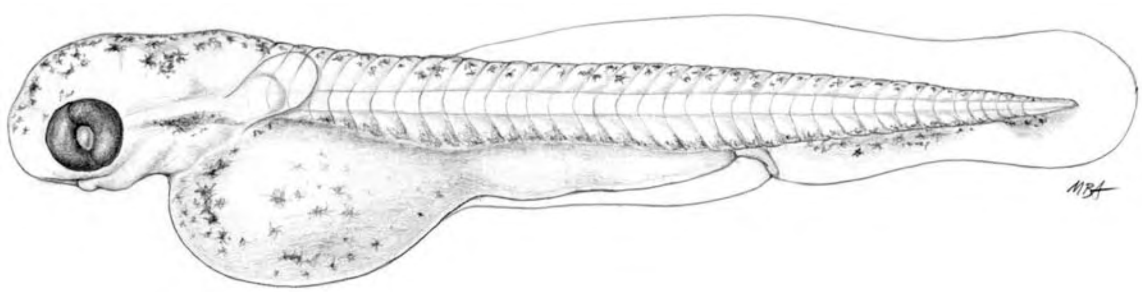


FIGURE 10-7.—Prolarva, 5.4 mm TL.

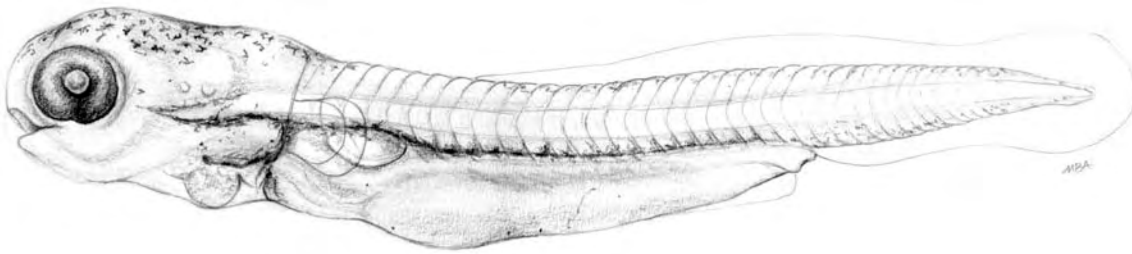


FIGURE 10-8.—Prolarva, 6.2 mm TL..

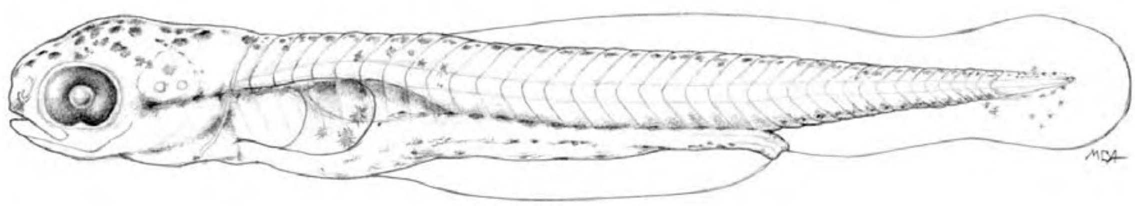


FIGURE 10-9.—Postlarva, 6.6 mm TL.

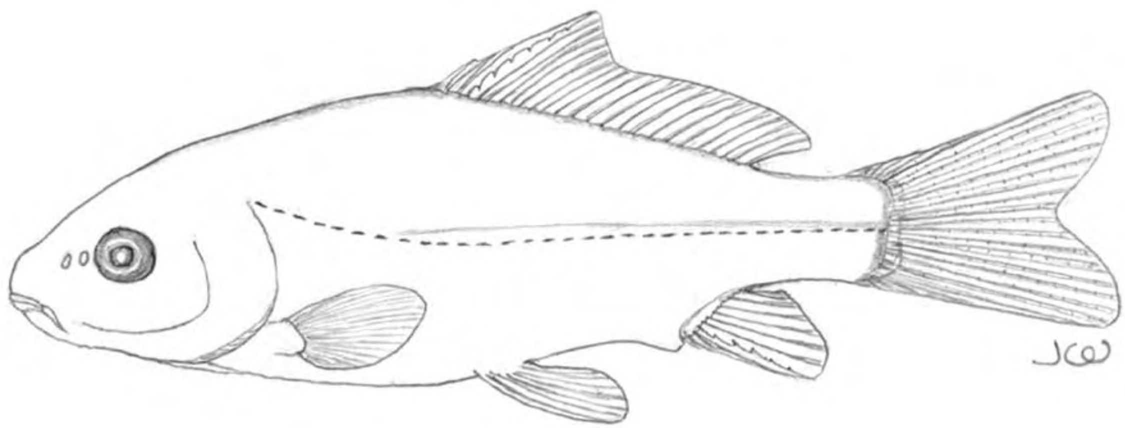


FIGURE 10-10.—Juvenile, 42 mm TL.

Cyprinidae: *Hesperoleucus symmetricus*, California roach.

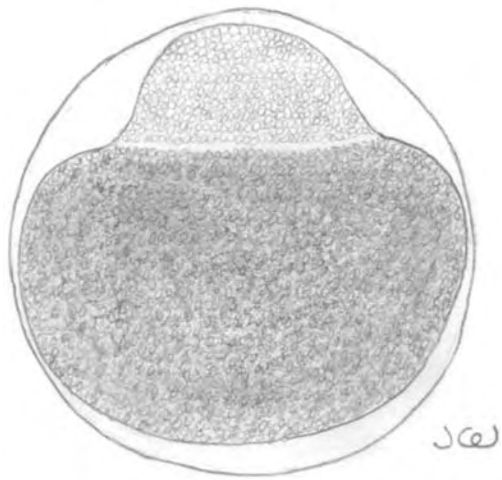


FIGURE 10-11.—Egg, morula, 2.1 mm diameter.

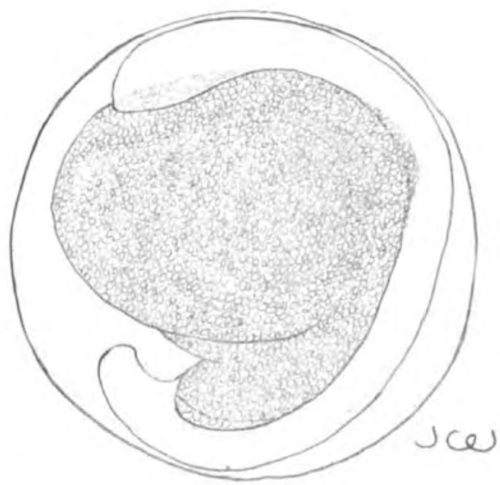


FIGURE 10-12.—Egg, late embryo, 2.0 diameter

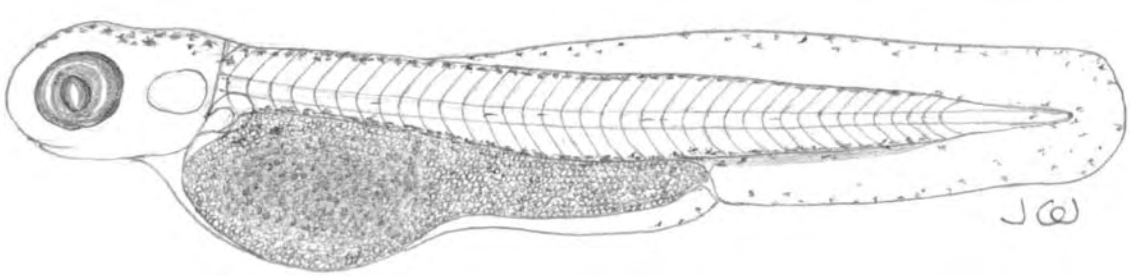


FIGURE 10-13.—Prolarva, 6.9 mm TL.

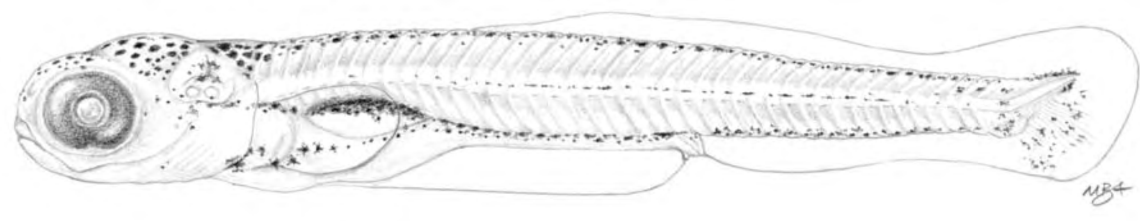


FIGURE 10-14.—Postlarva, 7 mm TL.

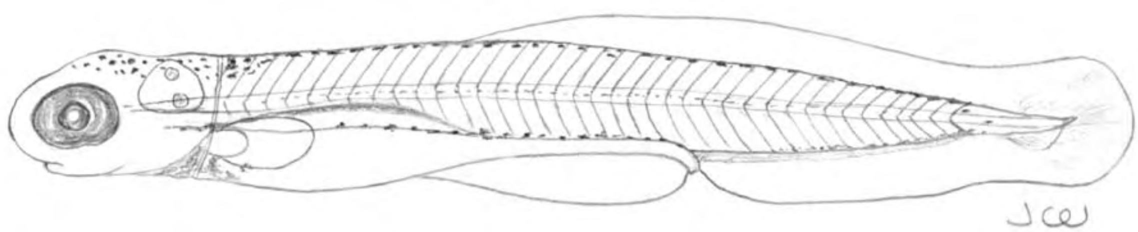


FIGURE 10-15.—Postlarva, 8.2 mm TL.

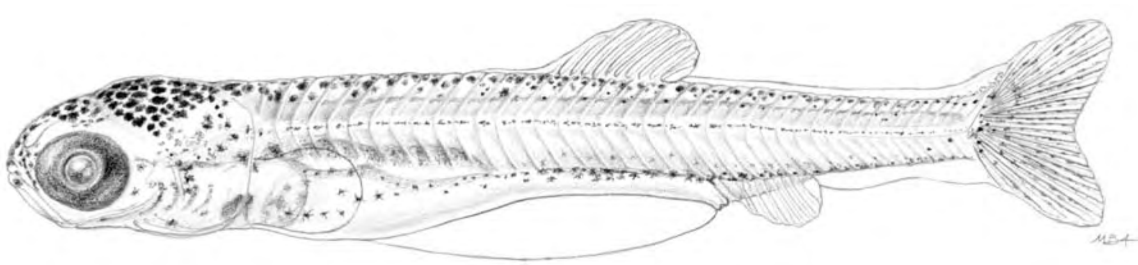


FIGURE 10-16.—Postlarva, 11 mm TL.

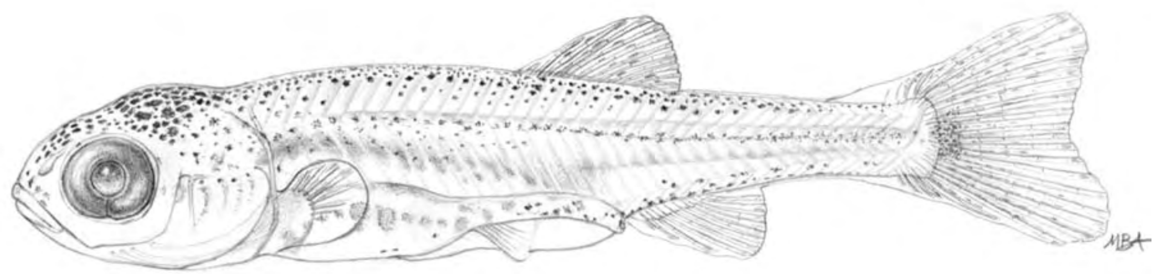


FIGURE 10-17.—Postlarva, 15 mm TL.

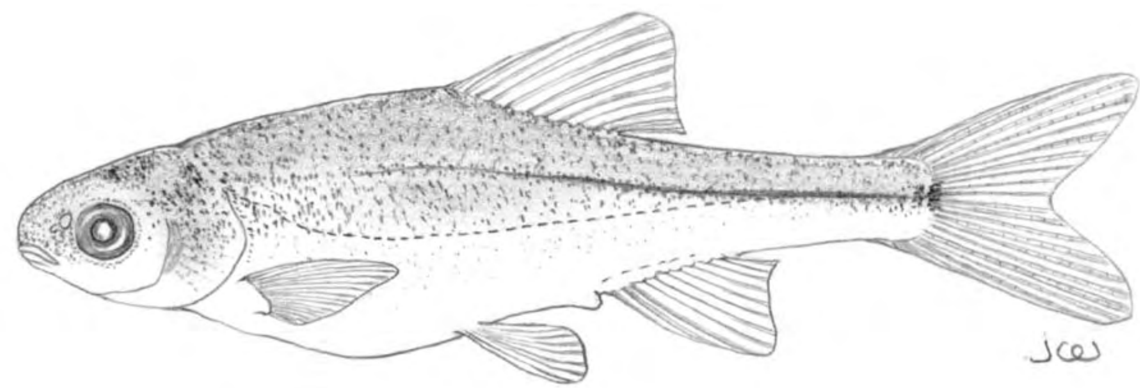


FIGURE 10-18.—Juvenile, 35 mm TL.

Cyprinidae: *Lavinia exilicauda*, hitch.

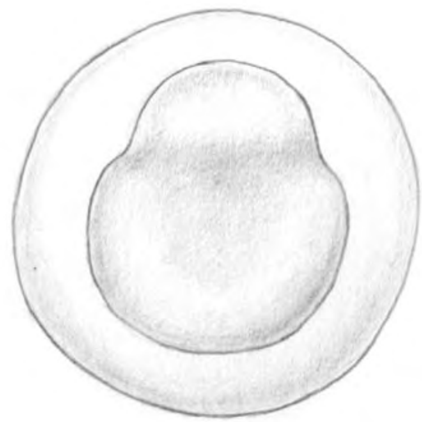


FIGURE 10-19.—Egg, 2-cell, 1.6 mm diameter.

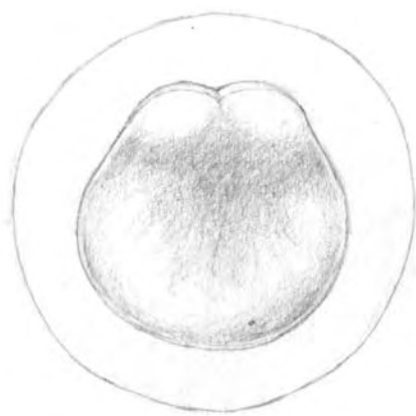


FIGURE 10-20.—Egg, 4-cell, 1.6 mm diameter.

FIGURE 10-21.—Egg, early embryo, 1.7 mm diameter.

FIGURE 10-22.—Late embryo, 1.7 mm diameter.

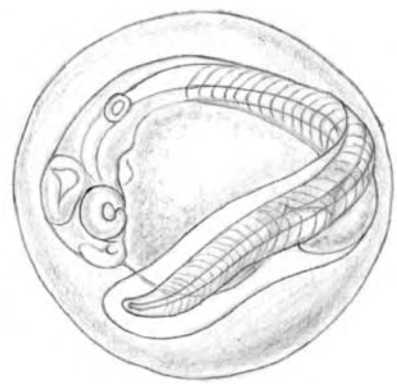


FIGURE 10-23.—Late embryo, 1.7 mm diameter.

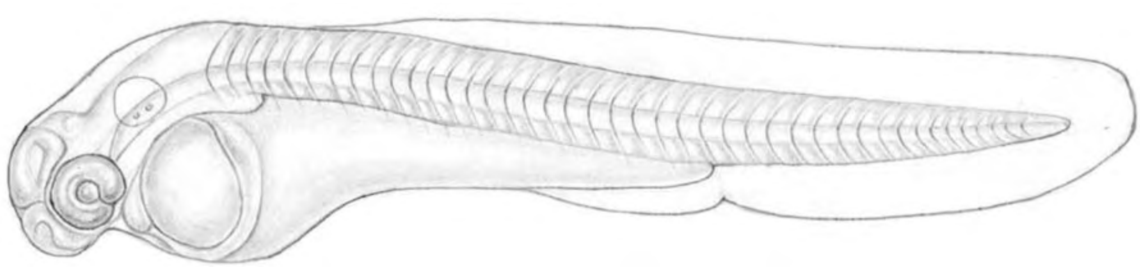


FIGURE 10-24.—Prolarva, 5.5 mm TL.

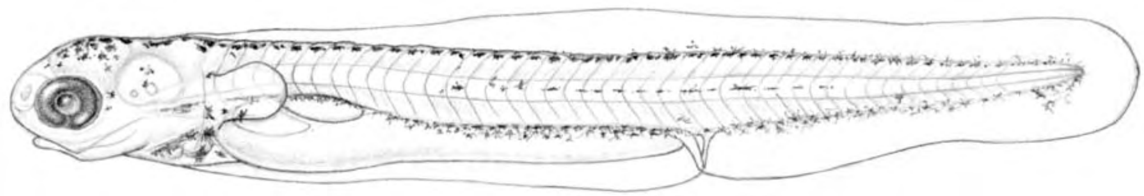


FIGURE 10-25.—Postlarva, 7 mm TL.

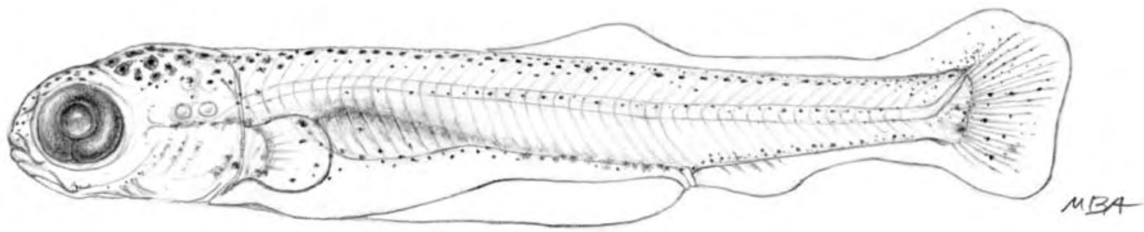


FIGURE 10-26.—Postlarva, 10 mm TL.

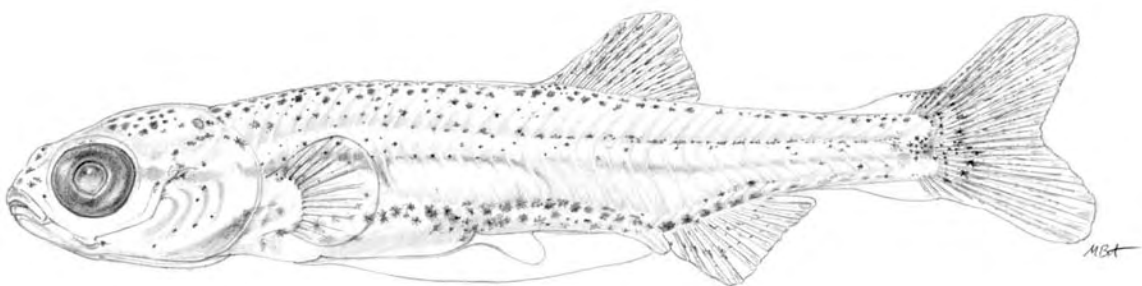


FIGURE 10-27.—Postlarva, 13 mm TL.

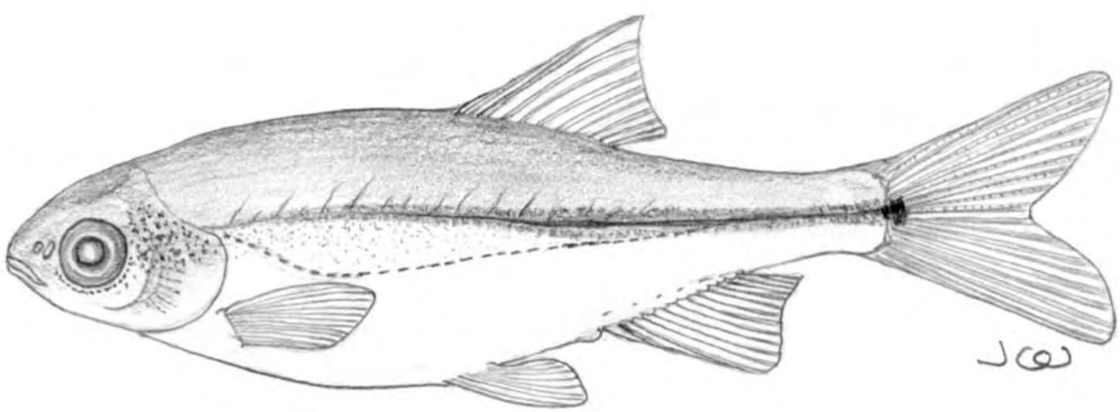


FIGURE 10-28.—Juvenile, 65 mm TL.

Cyprinidae: *Mylopharodon conocephalus*, hardhead.

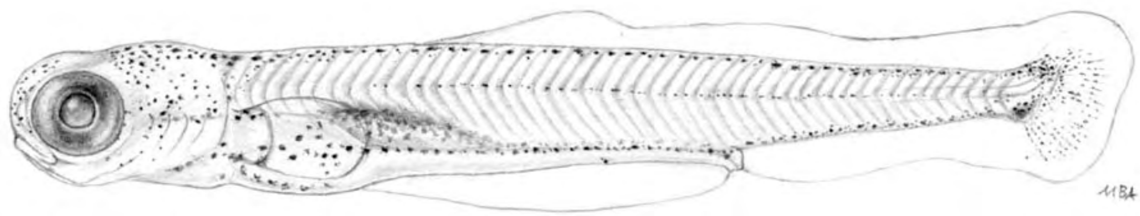


FIGURE 10-29.—Postlarva, 11 mm TL.

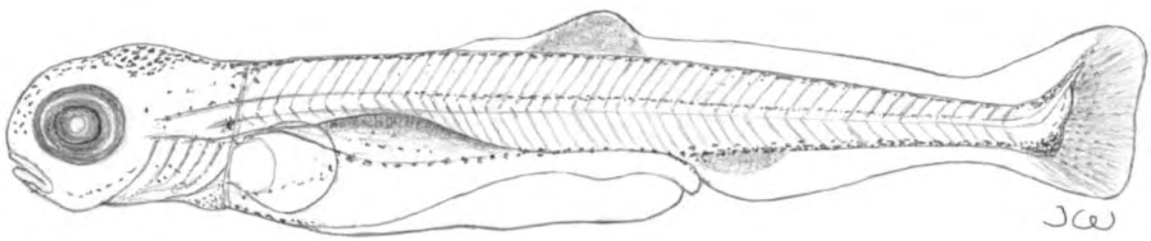


FIGURE 10-30.—Postlarva, 12.3 mm TL.

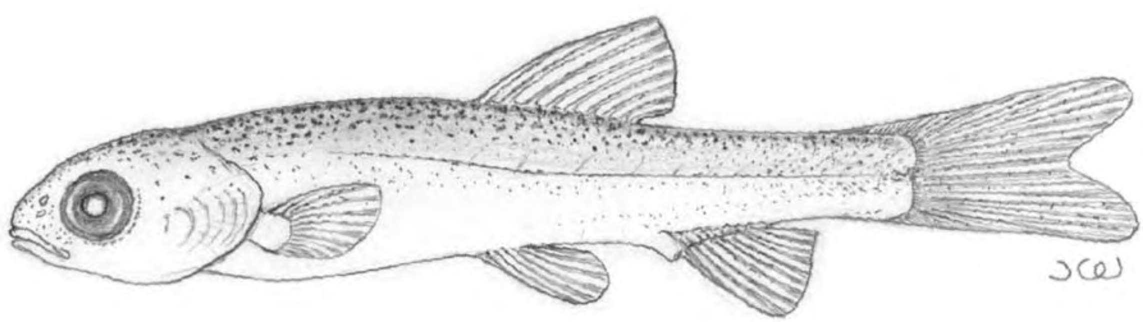


FIGURE 10-31.—Juvenile, 22.5 mm TL.

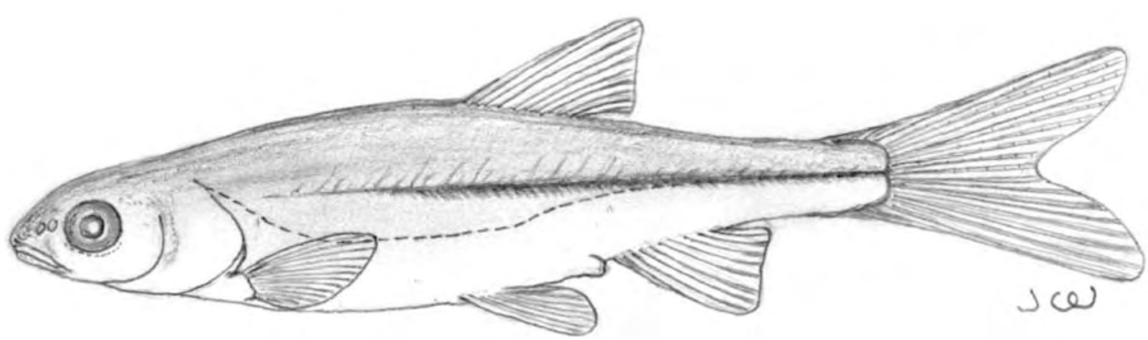


FIGURE 10-32.—Juvenile, 67 mm TL. .

Cyprinidae: *Notemigonus crysoleucas*, golden shiner.

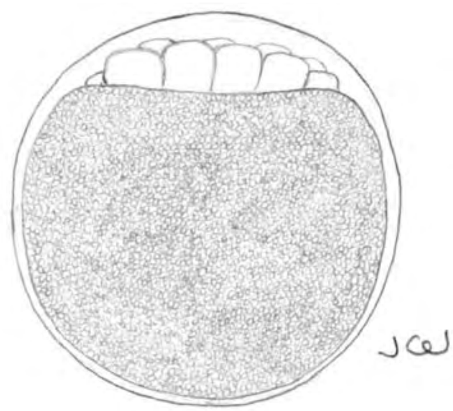


FIGURE 10-33.—Egg, 16-cell, 1.2 mm TL.

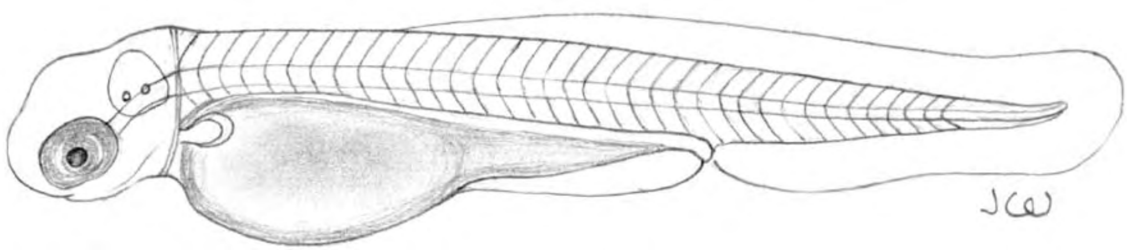


FIGURE 10-34.—Prolarva, 4.5 mm TL.

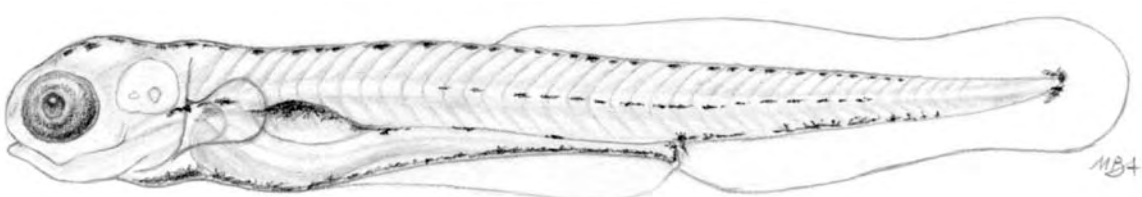


FIGURE 10-35.—Postlarva, 5 mm TL.

Cyprinidae: Minnows and Carps.

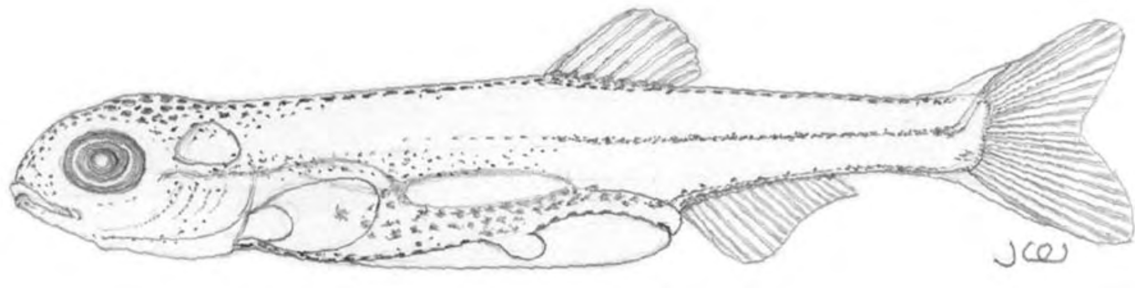


FIGURE 10-36.—*Notemigonus crysoleucas*, golden shiner postlarva, 13.3 mm TL.

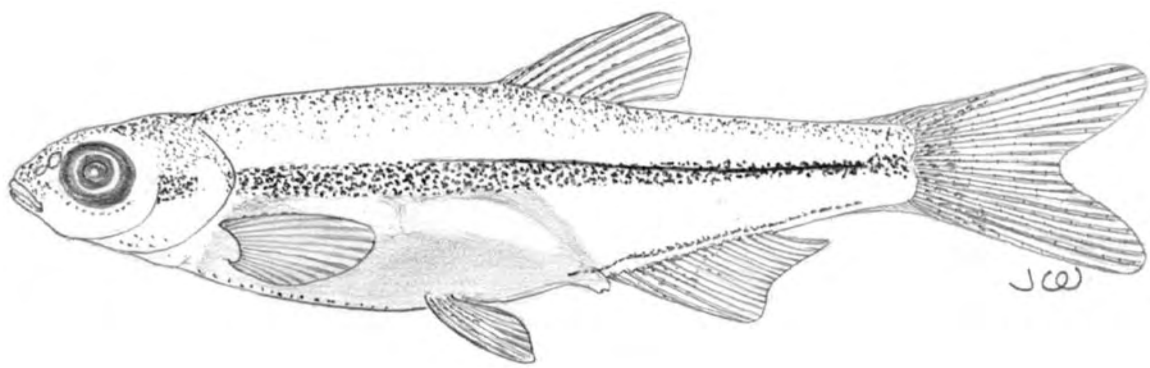


FIGURE 10-37.—*Notemigonus crysoleucas*, golden shiner juvenile, 23.8 mm TL.

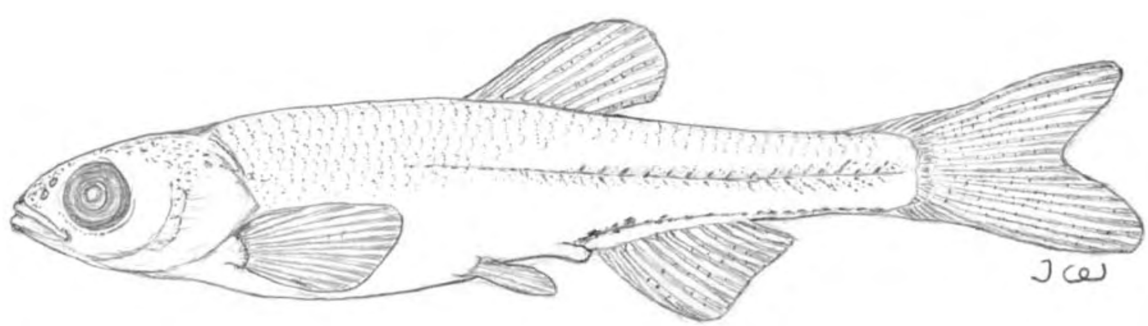


FIGURE 10-38.—*Notropis lutrensis*, red shiner juvenile, 22.5 mm TL.

Cyprinidae: *Orthodon microlepidotus*, Sacramento blackfish.

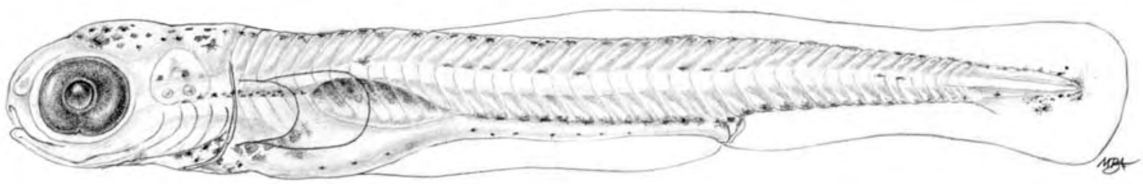


FIGURE 10-39.—Postlarva, 6.5 mm TL.

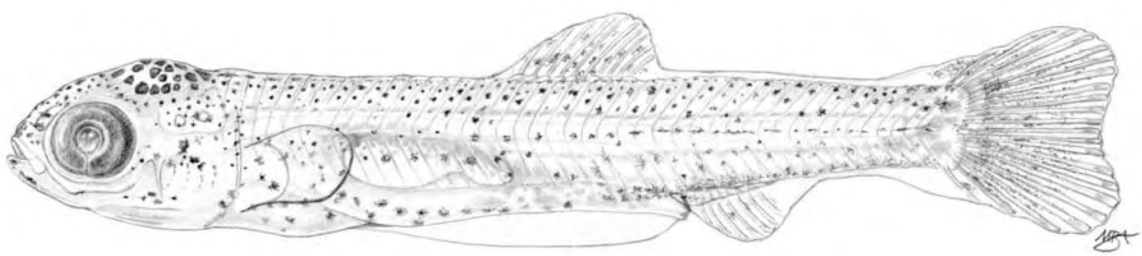


FIGURE 10-40.—Postlarva, 12.6 mm TL.

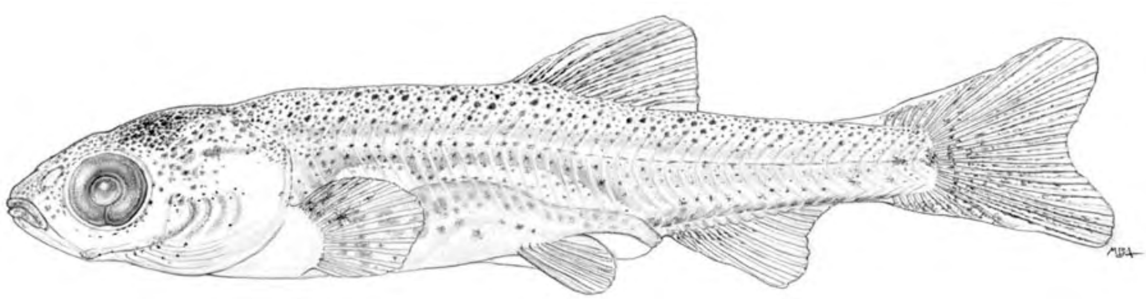


FIGURE 10-41.—Juvenile, 17 mm TL.

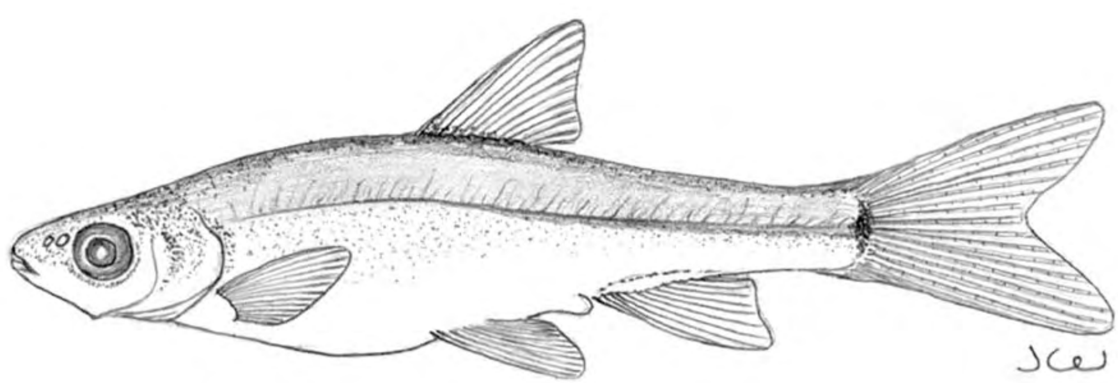


FIGURE 10-42.—Juvenile, 78 mm TL.

Cyprinidae: *Pimephales promelas*, fathead minnow.

FIGURE 10-43.—Egg, morula, 1.3 mm diameter.

FIGURE 10-44.—Egg, late embryo, 1.2 mm diameter.

FIGURE 10-45.—Egg, late embryo, 1.2 diameter.

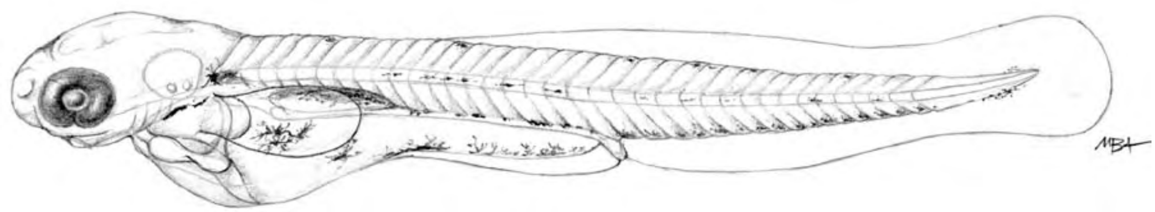


FIGURE 10-46.—Prolarva, 5.2 mm TL.

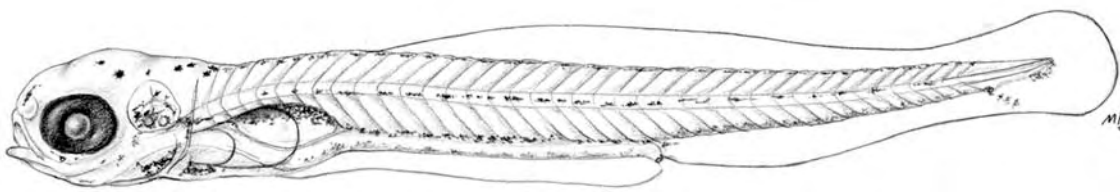


FIGURE 10-47.—Postlarva, 5.9 mm TL.

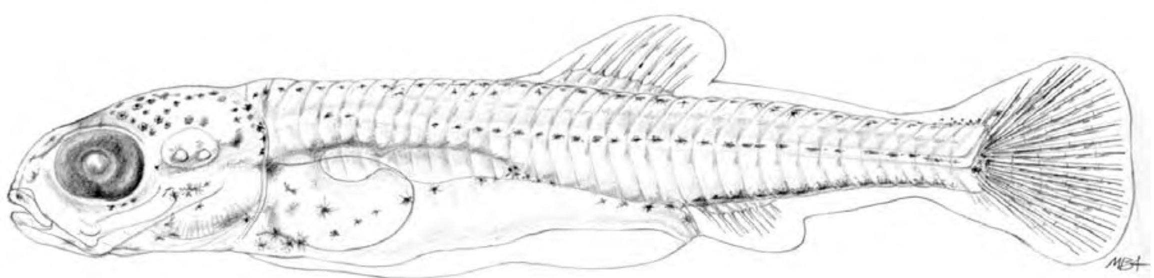


FIGURE 10-48.—Postlarva, 9 mm TL.

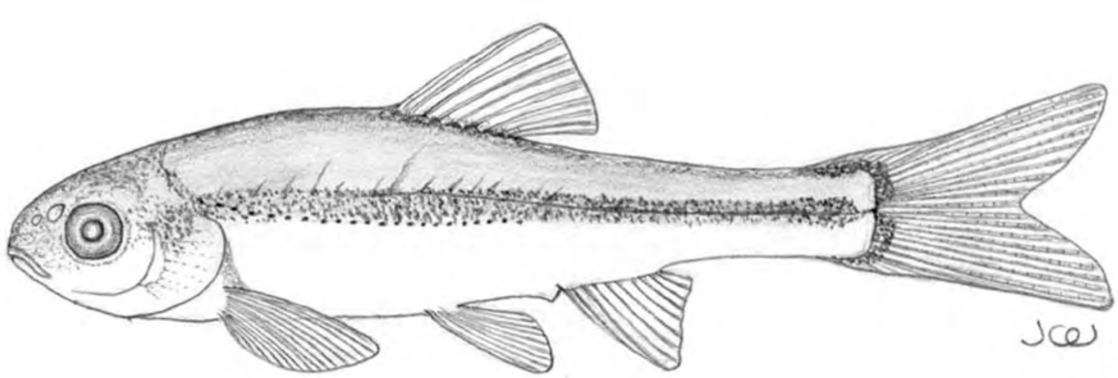


FIGURE 10-49.—Juvenile, 42.5 mm TL.

Cyprinidae: *Pogonichthys macrolepidotus*, splittail.

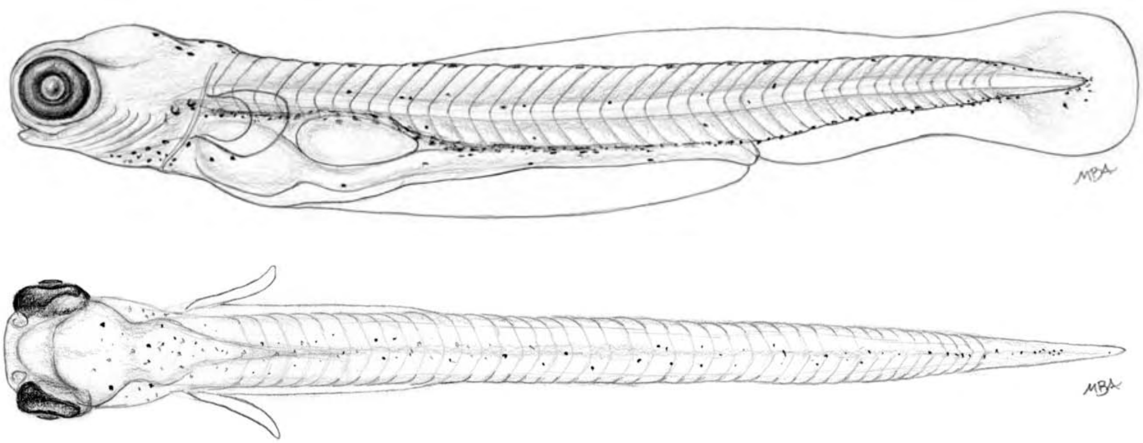


FIGURE 10-50, 10-51.—Postlarva, lateral and dorsal views, 7.5 mm TL.

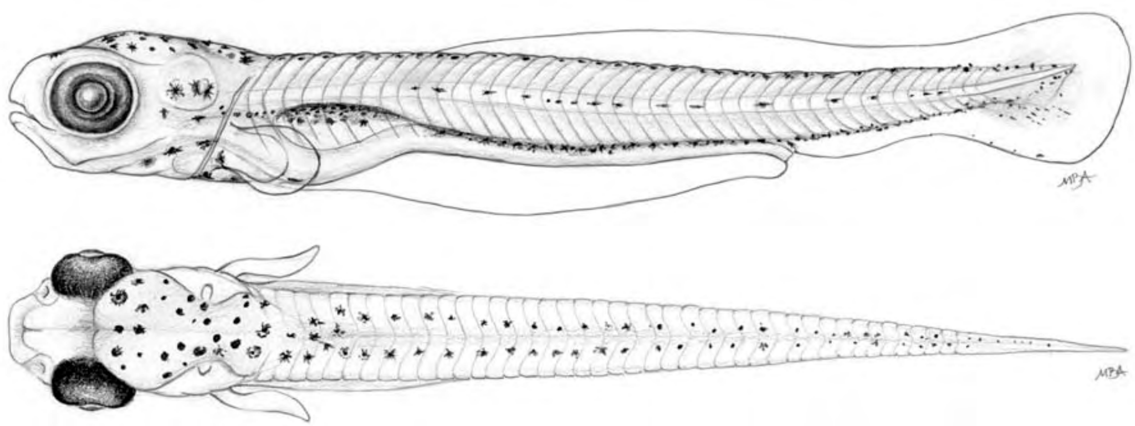


FIGURE 10-52, 10-53.—Postlarva, lateral and dorsal views, 8.1 mm TL.

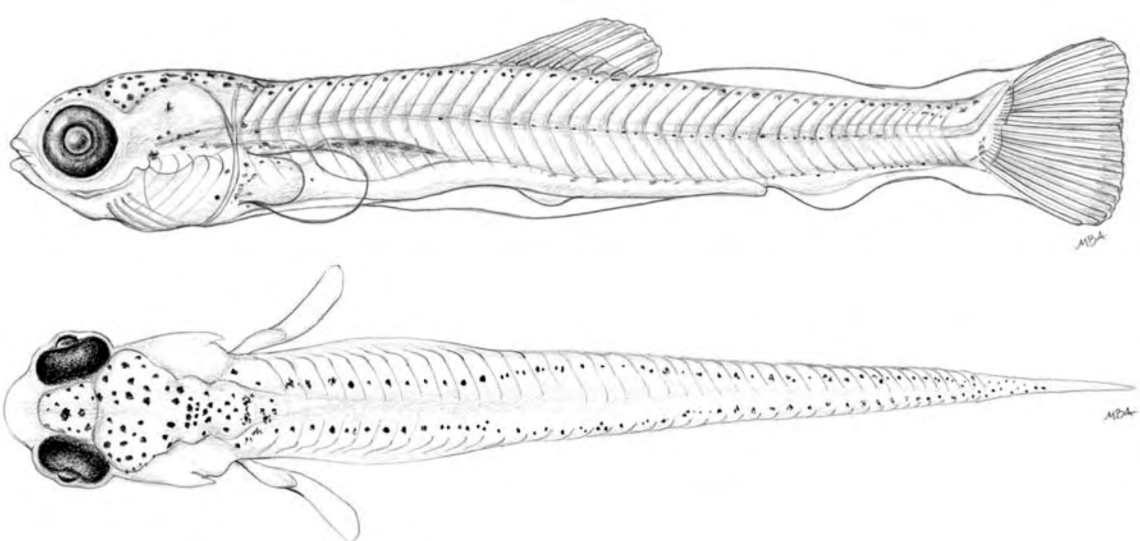


FIGURE 10-54, 10-55.—Postlarva, lateral and dorsal views, 10.4 mm TL.

FIGURE 10-56.—Juvenile, 24.2 mm TL.

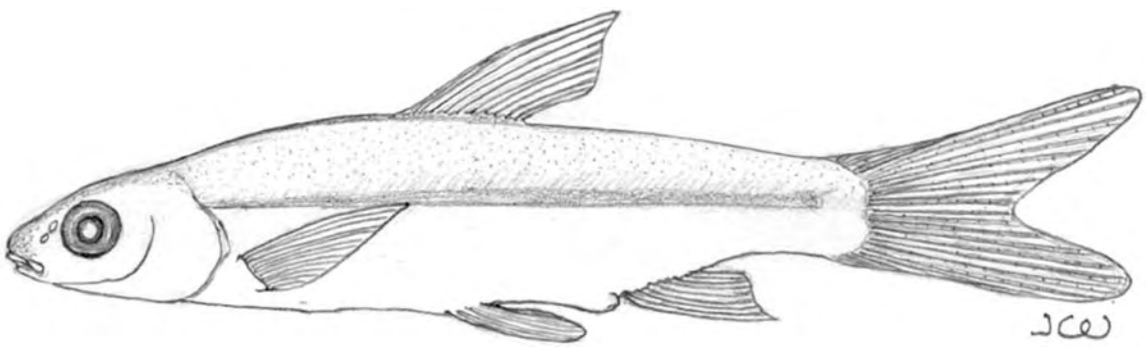


FIGURE 10-57.—Juvenile, 57 mm TL.

Cyprinidae: *Ptychocheilus grandis*, Sacramento squawfish.

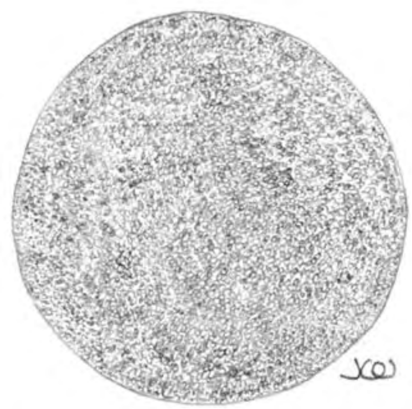


FIGURE 10-58.—Unfertilized egg, 2.2 mm diameter.

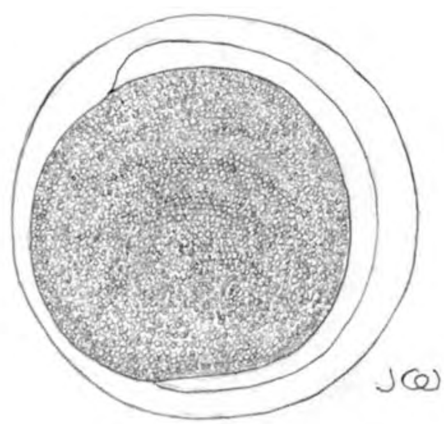


FIGURE 10-59.—Egg, early embryo, 2.5 mm diameter.

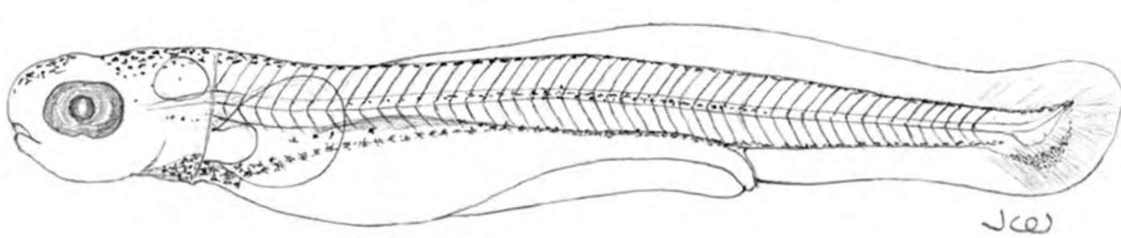


FIGURE 10-60.—Prolarva, 10.6 mm TL.

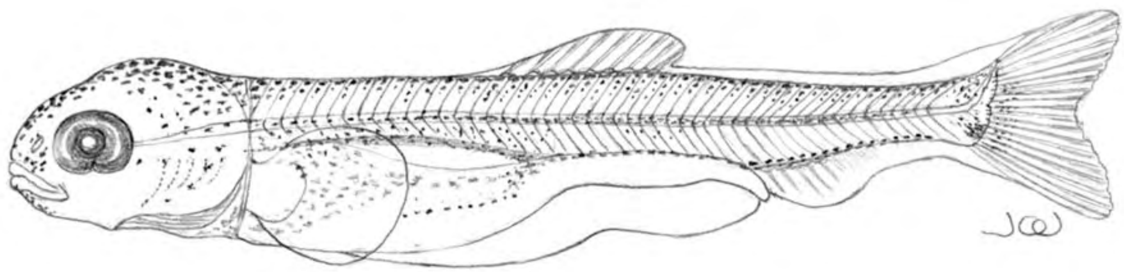


FIGURE 10-61.—Postlarva, 12.3 mm TL.

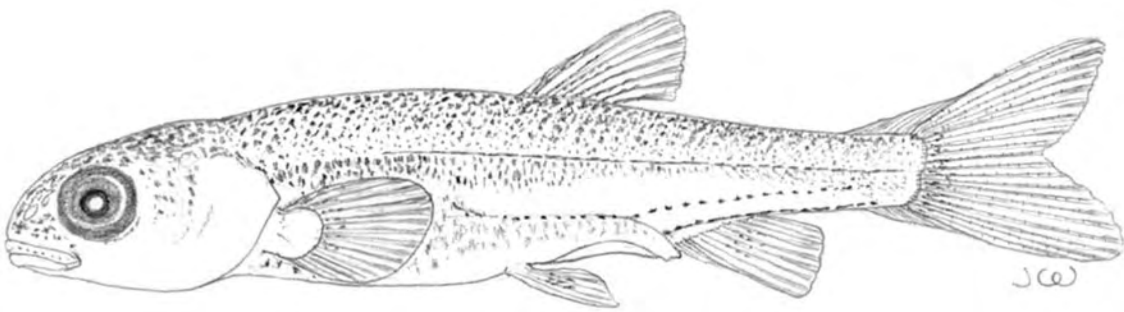


FIGURE 10-62.—Juvenile, 23 mm TL.

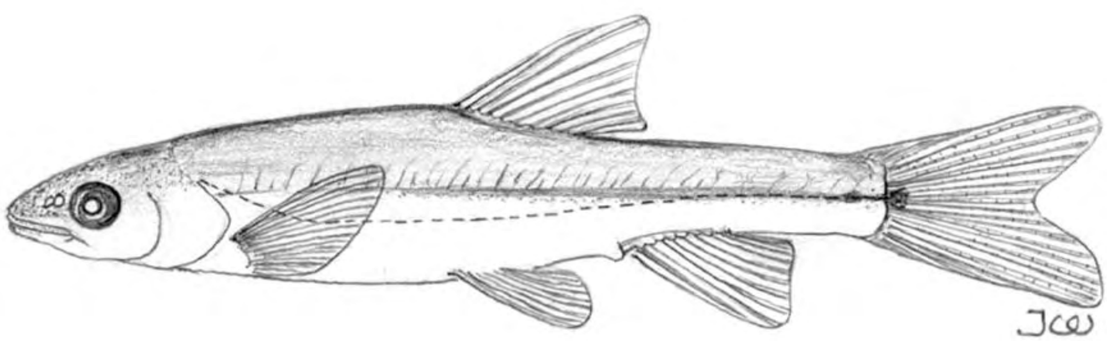


FIGURE 10-63.—Juvenile, 75 mm TL.

Cyprinidae: *Richardsonius egregius*, Lahontan redside.

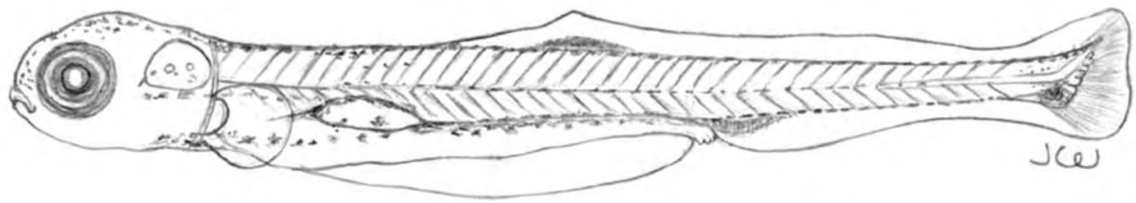


FIGURE 10-64.—Postlarva, 7.5 mm TL.

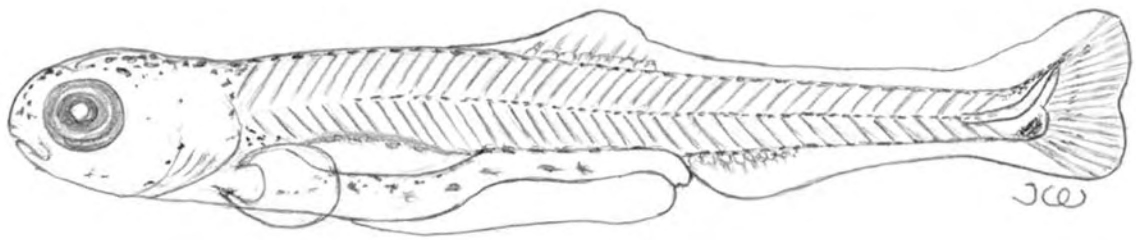


FIGURE 10-65.—Postlarva, 9.9 mm TL.

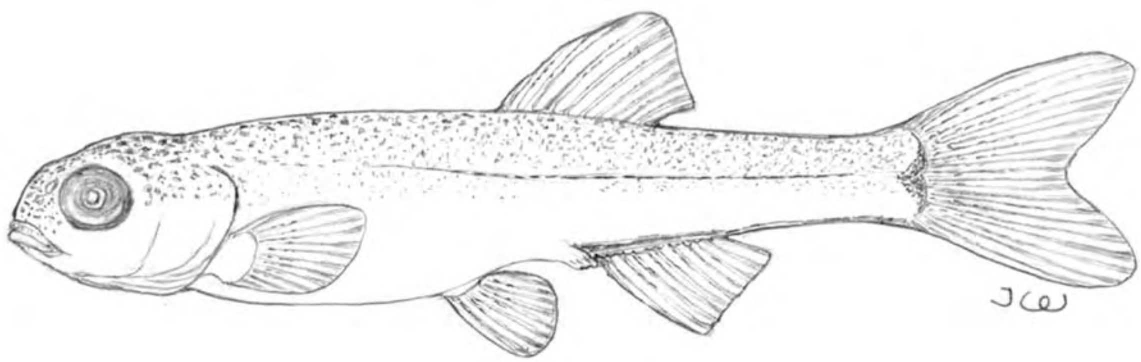


FIGURE 10-66.—Juvenile, 22.5 mm TL.

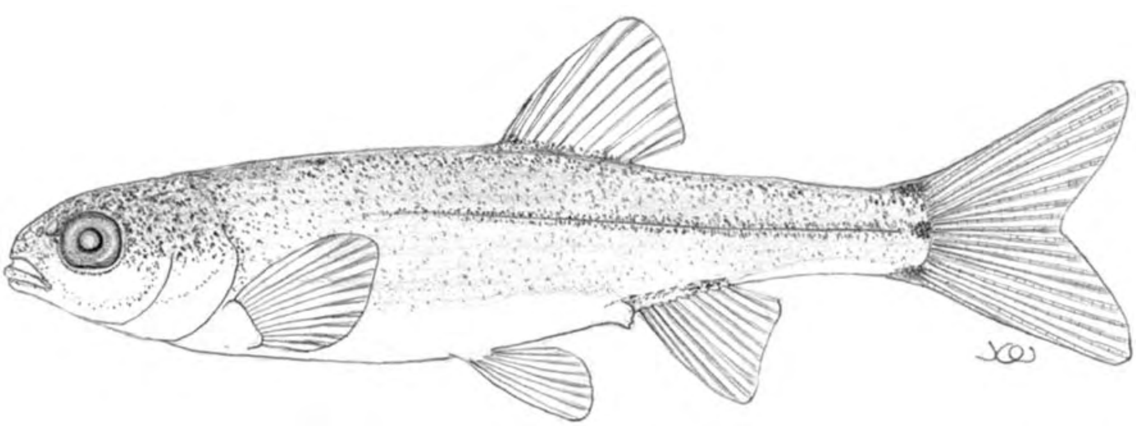


FIGURE 10-67.—Juvenile, 30.5 mm TL.

11. Catostomidae – Suckers

There are at least 11 species of catostomids inhabiting California freshwaters; the majority are native (Moyle 1976). In the study area of the Sacramento-San Joaquin River system, only the Sacramento sucker, *Catostomus occidentalis*, was collected.

References

Moyle 1976.

SACRAMENTO SUCKER, *Catostomus occidentalis* Ayres

SPAWNING

Location	Tributary streams (Moyle 1976), cool-water rivers or streams with sand, gravel, cobble bottom. General locations, tributaries of the Sacramento-San Joaquin River system. Specific locations: below Nimbus Dam and in the vicinity of Sailors Bar Park of the American River; lower reaches of Capell Creek of Lake Berryessa; at Glen Ellen on Sonoma Creek, upper Corte Madera Creek, San Pablo Creek, upper Alameda Creek, upper Walnut Creek, and San Ramon Creek. Spawning also occurs in the upper San Joaquin River at Millerton Lake, in a tributary of Union Valley Reservoirs, and the Rubicon River.
Season	February–June (Moyle 1976); judging by the small larvae taken in the San Joaquin River and Rubicon River in August and early September, this species will spawn until August in cool-water foothill streams or midelevation areas.
Temperature	Spawning runs in waters with temperatures ranging from 5.6–10.6˚C (Moyle 1976); actual spawn occurs ca. 12–17.5˚C.
Salinity	Freshwater.
Substrates	Gravel (Moyle 1976); sand, gravel, and cobbles.
Fecundity	4,700–11,000 for fish of 28–38 cm FL (Burns 1966b).

CHARACTERISTICS

EGGS (Figure 11-1)

Shape	Spherical or slightly irregular.

Diameter	Unfertilized eggs: 2.4–2.7 mm; fertilized eggs: 3.0–3.9 mm.
Yolk	Yellowish.
Chorion	Transparent, thick, and smooth.
Perivitelline space	Ca. 0.3–0.6 mm.
Egg mass	Deposited singly or in small clusters in the nest.
Adhesiveness	Adhesive (Moyle 1976).
Buoyancy	Demersal, sinking into interstices of the gravel (Moyle 1976).

LARVAE (Figures 11-2, 11-3, 11-4, 11-5, 11-6)

Length at hatching	Ca. 10.11.3 mm TL.
Snout to anus length	Ca. 70–78% of TL of both prolarvae and postlarvae.
Yolk sac	Very elongate, cylindrical, extending from thoracic to abdominal region. Yolk sac roughly divided into three sections.
Oil globule	None.
Gut	Straight.
Air bladder	Behind pectoral fin, shallow, elongate, developing into two chambers in postlarval stage.
Teeth	None.
Size at completion of yolk-sac stage	12.0–14.5 mm TL.
Total myomeres	45–49.
Preanal myomeres	35–40.
Postanal myomeres	8–12.
Last fin(s) to complete development	Pelvic.
Pigmentation	Newly hatched larvae have little pigmentation. Later, sparse melanophores are found on head, middorsum, and dorsal surface of gut and dotted melanophores on lateral line region. Very large melanophores are also found along thoracic and midventral regions, and a group of melanophores are at the base of the tail and on 2 caudal and dorsal fin membranes.
Distribution	Most of the planktonic yolk-sac larvae remain in the nesting area and then disperse into the water column; postlarvae prefer shallow inshore areas or pools, although some swim in the open waters of the Delta and Suisun Bay.

JUVENILES (Figure 11-7)

Dorsal fin	11–15 (Moyle 1976).
Anal fin	6–8 (Moyle 1976).
Pectoral fin	17–18 (this study).
Mouth	Subterminal to inferior, papillae on lips (Moyle 1976).
Vertebrae	46–50.
Distribution	The bulk of the juvenile population is in the cool-water nontidal tributaries of the estuary, but they may also be collected in shallows of tidal oligohaline and freshwaters. They are also observed in the foothill elevation of Millerton Lake and the mid-elevations of the Rubicon River and Union Valley Reservoirs.

LIFE HISTORY

The Sacramento sucker is a native California inland fish and is widely distributed throughout the Sacramento-San Joaquin River system. During this study, adults and large juveniles were found primarily in the open waters of the Delta and Suisun Bay, whereas larvae and smaller juveniles were more common in the cooler waters of the rivers and streams that drain into the estuary. No Sacramento sucker were observed in short coastal streams in the San Francisco Bay area such as Tennessee Valley and Purissima Creeks (this study).

Sacramento sucker are potamodromous, migrating from large bodies of freshwater to streams for spawning. Observations of large concentrations of larvae indicate that spawning occurs in the American River below Nimbus Dam and in the San Joaquin River below Kerckhoff Dam. Larvae were also abundant in smaller creeks such as upper Walnut Creek (or San Ramon Creek), Sonoma Creek, Corte Madera Creek, and Alameda Creek.

Based on the months in which eggs and larvae were collected, the spawning season for Sacramento sucker in the low elevation estuarine tributaries (such as Suisun Creek and Walnut Creek) appears to be from February to June; it may extend through August in mid-elevation and foothill streams. During spawning, each female, accompanied by several males, deposits eggs over a gravel substrate. The eggs settle into the gravel and adhere on the substrates, and the incubation period ranges from 3–4 weeks (Moyle 1976). In this study, sucker eggs were observed in Walnut, Sonoma, and Capell Creeks in loose form; apparently some are not adhesive throughout incubation.

Newly hatched larvae usually remain on the bottom within the interstices of the gravel until the yolk sac is absorbed. Very few were collected in plankton tows during this study. As postlarvae, however, Sacramento sucker emerge into the water column and will be found in moderate running water and side pools. Larvae have terminal mouths and feed primarily on early instars of aquatic insects (Moyle 1976).

According to Moyle (1976), Sacramento sucker juveniles are most common in tributary streams. In this study, juveniles were abundant in the sloughs of the Delta, irrigation and flood control ditches, and reservoirs at low to mid-elevations. Juveniles remain in the streams during the summer and fall and move to the deeper waters of pools or lakes in the winter. The mouth of juvenile Sacramento sucker is subterminal to inferior, and so they are able to browse on the bottom for detritus, algae, diatoms, and small organisms (Moyle 1976).

Sacramento sucker mature after 5–6 years. Large fish (60 cm TL) at least 10 years old were reported by Moyle (1976). They are edible but are not often sought after by fisherman.

References

Burns 1966b; Moyle 1976.

Figure 11.—Catostomidae: *Catostomus occidentalis*, Sacramento sucker.

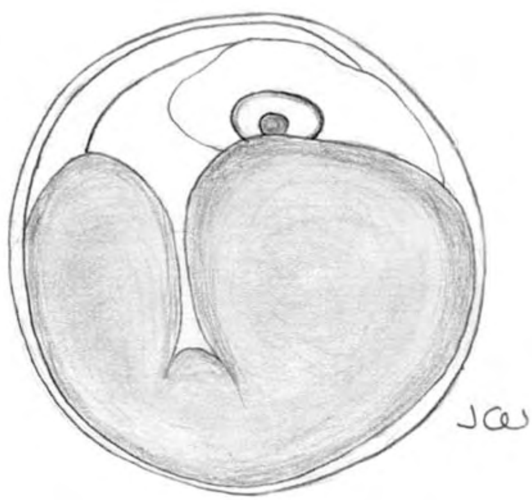


FIGURE 11-1.—Egg, late embryo, 3.8 mm diameter.

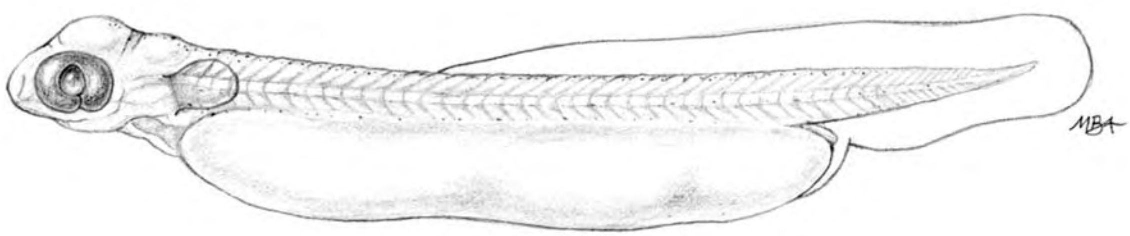


FIGURE 11-2.—Prolarva, 13 mm TL.

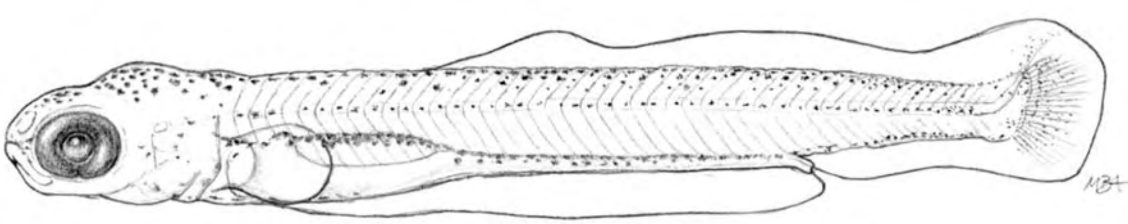


FIGURE 11-3.—Postlarva, 13 mm TL.

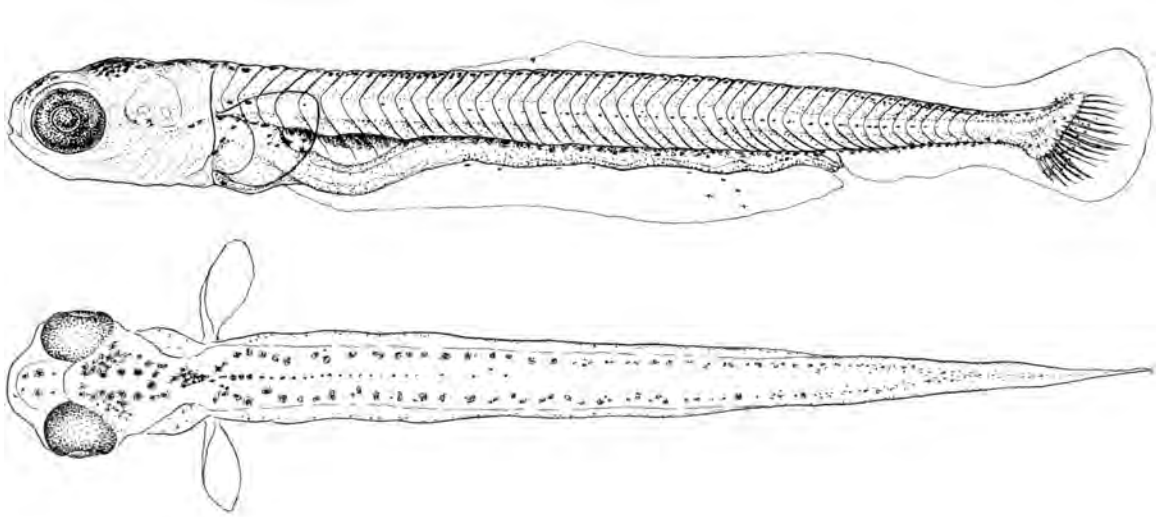


FIGURE 11-4, 11-5.—Postlarva, lateral and dorsal views, 14 mm TL.

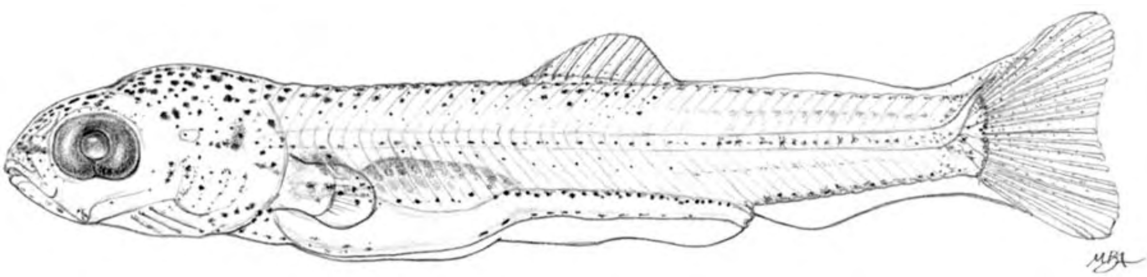


FIGURE 11-6—Postarva, 16 mm TL.

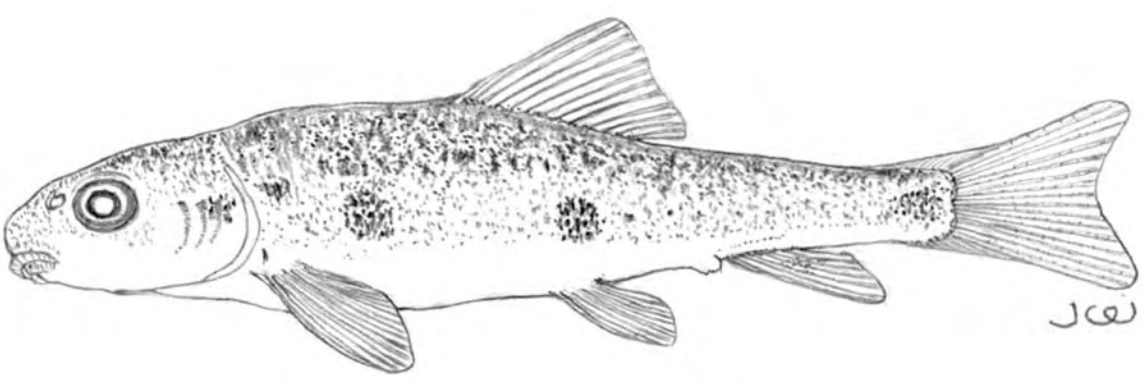


FIGURE 11-7.—Juvenile, 41 mm TL.

12. Ictaluridae – Catfishes

Moyle (1976) recorded five species of catfishes, all introduced, inhabiting the Sacramento-San Joaquin river system: white catfish, *Ictalurus catus*; black bullhead, *Ictalurus melas*; yellow bullhead, *Ictalurus natalis*; brown bullhead, *Ictalurus nebulosus*; and channel catfish, *Ictalurus punctatus.*

Taylor (1980) captured a single specimen of the blue catfish, *Ictalurus furcatus*, also an introduced ictalurid, from the San Joaquin River near Mossdale in 1978. The blue catfish and yellow bullhead are not discussed in this chapter.

References

Moyle 1976, Taylor 1980, Turner 1966a.

WHITE CATFISH, *Ictalurus catus* (Linnaeus)

SPAWNING

Location	Near banks (Jones *et al.* 1978); shallow waters throughout the Delta and reservoirs, such as Folsom and Millerton Lakes; and near shores and banks of Montezuma Slough, the vicinity of the Contra Costa and Pittsburg Powerplants, and Suisun Bay.
Season	Early July (Murphy 1951); June and July (Moyle 1976); June through August or early September.
Temperature	21˚C (La Rivers 1962, Miller 1966); ca. 20°C.
Salinity	Freshwater.
Substrates	Sand or gravel (Jones *et al.* 1978); hollowed tubes, large cans, crevices or cement or rocky jetties.
Fecundity	2,000–4,000 (Moyle 1976); 1,000 (La Rivers 1962); 3,550 (Menzel 1945).

CHARACTERISTICS

EGGS (Figure 12-1)

Shape	Spherical.
Diameter	Ca. 4.2 mm (Trautman 1957); 4.0–5.5 mm.
Yolk	Yellow-white (Fowler 1917); granular (Ryder 1887); pale yellow, granular.
Oil globule	None.

Chorion	Transparent to translucent, covered with gelatinous coat (Ryder 1887).
Perivitelline space	Fertilized eggs, initially ca. 10–20% of egg diameter.
Egg mass	Deposited in large clusters.
Adhesiveness	Very adhesive.
Buoyancy	Demersal.

LARVAE (Figures 12-2, 12-3)

Length at hatching	9.0–9.75 mm TL (Jones *et al.* 1978); 9.0–10.0 mm TL (Wang and Kernehan 1979).
Snout to anus length	Ca. 50–53% of TL of prolarvae at 9.0–9.5 mm TL; 46–48% of TL of postlarvae (early juveniles) at 14.0–15.5 mm TL.
Yolk sac	Large, spherical to oval, hard, extends from jugular to abdominal region.
Oil globule	None.
Gut	Straight and later twisted.
Air bladder	Spherical to oval, above the base of pectoral fins.
Teeth	None at this stage.
Size at completion of yolk-sac stage	Ca. 14–15 mm TL.
Total myomeres	38–44.
Preanal myomeres	16–20.
Postanal myomeres	19–25.
Last fin(s) to complete development	Pelvic.
Pigmentation	Newly hatched larvae have no pigmentation; light pigmentation later covers head, sides of body, and finfolds; little or no pigmentation on lower jaw, barbels, or ventral area of yolk sac.
Distribution	Prolarvae remain in the nest and guarded by parent. They then disperse into shallow waters with muddy bottoms, in both tidal and nontidal waters of upper Suisun Bay, the Delta, and reservoirs.

JUVENILES (Figure 12-4)

Dorsal fin	I, 5–6 (Moyle 1976); soft dorsal fin rays up to 7 (Frey 1951); the dorsal spine is actually fused from several segments of hardened fin ray in larval stage.

Anal fin	18–24 (Moyle 1976); 22–23 (Hildebrand and Schroeder 1928); 19–23 (Wang and Kernehan 1979).
Pectoral fin	I, 8–9 (Jones *et al.* 1978).
Adipose fin	Long, fleshy.
Mouth	Upper jaw protruding, mouth slightly inferior or subterminal (Jones *et al.* 1978; this study).
Vertebrae	40–41, plus Weberian ossicles, or 43–44 in total.
Distribution	Stagnant or slow current habitats in the Sacramento-San Joaquin river system, including the upper estuary and the oligohaline portion of San Pablo Bay; in shallow weedy areas of reservoirs, such as Millerton and Folsom Lakes.

LIFE HISTORY

White catfish are native to eastern coastal streams from New York to Texas (Hildebrand and Schroeder 1928). Trautman (1957) reported this species along the Atlantic cCoast north from Pennsylvania; Bailey *et al.* (1954) recorded them along the Gulf Coast to the Escambia drainage system. White catfish were introduced into the San Joaquin River near Stockton in 1874 (Shapovalov and Dill 1950, Skinner 1962). Currently, white catfish is the most abundant of the catfishes in the Delta, the estuary (Turner 1966a, Ganssle 1966), and some reservoirs.

Spawning takes place in June and July in the Delta (Miller 1966); judging from the small size of white catfish collected in the vicinity of the Contra Costa and Pittsburg Powerplants, spawning starts there in early June and lasts to the end of August or early September; in Millerton Lake, the peak of spawning is in June and July. The male catfish builds a nest on a sand or gravel substrate (Miller 1966). Nests are located near the shore and are sometimes associated with logs and other sheltering objects. During the breeding season, male fish exhibit a darker body coloration, particularly the head, lips, and barbels; the urogenital papilla is also swollen. After spawning, the male fish drives the female away while he guards and aerates the eggs on top of the nest. The male will protect the nest throughout the incubation (Gill 1906, this study). The eggs are very adhesive and hatch within 6 or 7 days at 24–29˚C (Prather and Swingle 1960). The spawning behavior of the white catfish is, in general, similar to that of the bullheads (Breder and Rosen 1966).

Newly hatched larvae have a yellowish, oversized yolk sac and will remain in the nest until the yolk is absorbed. The male fish continue guarding until the young swim freely.

The juveniles congregate in large schools near the shoreline or in sheltered coves where there is muddy bottom; large juveniles (ca. 40–60 mm TL) gradually become solitary and move into various niches close to the bottom. Large numbers of juvenile white catfish were captured in the Delta by otter trawl (Turner 1966a). In this study, juvenile white catfish were observed at the Clifton Court Forebay, throughout the Delta, Suisun Bay, San Pablo Bay, and the vicinity of the Oleum Powerplant, and were also collected from Millerton and Folsom Lakes. Juveniles in the estuary feed mostly on amphipods, mysid shrimp, chironomid larvae, and small fishes (Turner 1966a, Ganssle 1966).

White catfish in California reach maturity in 3–4 years (Moyle 1966). This species is one of the most common sport fish in the Delta and upper estuary, although they have a relatively slow growth rate (Turner 1966a, Moyle 1976). In California the number of catfish anglers ranks second only to those who are fishing for trout (Ryan 1959).

White catfish, in their native habitat, have been collected in salinities as high as 12 ppt (Kendall and Selwartz 1968) and 14.5 ppt (Schwartz 1964). They are common in brackish tidal creeks in Delaware (Smith 1971). Apparently the white catfish can tolerate a broad range of salinities. It has potential to be raised as a food fish in some brackish waters unsuitable for other sport fishes.

References

Bailey *et al.* 1954, Breder and Rosen 1966, Fowler 1917, Frey 1951, Ganssle 1966, Gill 1906, Hildebrand and Schroeder 1928, Jones *et al.* 1978, Kendall and Schwartz 1968, La Rivers 1962, Menzel 1945, Miller 1966, Moyle 1976, Murphy 1951, Prather and Swingle 1960, Ryan 1959, Ryder 1887, Schwartz 1964, Shapovalov and Dill 1950, Skinner 1962, Smith 1971, Trautman 1957, Turner 1966a, Wang and Kernehan 1979.

BLACK BULLHEAD, *Ictalurus melas* (Rafinesque)

SPAWNING

Location	Adults were common in the deadend sloughs of the Delta, such as Hog, Sycamore, and Indian Sloughs (Turner 1966a), and it was assumed that they spawned in those areas and in ponds, lakes, rivers with backwaters, and pools or streams with muddy bottoms (Moyle 1976).
Season	June and July (Moyle 1976); May and June in Missouri (Pflieger 1975); May through August in Kansas (Cross 1967); May and June in Canada (Scott and Crossman 1973).
Temperature	Exceeding 20˚C (Moyle 1976); 21˚C (Scott and Crossman 1973).
Salinity	Freshwater.
Substrates	Probably bare mud or clay bottom, since gravel and debris are pushed out of the nest (Scott and Crossman 1973, Moyle 1976); eggs are beneath matted vegetation or woody debris (Cross 1976); attached to aquatic vegetation (Baxter and Simon 1970).

Fecundity	2,000–6,000 or more depending upon age and size of females (Harlan and Speaker 1969); 1,000–7,000 (Dennison and Bulkley 1972); 3,000–4,000 (Scott and Crossman 1973).

CHARACTERISTICS

EGGS

Shape	Spherical.
Diameter	Ca. 3.0 mm (Scott and Crossman 1973).
Yolk	Yellow (Moyle 1976); pale cream (Scott and Crossman 1973); golden (Cross 1967); golden-yellow (Pflieger 1975).
Chorion	Translucent, covered with gelatinous coat (Scott and Crossman 1973).
Egg mass	Deposited in clusters (Moyle 1976, Pflieger 1975; Scott and Crossman 1973).
Adhesiveness	Eggs adhere to one another (Cross 1973); adhesive (Scott and Crossman 1973).
Buoyancy	Demersal.

LARVAE

Total myomeres	Ca. 35–36 (data derived from juvenile fish).
Preanal myomeres	14–15 (data derived from juvenile fish).
Postanal myomeres	21–22 (data derived from juvenile fish).
Distribution	It is assumed that they remain in the nesting area first and then disperse into the sloughs of the Delta.

JUVENILES

Dorsal fin	I, 5–6 (Scott and Crossman 1973).
Anal fin	17–24 (Moyle 1976); 17–21 (Cross 1967, Baxter and Simon 1970, Pflieger 1975); 15–19 (Scott and Crossman 1973); 17–20 (Harlan and Speaker 1969).
Pectoral fin	I, 8 (Scott and Crossman 1973); I, 7 (Baxter and Simon 1970).
Adipose fin	Long and fleshy (Scott and Crossman 1973).
Mouth	Terminal (Scott and Crossman 1973); upper jaw protrudes slightly (Moyle 1976).
Vertebrae	34 or 35, plus Weberian ossicles (Scott and Crossman 1973); 39 or 40 in total (Cross 1967).

Distribution	Lower reaches of the Sacramento-San Joaquin River and Delta (Turner 1966a); some are occasionally found in Suisun Bay (this study).

LIFE HISTORY

The black bullhead is a freshwater fish native to central and eastern North America; the western boundary includes most of the Mississippi drainage to the Gulf of Mexico and northern Mexico; on the east side, from the St. Lawrence River southward following the west slopes of Appalachians; north, covering Montana to Saskatchewan through the Great Lakes (Hubbs and Lagler 1958, Scott and Crossman 1973). Black bullhead were introduced into California in 1874 (Curtis 1949). Currently, they are found in the Delta sloughs (Turner 1966a) and at the Tracy Pumping Station (A. Pickard 1982, personal communication), and they are occasionally observed in Suisun Bay (this study).

Judging from the juveniles taken, the spawning likely occurs in June and July in the Delta (this study). Nests are excavated by female fish (Scott and Crossman 1973) or by both parents (Minckley 1973, Pflieger 1975) in shallow waters. Nests are also found beneath submerged logs (Pflieger 1975) or cavities (Minckley 1973). Eggs are usually concealed under some protective cover (Cross 1967). One parent guards and fans the eggs (Baxter and Simon 1970, Pflieger 1975), or both sexes are involved in protecting the egg mass (Minckley 1973, Scott and Crossman 1973). The eggs adhere more to one another than to the substrate. Details of the reproductive biology of the black bullhead have been studied by Breder and Rosen (1966) and Wallace (1967).

Newly hatched larvae probably remain in the nest and are guarded by the parent.

Free-swimming juveniles stay in a tight school; they move slowly near shore or near the surface in deeper water and appear as a "black ball" (Forney 1955, Cross 1967). At this stage, one or both parents accompany the schooling young for 2 or 3 weeks. The parents abandon the young when they reach ca. 25 mm TL. The young persist in schooling throughout their first summer (Forney 1955). Black bullhead are omnivorous, but juveniles feed mainly on small crustaceans (Forney 1955) and aquatic insects (Turner 1966a, Baxter and Simon 1970). Large juveniles devour other fish (Turner 1966a). Dawn and dusk are the times of active feeding (Darnell and Meierotto 1965).

Depending on the environmental conditions, black bullhead mature at 1–3 years of age (Cross 1967). The maximum lifespan is 10 years or more, but few of them live more than 5 years (Pflieger 1975). The black bullhead is of little importance in the sport fishery in the study area because of their scarcity (Turner 1966a, Moyle 1976), although they are considered a good food fish (Baxter and Simon 1970).

References

Baxter and Simon 1970; Breder and Rosen 1966; Cross 1967; Darnell and Meierotto 1965; Dennison and Bulkley 1972; Forney 1955; Harlan and Speaker 1969; Hubbs and Lagler 1958; Minckley 1973; Moyle 1976; Pflieger 1975; Scott and Crossman 1973; Turner 1966a; Wallace 1967.

BROWN BULLHEAD, *Ictalurus nebulosus* (Lesueur)

SPAWNING

Location	Mostly in the shallow vegetated areas in the sloughs of the Delta; shallow water of reservoirs, such as Millerton Lake, Folsom Lake; small ponds, such as Heather Farm Pond of Walnut Creek; stagnant weedy creeks, such as the Napa River (this study); weedy streams and lakes (Breder 1935).
Season	May and June (Moyle 1976); April and May in Iowa (Harlan and Speaker 1969); May through July in Delaware (Wang and Kernehan 1979); May and June in Canada (Scott and Crossman 1973); April through August (Breder 1935, Carlander 1969).
Temperature	21–25°C (Breder 1935); temperature reaching 21˚C (Scott and Crossman 1973).
Salinity	Freshwater.
Substrates	Natural substrates, such as sand, gravel, logs, rocks, vegetation (Webster 1942); artificial substrates, such as automobile tires (Scott and Crossman 1973); tin cans and cement blocks (Wang and Kernehan 1979).
Fecundity	2,000–13,800 (Carlander 1953); 2,000–10,000 or more (Harlan and Speaker 1969); 2,000–13,000 eggs in ovaries (Scott and Crossman 1973).

CHARACTERISTICS

EGGS

Shape	Spherical
Diameter	Unfertilized eggs, 3.0–3.4 mm (this study); fertilized eggs, ca. 3.0 mm (Breder 1935).
Yolk	Pale cream (Breder 1935, Scott and Crossman 1973); yellowish white, granular (this study).
Oil globule	None.
Chorion	Nearly transparent (Breder 1935); transparent (Armstrong 1962); eggs covered with gelatinous mucus (Scott and Crossman 1973).
Perivitelline space	Fairly wide, ca. 30% of egg diameter (Armstrong 1962).
Egg mass	Deposited in clusters (Forbes and Richardson 1920).
Adhesiveness	Adhesive (Breder 1935).

Buoyancy	Demersal.

LARVAE (Figures 12-5, 12-6)

Length at hatching	Ca. 8.0 mm TL (Eycleshymer 1901); ca. 6.0 mm TL (Scott and Crossman 1973).
Snout to anus length	Ca. 47–49% of TL of prolarvae at 7.8–9.0 mm TL.
Yolk sac	Large, spherical to oval, extends from jugular to abdominal regions.
Oil globule	None.
Gut	Straight, bends ventrically in anal region in prolarval stage.
Air bladder	Oval, above base of pectoral.
Teeth	No teeth at this stage.
Size at completion of yolk-sac stage	Ca. 10–12 mm TL.
Total myomeres	39–42.
Preanal myomeres	14–16.
Postanal myomeres	25–26.
Last fin(s) to complete development	Pelvic.
Pigmentation	Newly hatched larvae have no pigments and are cream white (Breder 1935); darker and dense pigmentation covers head, finfolds, and barbells 1–2 days after hatching (Smith and Harron 1904, Scott and Crossman 1973, this study).
Distribution	Mostly remain in the nesting area for 5 days (Emig 1966) to 7 days (Scott and Crossman 1973); stay as a tight mass at the bottom (Adams and Harkinson 1928).

JUVENILES (Figure 12-7)

Dorsal fin	I, 6 (Fowler 1917); I, 6–7 (Scott and Crossman 1973).
Anal fin	21–24 (Moyle 1976, Pflieger 1975); 18–21 (Scott and Crossman 1973).
Pectoral fin	I, 7–9, usually 8 (Scott and Crossman 1973).
Adipose fin	Long, fleshy (Scott and Crossman 1973).
Mouth	Terminal, upper jaw slightly protruding (Scott and Crossman 1973).

Vertebrae	34–39, plus Weberian ossicles (Scott and Crossman 1973); 14 + 26 (Fish 1932).
Distribution	In the backwater and deadend sloughs of the Delta (Turner 1966a); stagnant creeks such as Napa River; protective coves of reservoirs, such as Millerton Lake.

LIFE HISTORY

The brown bullhead is native to the freshwaters of the eastern United States and Canada, being found in the east from the Maritime Provinces to Florida; in the west from Saskatchewan to central Alabama (Armstrong 1962, Scott and Crossman 1973). This species is also common in brackish tidal creeks along the Atlantic Coast (Fowler 1917, Smith 1971). Brown bullhead were introduced into California in 1874 (Curtis 1949). Turner (1966a) found this species to be sparse in the Delta; it is also uncommon in the Tracy Pumping Station collections (A. Pickard 1982, personal communication). However, the species is reported to be common in most warm waters in this state (Moyle 1976). In this study, brown bullhead were observed in Three Mile Slough near Brannan Island State Recreation Area, Montezuma Slough, Napa River, Millerton Lake, Folsom Lake, and Heather Farm Pond of Walnut Creek. Its distribution is patchy.

The brown bullhead spawns in May and June (Moyle 1976), extending into July in foothill streams and reservoirs (this study). Nests are excavated by either the female (Wallace 1969) or both parents (Scott and Crossman 1973). They prefer the shallow weedy areas of streams and lakes as spawning sites (Wright and Alan 1913); most spawning probably occurs in nontidal freshwater (Wang and Kernehan 1979). The female expels about 30–50 eggs at a time, which are fertilized by the male (Breder and Rosen 1966). Eggs stick to one another and are covered by a gelatinous coating. Eggs are guarded and aerated by one or both parents. Smith and Harron (1904) have reported that adult brown bullhead took the egg mass into their mouth and then ejected them. Eggs hatch in 5 days at 25˚C (Smith 1903), in 6–9 days at 20.6–23.3˚C (Raney 1967), or 5–8 days at unspecified field temperatures (Harlan and Speaker 1969).

Newly hatched larvae have a very large yolk sac and remain in the nest for about a week (Emig 1966, Scott and Crossman 1973). The yolk sac is absorbed by the end of the first week after hatching. The larvae swim in dense schools in pitch-black “balls” like those of black bullhead juveniles. These were observed in the Napa River near a sewage treatment plant and in shallow protected coves of Millerton Lake. The guarding school breaks down when the young are ca. 50 mm TL (Scott and Crossman 1973). Large juveniles were occasionally collected from Lindsey Slough, Suisun Bay, and Montezuma Slough. Juveniles consume amphipods, mysid shrimps, and dragonfly nymphs in the Delta (Turner 1966a). They also take chironomid larvae (Moyle 1976, Harlan and Speaker 1969).

Moyle (1976) states that brown bullhead in California mature at 3 years of age. The brown bullhead is an excellent food fish, but most populations are unexploited because of their nocturnal feeding and inactivity during daytime (Emig 1966, Moyle 1976).

References

Adams and Harkinson 1928; Armstrong 1962; Breder 1935; Breder and Rosen 1966; Carlander 1953, 1969; Curtis 1949; Emig 1966; Eycleshymer 1901; Fish 1932; Forbes and Richardson 1920; Fowler 1917; Harlan and Speaker 1969; Moyle 1976; Pflieger 1975; Raney 1967; Scott and Crossman 1973; Smith 1971; Smith and Harron 1904; Turner 1966a; Wallace 1969; Wang and Kernehan 1979; Webster 1942; Wright and Alan 1913.

CHANNEL CATFISH, *Ictalurus punctatus* (Rafinesque)

SPAWNING

Location	Near lake shores (Fish 1932); in undercut banks (Harlan and Speaker 1969); dark places in lake and stream (Baxter and Simon 1970); throughout the Sacramento-San Joaquin River system in areas with suitable nesting sites, such as the holes and cavities of rocky jetties, in the vicinity of the Contra Costa and Pittsburg Powerplants, and undercut bank and peat moss substrates in the sloughs of the Delta.
Season	April through June (Moyle 1976); May through late July or early August (this study); June in Lake Erie (Fish 1932); May or June in Oklahoma (Miller and Robison 1973); May through July in Missouri (Marzolf 1957); May through July in Kansas (Cross 1967); April through June in Arizona (Minckley 1973). This species may spawn more than once per year (Dill 1946, Carlander 1969, Miller 1966).
Temperature	21–29 °C, with optimal temperature 27–28˚C (Clemens and Sneed 1957); 27˚C optimum (Cross 1967).
Salinity	Freshwater; 2 ppt or less (Perry 1973).
Substrates	In cave-like areas such as undercut banks, under rock ledges, in weedy areas, log jams, muskrat burrows (Cross 1967, Harlan and Speaker 1969, Scott and Crossman 1973, Moyle 1976); artificial substrates, such as ceramic drain tile (Canfield 1947).
Fecundity	1,000 (Jearld and Brown 1971); 70,000 (Carlander 1953); 1,600 (Dill 1946).

CHARACTERISTICS

EGGS (Figures 12-8,12-9)

Shape	Spherical.
Diameter	3.53 mm (Shira 1917); 3.5–4.0 mm (Scott and Crossman 1973); 3.3–4.0 mm (this study).
Yolk	Yellow when laid (Davis 1959, Miller 1966, Scott and Crossman 1973); becoming browner just before hatching (Brown 1942); yellowish, granular.
Oil globule	None.
Chorion	Transparent to translucent, thick, covered with gelatinous mucus (Saksena *et al.* 1961, this study).
Perivitelline space	Fairly wide in newly fertilized eggs.
Egg mass	Deposited in large clusters (Doze 1925, Plosila 1961).
Adhesiveness	Adhesive.
Buoyancy	Demersal.

LARVAE (Figures 12-10, 12-11)

Length at hatching	Ca. 6.4 mm (McClellan 1954); 10.3–11.8 mm TL of one-day-old specimens (this study).
Snout to anus length	Ca. 47–52% of TL of larvae at 10.6–11.8 mm TL; ca. 45–48% at 13.3–15.0 mm TL.
Yolk sac	Oval, large, extends from anterior thoracic to abdominal regions; yolk sac is pointed at posterior end.
Oil globule	None.
Gut	Initially straight, later twisted.
Air bladder	Oval, above the base of pectoral.
Teeth	None at larval stage.
Size at completion of yolk-sac stage	Ca. 14–15 mm TL.
Total myomeres	44–46.
Preanal myomeres	16–21.
Postanal myomeres	25–28.
Last fin(s) to complete development	Pelvic.
Pigmentation	Newly hatched larvae have no pigments; 1–2 days later melanophores appear on head, then on head,

	body, and adipose fin; no pigmentation found in yolk-sac region.
Distribution	Newly hatched larvae remain in nesting area, then disperse into shallow water. They are found throughout the Sacramento-San Joaquin River system, particularly in the sloughs of the Delta and commercial catfish farming ponds of the study area.

JUVENILES (Figures 12-12, 12-13)

Dorsal fin	I, 5–6 (Moyle 1976); I, 6 (Jordan and Everman 1902, Scott and Crossman 1973).
Anal fin	24–29 (Moyle 1976, Minckley 1973); 23–26 (Scott and Crossman 1973).
Pectoral fin	I, 8–9 (Scott and Crossman 1973); soft pectoral rays up to 10 (Stevens 1959).
Adipose	Small.
Mouth	Inferior, lower jaw shorter than upper jaw (Scott and Crossman 1973).
Vertebrae	42–44, plus Weberian ossicles (Scott and Crossman 1973).
Distribution	Throughout the Sacramento-San Joaquin River system and upper oligohaline portion of the estuary (this study).

LIFE HISTORY

Channel catfish are freshwater fish, native to the central and eastern United States and southern Canada. They are found to the west from the Mississippi River system to northeastern Mexico; to the east from the St. Lawrence River along the western slope of the Appalachian Mountains to central Florida (Scott and Crossman 1973). They have been widely introduced elsewhere in the United States. Moyle (1976) reported that channel catfish were introduced into the Sacramento-San Joaquin River system in 1874, but not firmly established until the early 1940. During a fishery survey in the Sacramento-San Joaquin Estuary conducted in 1963–1964 by the CDFG, channel catfish were found to be the second most abundant ictalurid (after the white catfish) (Turner 1966a). Channel catfish were also the second most abundant of all catfishes collected at the Tracy Pumping Station (A. Pickard 1982, personal communication). In this study, channel catfish were found to be common in trawl and fyke net catches in the vicinity of the Contra Costa and Pittsburg Powerplants, in Montezuma Slough, and in the Delta.

Moyle (1976) reported that channel catfish spawn from April through June in California. Judging form the small juveniles taken in this study, spawning occurs from May through August in the Delta, and may begin as early as April in the vicinity of the Contra Costa and Pittsburg Powerplant thermal plumes. Nests are constructed by one or both parents among the crevices and holes in the rocky jetties in the areas near the powerplants, in the Delta, and in its tributaries. They may use undercut banks, holes of peat moss, hollowed containers, submerged logs and other secluded or dark places as their spawning sites (this study). Eggs are very adhesive, and are deposited in a large, flat gelatinous mass (Doze 1925). During the reproductive season, the male assumes a darker body coloration, with thick lips (Minckley 1973). After spawning takes place, the male drives the female away from the nest. The male guards the eggs from predators and aerates the eggs to prevent oxygen depletion (Cross 1967). Eggs hatch in 7–10 days at 24–26˚C (Clemens and Sneed 1957), or 6 days at 24˚C (Harlan and Speaker 1969). The spawning behavior of the channel catfish is said to be much like that of the brown bullhead (Clemens and Sneed 1957) and the white catfish (this study). During incubation, the male channel catfish may eat some of the eggs (Brown 1942), a fact not reported for other catfishes. Newly hatched larvae stay at or near the nest for several days (Cross 1967). The male guards the young until they disperse (Minckley 1973).

Scott and Crossman (1973) reported that small juvenile channel catfish swim near the surface. In this study, small juveniles (ca. 20–60 mm TL) were found at all levels of the water column, since many of them were captured by the ichthyoplankton nets at various depths in Suisun Bay and the Delta. In streams, juveniles inhabit shallow riffles and turbulent areas near sandbars (Davis 1959). The school of young stays together for several days or even less than 100 mm TL, feed on aquatic invertebrates (Minckley 1973); specimens less than 20 cm FL feed mainly on crustaceans and the larvae of insects (Turner 1966a; large juveniles take aquatic insects, crayfish, and fishes (Turner 1966a, Miller 1966).

Channel catfish mature at 2–8 years (Carlander 1969) or 2–5 years (Baxter and Simon 1970). The channel catfish is an excellent food fish. Under controlled conditions, such as an impoundment, nonreproducing populations grow much faster than the naturally reproducing population, and can be stocked at a higher density. Therefore, the channel catfish has been used heavily for aquaculture in the United States.

Channel catfish prefer habitats such as large rivers but can adapt to small turbid farm ponds (Baxter and Simon 1970). They can tolerate salinities up to 10 ppt along the Gulf of Mexico (Christmas and Waller 1973). They may have some potential to be raised as food fish in the Central and Imperial Valleys where the water is saltier (Moyle 1976).

References

Baxter and Simon 1970; Brown 1942; Canfield 1947; Carlander 1953, 1969; Christmas and Waller 1973; Clemens and Sneed 1957; Cross 1967; Davis 1959; Dill 1946; doze 1925; Fish 1932; Harlan and Speaker 1969; Jearld and Brown 1971; Jordan and Everman 1902; McClellan 1954; Marzolf 1957; Miller 1966; Miller and Robison 1973; Minckley 1973; Moyle 1976; Perry 1973; Plosila 1961; Saksena *et al.* 1961; Scott and Crossman 1973; Shira 1917; Stevens 1959; Turner 1966a.

Characteristic Comparison: Catfishes

Characteristic	White Catfish	Black Bullhead	Brown Bullhead	Channel Catfish
Larvae				
Total myomeres	38–44	35–36	39–42	44–46
Preanal myomeres	16–20	14–15	14–16	16–21
Postanal myomeres	19–25	21–22	25–26	25–28
Pigmentation	No pigmentation on newly hatched larvae; light pigment later covers head, side of body, finfolds; little or no pigment on ventral side of yolk sac or lower jaw barbels		No pigmentation on newly hatched larvae; dark and dense melanophores cover head, body, finfolds, and barbels 1–2 days after hatching	No pigmentation on newly hatched larvae; sparse melanophores later cover head, body, fins, and upper jaw barbels; little pigmentation or none on lower jaw barbells
Juveniles				
Dorsal fin	I, 5–7	I, 5–6	I, 6–7	I, 5–6
Anal fin	18–24	15–19	18–24	23–29
Pectoral fin	I, 8–9	I, 8	I, 7–9	I, 8–10
Caudal fin	Moderately forked; symmetrical	Rounded, with pale vertical bar at base of fin; symmetrical	Truncated or slightly forked; dorsal lobe smaller than ventral	Deeply forked; symmetrical
Narial barbel	Short	Elongate	Elongate	Undeveloped or very short

Figure 12.—Ictaluridae: *Ictalurus catus*, white catfish.

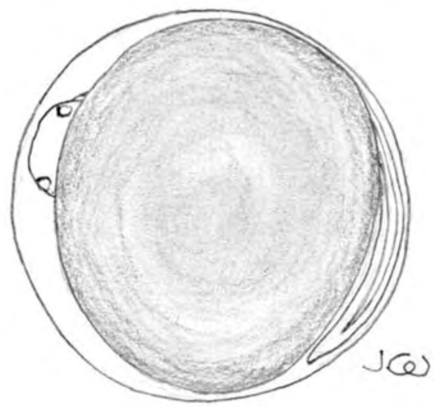


FIGURE 12-1.—Egg, late embryo, 4.5 mm diameter.

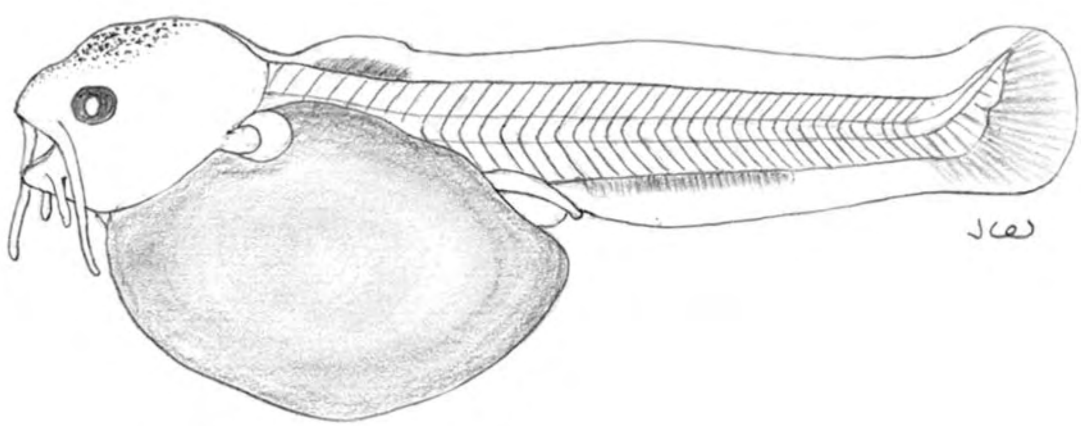


FIGURE 12-2.—Prolarva, 10.2 mm TL.

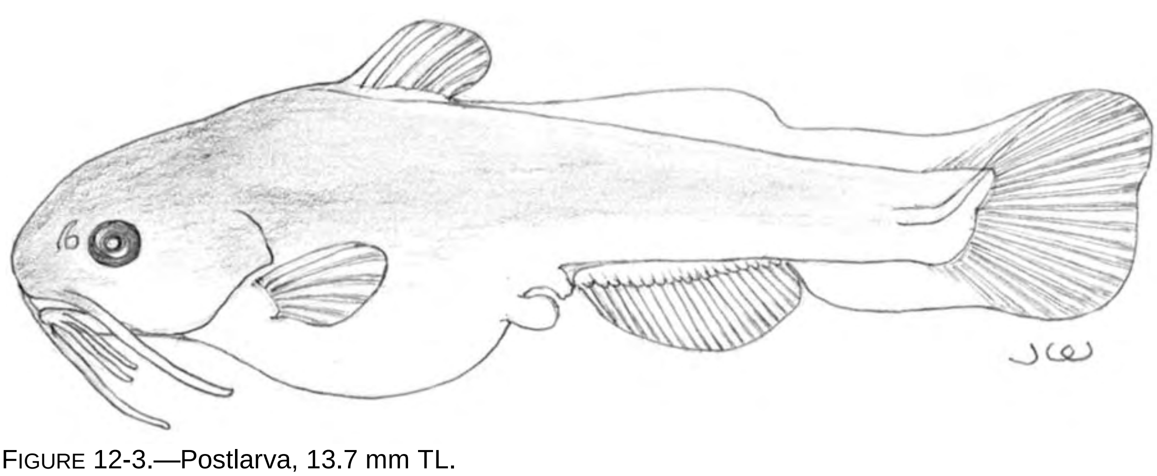


FIGURE 12-3.—Postlarva, 13.7 mm TL.

Ictaluridae: Catfishes.

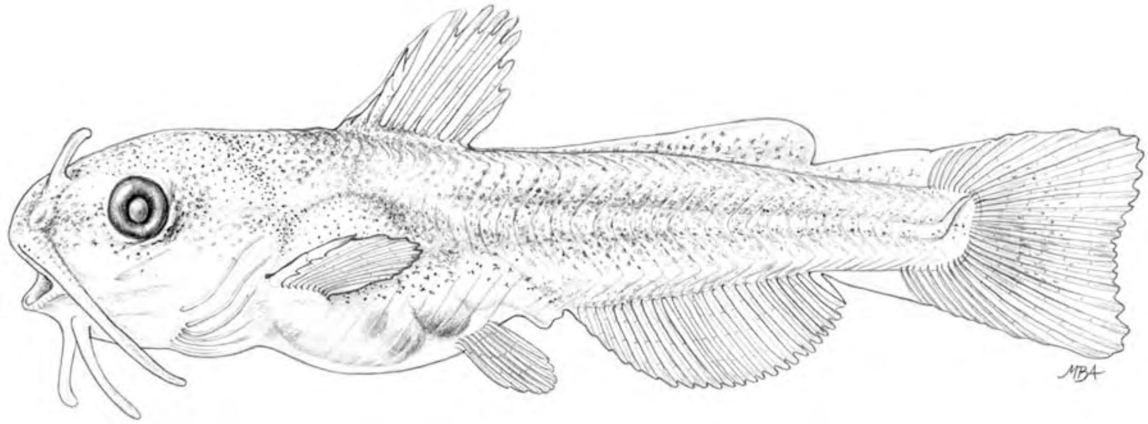


FIGURE 12-4.—White catfish, *Ictalurus catus* juvenile, 16.6 mm TL.

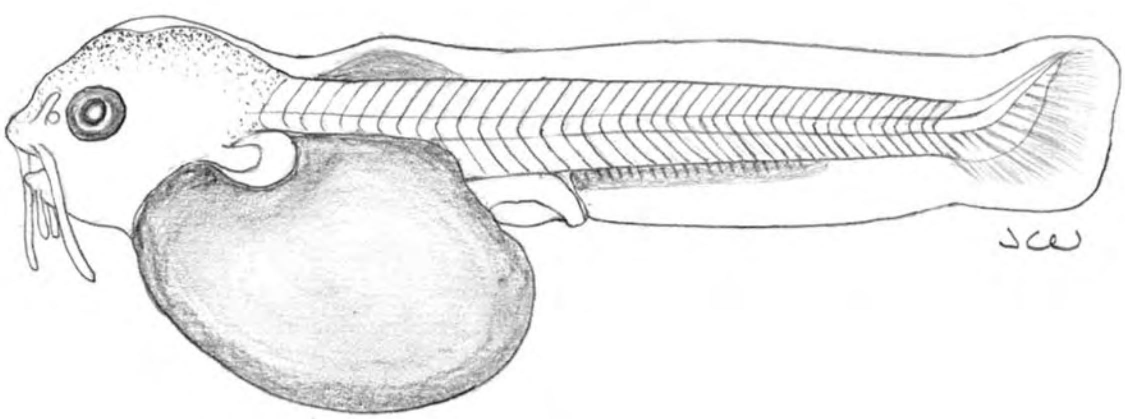


FIGURE 12-5.—Brown bullhead, *Ictalurus nebulosus* prolarva, 8.5 mm TL.

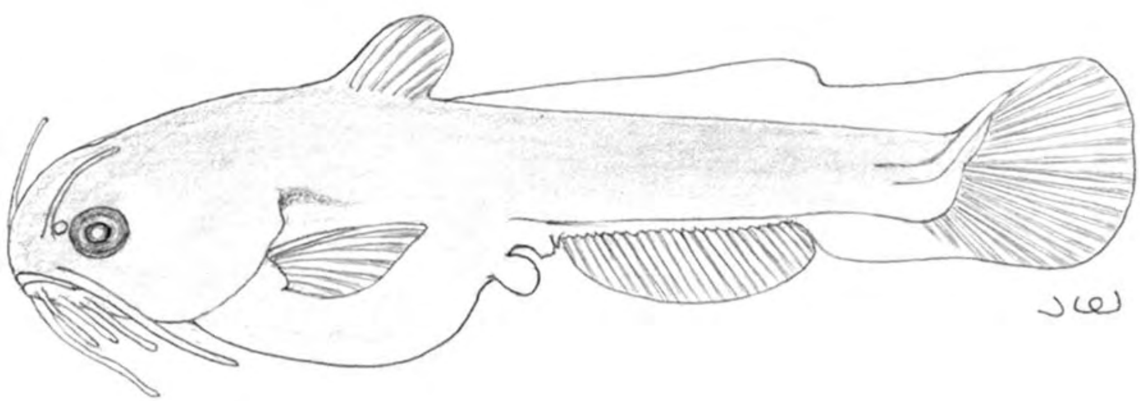


FIGURE 12-6.—Brown bullhead, *Ictalurus nebulosus* postlarva, 12.2 mm TL.

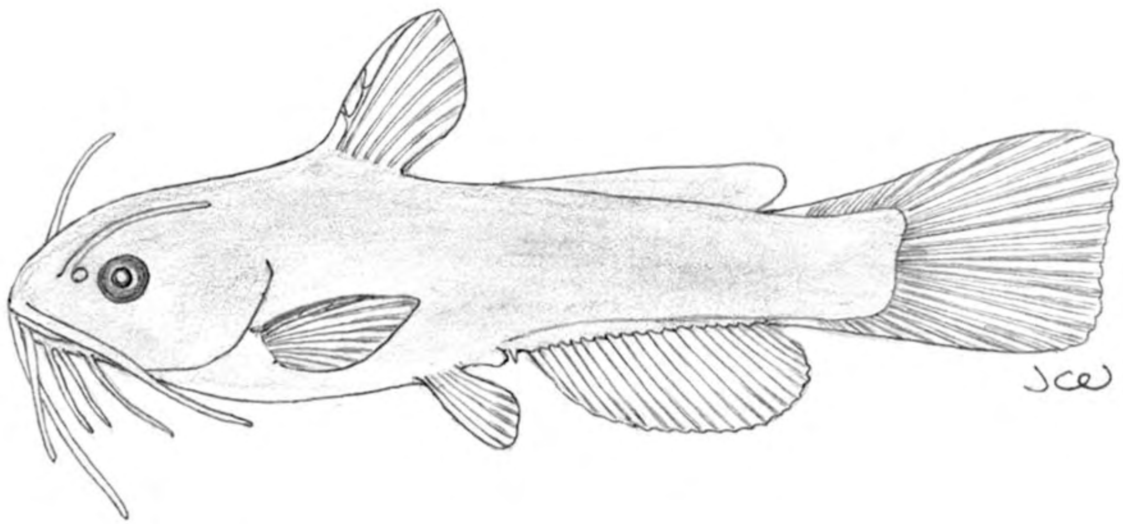


FIGURE 12-7.—Brown bullhead, *Ictalurus nebulosus* juvenile, 20.8 mm TL.

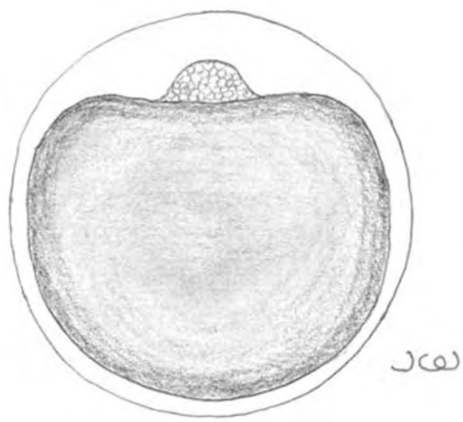


FIGURE 12-8.—Channel catfish, *Ictalurus punctatus* egg, morula, 3.8 mm diameter.

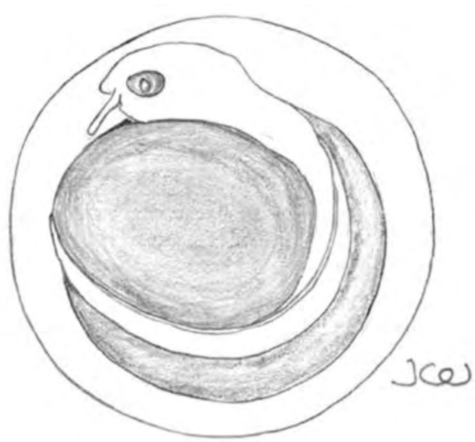


FIGURE 12-9.—Channel catfish, *Ictalurus punctatus* egg, late embryo, 4.3 mm diameter.

Ictaluridae: *Ictalurus punctatus*, channel catfish.

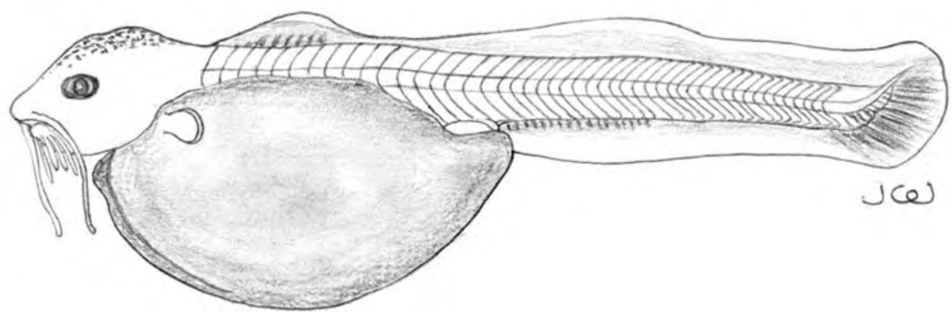


FIGURE 12-10.—Prolarva, 11.4 mm TL.

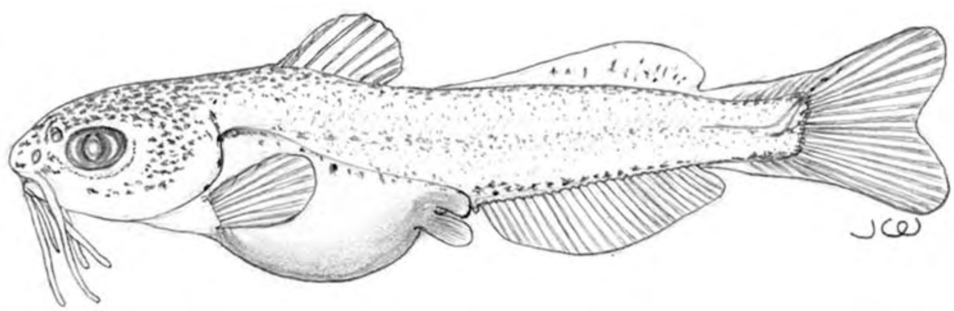


FIGURE 12-11.—Prolarva, 15.5 mm TL.

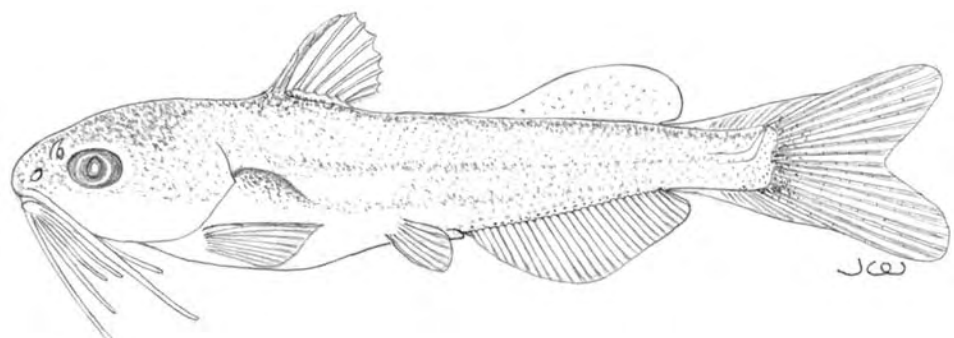


FIGURE 12-12.—Juvenile, 17 mm TL.

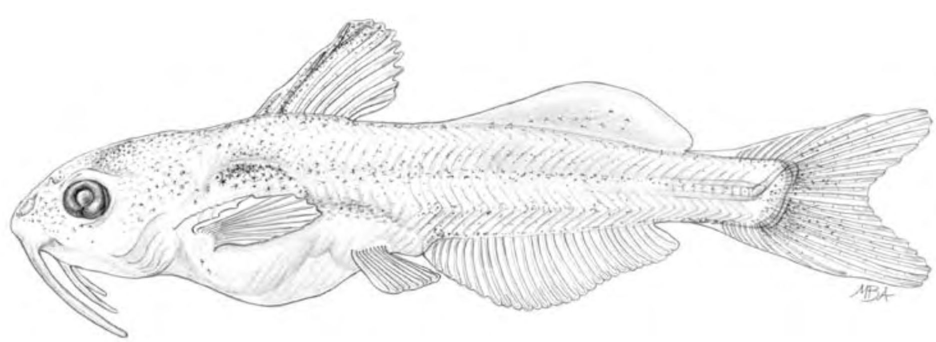


FIGURE 12-13.—Juvenile, 19.5 mm TL.

13. Batrachoididae –Toadfishes

The specklefin midshipman *Porichthys myriaster*, and the plainfin midshipman *Porichthys notatus*, are the two batrachoidids known to California coastal waters (Hubbs and Schultz 1939, Arora 1948). Only the plainfin midshipman was observed in this study.

References

Arora 1948, Hubbs and Schultz 1939.

PLAINFIN MIDSHIPMAN, *Porichthys notatus* Girard

SPAWNING

Location	Shallow water within tidal limits (Hubbs 1920); tidewater of rocky shores (Greene 1924); shallow intertidal coastal waters (Hart 1973); may spawn within San Francisco Bay and in Moss Landing Harbor-Elkhorn Slough.
Season	Late spring and early summer (Hubbs 1920). June–July (Greene 1924); late spring through early summer, with a peak in June (Arora 1948); in summer (Crane 1965); summer (Hart 1973); April through August.
Temperature	18.4˚C when eggs were collected.
Salinity	Seawater, although they may occur in polyhaline.
Substrates	Rocks, boulders (Hubbs 1920); under surface of rocks (Greene 1924).
Fecundity	20–800 (Arora 1948); ca. 200 (Fitch and Lavenberg 1971); 154 eggs from a single female at 181 mm TL.

CHARACTERISTICS

EGGS

Shape	Spherical to subspherical (Hubbs 1920, Hart 1973).
Diameter	4.0–6.0 mm (Hubbs 1920); unfertilized mature eggs, 4.5–7.5 mm.
Yolk	Yellow to bright yellow to pinkish, firm and hard (Arora 1948, Bane and Bane 1971, Fitch and Lavenberg 1971).
Oil globule	None.
Chorion	Transparent to opaque, firm (Arora 1948).

Perivitelline space	Very narrow.
Egg mass	Deposited singly and in single layer (Arora 1948).
Adhesiveness	Adhesive (Hubbs 1920, Arora 1948).
Buoyancy	Demersal.

LARVAE (Figures 13-1, 13-2)

Length at hatching	Ca. 7.0–8.0 mm TL (Arora 1948).
Snout to anus length	Ca. 42–44% of TL of prolarvae at 17.5–19.0 mm TL.
Yolk sac	Bright yellow, very large; shape of yolk sac changes from spherical to ellipsoid to spherical to oval.
Oil globule	None.
Gut	Short and thick.
Air bladder	Behind pectorals, paired and modified into a vocal organ (Greene 1924).
Teeth	Sharp, pointed, apparent in late yolk-sac larval stage (this study).
Total myomeres	41–45.
Preanal myomeres	7–11.
Postanal myomeres	29–35.
Last fin(s) to complete development	Pelvic.
Pigmentation	8–9 dark vertical blotches extend equally from head to end of dorsum; melanophores encircle all photophores.
Distribution	Attached to the substrates in intertidal coastal waters (Hubbs 1920, Arora 1948). Detached larvae were observed in San Francisco Bay and Moss Landing Harbor-Elkhorn Slough.

JUVENILES

Dorsal fin	II, 33–38 (Miller and Lea 1972); II, 33–37 (Hart 1973).
Anal fin	28–24 (Miller and Lea 1972); 39–37 (Hart 1973).
Pectoral fin	18 (Hart 1973).
Mouth	Terminal, large, directed upward (Hart 1973).
Vertebrae	41–44 (Clothier 1950).
Distribution	Epibenthic, mostly in the bays and some up to the oligohaline portion of the estuary.

LIFE HISTORY

The plainfin midshipman is distributed from Gorda Bank, Gulf of California, to Sitka, Alaska (Hubbs and Schultz 1939, Arora 1948, Miller and Lea 1972, Hart 1973). In the Sacramento-San Joaquin Estuary the plainfin midshipman was reported in San Francisco Bay, San Pablo Bay, and up to Suisun Bay (Ganssle 1966, Messersmith 1966, Aplin 1967). In waters near the study area, this species was recorded in Tomales Bay (Bane and Bane 1971); Bodega Bay (Standing *et al.* 1975); and in Moss Landing Harbor-Elkhorn Slough (Kukowski 1972b, Nybakken, *et al.* 1977). In this study, the plainfin midshipman was collected mostly from powerplant intake screen sampling and from bottom trawls from mostly powerplant intake screen sampling and from bottom trawls from San Francisco Bay to Suisun Bay and in Moss Landing Harbor-Elkhorn Slough.

In the study area, spawning of the plainfin midshipman extends from April through August. During courtship, both sexes display bioluminescence from their photophores (Crane 1965). Eggs, ca. 4–6 mm in diameter, are attached rocks, old shells, or sand pits in the intertidal zone (Arora 1948, Hart 1973). Male fish guard the nest to prevent predation during incubation until the larvae completely detach from the substrate (Hubbs 1920, Arora 1948). A nest was found under a concrete block during ebb tide at Keller Beach, San Francisco Bay, on April 26, 1982. Eggs were attached to the underside of this concrete block. A male fish was guarding and aerating the eggs. Several other males were also found buried in the sand adjacent to the nesting area, which had about 15 cm depth of water, apparently waiting for the tide to come in (K. Hieb 1982, personal communication). During larval development, the yolk sac is initially spherical and large, then becomes ellipsoid, and returns to spherical as the larva grows larger (Arora 1948). The spawning behavior and larval development process of the plainfin midshipman require habitat similar to that of the oyster toadfish, *Opsanus tau*, which is found along the Atlantic Coast of the United States (Gudger 1908, Dovel 1960).

When the larvae become free swimming and turn into fully developed juveniles, they almost immediately settle on the bottom or bury in the substrates and can be found in shallow as well as deeper waters (Hubbs 1920, Arora 1948). A vertical migration, coming up to feed at night, was also reported in this species (Arora 1948, Fitch and Lavenberg 1971). Juvenile plainfin midshipman were often observed in the freshwater or oligohaline ranges of the Sacramento-San Joaquin Estuary, indicating euryhaline characteristics for their early life (this study). The small shrimp-like crustaceans are major components of the diet of the juvenile plainfin midshipman (Bane and Bane 1971, this study).

Age at maturity is not found in the literature, but mature fish of 165–181 mm TL were often captured in the intake areas of the Potrero, Hunters Point, and Moss Landing Powerplants in spring and summer months (this study). Both sexes are believed to die after spawning (Fitch and Lavenberg 1971). The plainfin midshipman is of no commercial or sport value (Bane and Bane 1971).

References

Aplin 1967; Arora 1948; Bane and Bane 1971; Clothier 1950; Crane 1965; Dovel 1960; Fitch and Lavenberg 1971; Ganssle 1966; Greene 1924; Gudger 1908; Hart 1973; Hubbs 1920; Hubbs and Schultz 1939; Kukowski 1972b; Messersmith 1966; Miller and Lea 1972; Nybakken *et al.* 1977; Standing *et al.* 1975.

Figure 13.—Batrachoididae: *Porichthys notalus*, plainfin midshipman.

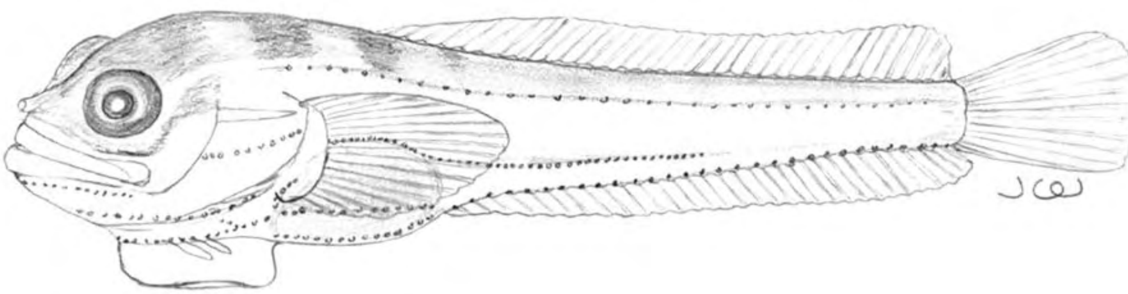


FIGURE 13-1.—Prolarva, 19 mm TL.

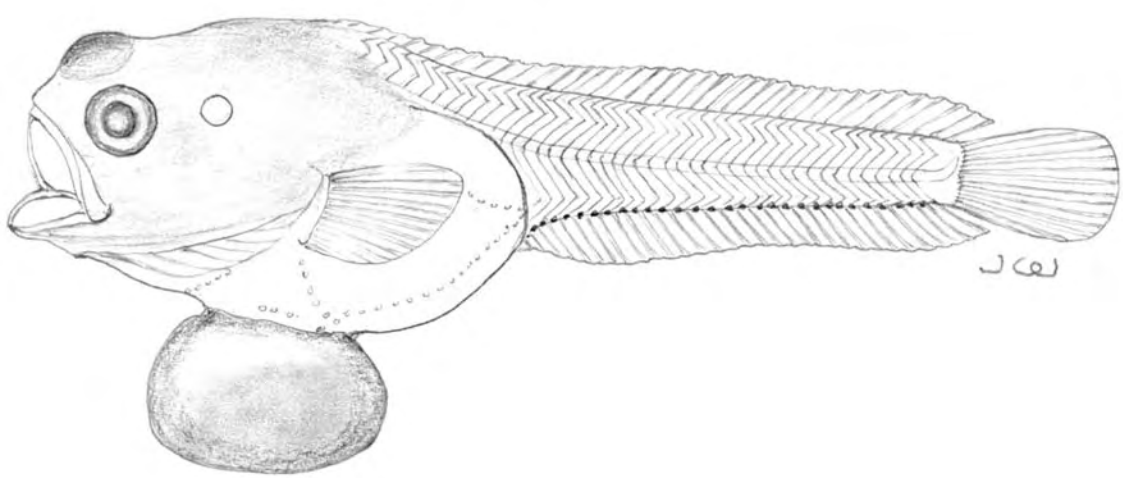


FIGURE 13-2.—Postlarva, 21.7 mm TL.

14. Gobiesocidae – Clingfishes

There are seven species of clingfishes known to the Pacific coast of California (Briggs 1955, Miller and Lea 1972). Only one species, the northern clingfish, *Gobiesox maeandricus*, was collected in this study.

References

Briggs 1955, Miller and Lea 1972.

NORTHERN CLINGFISH, *Gobiesox maeandricus* (Girard)

SPAWNING

Location	Underside of boulders in sounds and inlets (Marliave 1975).
Season	November–May in British Columbia (Marliave 1975); February–April.
Temperature	Ca. 14 C.
Salinity	Seawater.
Substrates	Rocks (Marliave 1975).
Fecundity	200–500 per batch (Marliave 1975).

CHARACTERISTICS

EGGS

Shape	Hemispherical, or flat at the point of attachment (Marliave 1975).
Diameter	2 mm (Marliave 1975).
Yolk	Bright yellow, becoming golden brown towards hatching (Marliave 1975).
Oil globule	Single (Marliave 1975).
Egg mass	One layer of concentric rings (Marliave 1975).
Adhesiveness	Adhesive (Marliave 1975).
Buoyancy	Demersal.

LARVAE (Figure 14-1)

Length at hatching	6.0 mm TL (Marliave 1975).
Snout to anus length	Ca. 47–53% of TL of larvae at 6.0–8.6 mm TL.
Yolk sac	Bilobed, in thoracic region (Marliave 1975).

Gut	Straight, thick, with two constrictions.
Air bladder	Shallow, oval, near pectorals.
Teeth	Small, pointed teeth, apparent in postlarvae.
Size at completion of yolk-sac stage	Ca. 8.0 mm TL (Marliave 1975).
Total myomeres	31–33 (Allen 1979); 32–34.
Preanal myomeres	14–16
Postanal myomeres	17–19
Last fin(s) to complete development	Pelvic (pelvic disc).
Pigmentation	A series of large melanophores (ca. 8–10) along esophagus and dorsal surface of gut; dotted melanophores (ca. 9) along postanal and hypleural regions.
Distribution	School in shallow subtidal areas, especially around kelp beds (Marliave 1975), found in San Francisco Bay, Moss Landing Harbor-Elkhorn Slough.

JUVENILES (Figure 14-2)

Dorsal fin	14–16 (Briggs 1955, Miller and Lea 1972); 13–16 (Hart 1973).
Anal fin	13–15 (Briggs 1955, Miller and Lea 1972); 12–14 (Hart 1973).
Pectoral fin	21–23 (Briggs 1955, Miller and Lea 1972); ca. 21 (Hart 1973).
Mouth	Terminal, large (Hart 1973); terminal to subterminal, large (this study).
Vertebrae	32–34 (Miller and Lea 1972).
Distribution	Intertidal pools, cling on rocks (Hart 1973).

LIFE HISTORY

The northern clingfish ranges from the area between Guadalupe Island and main land Baja California to Mud Bay, Revillagigedo Island, Alaska (Miller and Lea 1972). This species was recorded as being in San Francisco Bay by Ruth (1969) and in Tomales Bay by Bane and Bane (1971). Northern clingfish were collected in San Francisco Bay, San Pablo Bay, Suisun Bay, and Moss Landing Harbor-Elkhorn Slough in this study.

In British Columbia, spawning of the northern clingfish occurs from November through May (Marliave 1975). In the San Francisco Bay area the spawning season is apparently from February to April, based on the time when larvae were collected. Eggs and larvae of this species have been described by Marliave (1975). Eggs are deposited on the underside of rocky substrates, and the males remain to tend the egg masses. Larvae have very specific pigmentation on the sides of their bodies and are similar in appearance to the California clingfish, *Gobiesox rhessodon*, and the kelp clingfish, *Rimicola muscarum*, found along the West Coast (Allen 1979) and to the skilletfish, *Gobiesox strumosus* found along the Atlantic Coast (Runyan 1961, Dovel 1963). Larvae swim in large schools around kelp beds (Marliave 1975). Larvae have been found in the Sacramento-San Joaquin Estuary as far inland as Suisun Bay. It is assumed that northern clingfish larvae are pelagic because they were captured in plankton nets.

The pelvic fin of the northern clingfish becomes modified into an adhesive disc when it reaches ca. 18 mm TL (Marliave 1975). Juveniles and adults prefer to cling to rocky substrates; they were occasionally found in the bays. An analysis of juvenile stomach contents showed that they feed on limpets, chitons, and other small molluscs and crustacea (Bane and Bane 1971).

The age at maturity is unclear in the literature. This species has no sport or commercial value.

References

Allan 1979, Bane and Bane 1971, Briggs 1955, Dovel 1963, Hart 1973, Marliave 1975, Miller and Lea 1972, Runyan 1961, Ruth 1969.

Figure 14.—Gobiesocidae: *Gobiesox maeandricus*, northern clingfish.

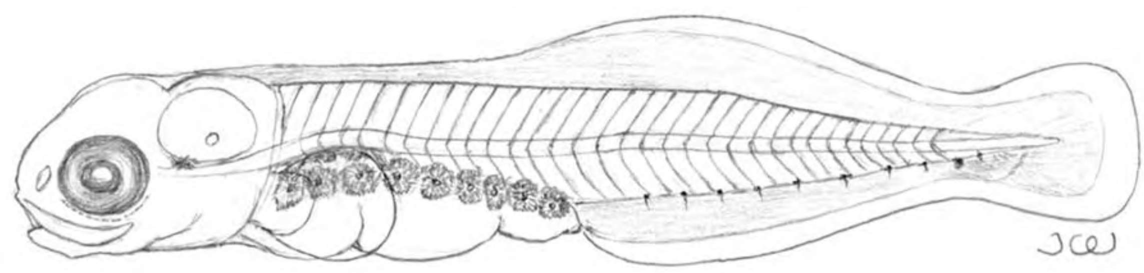


FIGURE 14-1.—Postlarva 8.4 mm TL.

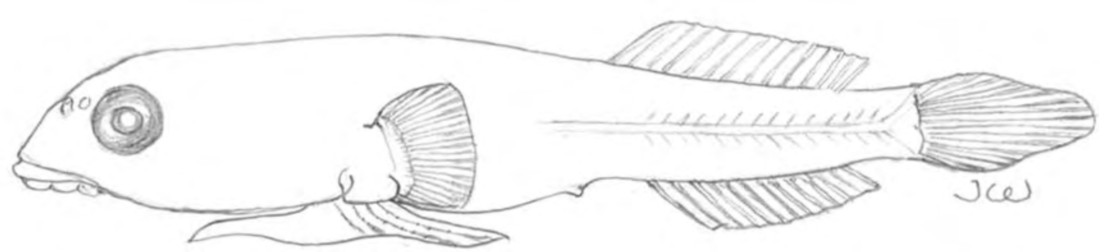


FIGURE 14-2.—Juvenile, 27 mm TL.

15. Gadidae – Codfishes

Six species of codfish are known to the Pacific Coast of the United States and Canada (Robins *et al.* 1980). Of these species, two have been reported in the study area; the Pacific hake, *Merluccius productus* (Ruth 1969, Kukowski 1972b, Green 1975) and the Pacific tomcod, *Microgadus prosimus* (Ganssle 1966, Aplin 1967, Bane and Bane 1971, Standing *et al*. 1975, Nybakken *et al.* 1977). Only the Pacific tomcod is discussed in this chapter.

References

Aplin 1967, Bane and Bane 1971, Ganssle 1966, Green 1975, Kukowski 1972b, Nybakken *et al* 1977, Robins *et al* 1980, Ruth 1969, Standing *et al* 1975.

PACIFIC TOMCOD, *Microgadus prosimus* (Girard)

SPAWNING

Location	Coastal waters off Washington (Waldron 1972); coastal waters off Oregon (Pearcy and Meyer 1974, Misitano 1977, Richardson and Pearcy 1977, Matarese *et al.* 1981); coastal waters off San Francisco Bay.
Season	Winter and spring in Oregon (Matarese *et al.* 1981); January through June off San Francisco Bay.
Temperature	Larvae taken at a temperature range of 10.4–11.2°C.
Salinity	Sea water.
Fecundity	Estimated 1,200 ova in a mature fish at 262 mm TL (Bane and Bane 1971).

CHARACTERISTICS

LARVAE (Figure 15-1)

Length at hatching	Less than 2.7 mm SL (Matarese *et al.* 1981).
Snout to anus length	Ca. 41–48% of SL of preflexion and postflexion larvae (Matarese *et al.* 1981); ca. 39–41% of TL of postlarvae at 3.5–4.0 mm TL (this study).
Yolk sac	Small in thoracic area (Matarese *et al.* 1981); oval, moderate, in thoracic area (this study).
Gut	Straight in early preflexion and coiled at ca.5.7 mm SL; gut bends ventrally at anal region and anus opens

	on lateral side of finfold (Matarese *et al.* 1981); coiled or twisted at ca. 3.5 mm TL.
Air bladder	Spherical, behind and above base of pectoral fin.
Teeth	Small, pointed, becoming evident at 11.9–12.2 mm SL (Matarese *et al.* 1981).
Size at completion of yolk-sac stage	Ca. 3.0 mm SL (Matarese *et al.* 1981).
Total myomeres	52–57 (this study).
Preanal myomeres	18–20 (this study).
Postanal myomeres	34–38 (this study).
Last fin to complete development	Pectoral (Matarese *et al.* 1981).
Pigmentation	Stellate melanophores on snout and cephalic region, lower jaw, midventral and dorsal surfaces of gut region; there is a series of melanophores on mid-dorsum behind anus which form 2 bars or stripes, and each is matched up with ventral bars or stripes along the postanal region (Matarese *et al.* 1981).
Distribution	Pelagic, along Pacific coast of Oregon (Pearcy and Meyer 1974); mostly within 18 km from shore of Oregon (Richardson and Pearcy 1977); pelagic in San Francisco Bay (this study).

JUVENILES (Figure 15-2)

Dorsal fin	11–15 + 16–21 + 18–22 (Miller and Lea 1972); 11–14 + 17–20 + 18–20 (Hart 1973); 9–15 + 16–21 + 17–24 (Matarese *et al.* 1981).
Anal fin	20–29 + 18–24 (Miller and Lea 1972); 20–25 + 18–21 (Hart 1973); 22–28 + 20–28 (Matarese *et al.* 1981).
Pectoral fin	Ca. 19 (Hart 1973); 18–20 (Matarese *et al.* 1981).
Mouth	Terminal, moderate (Hart 1973); terminal large, oblique (this study).
Vertebrae	53–60 (Miller and Lea 1972); 54–58 (Matarese *et al.* 1981).
Distribution	Mostly in coastal waters of northern Pacific (Pearcy and Meyer 1974, Matarese *et al.* 1981); some entering estuaries (Ganssle 1966, Misitano 1977, this study).

LIFE HISTORY

The range of the Pacific tomcod extends from Point Sal (Miller and Lea 1972) or central California (Isaacson 1965) to Unalaska Island, Alaska (Wilimovsky 1964). In the study area, Pacific tomcod were reported from San Francisco Bay (Aplin 1967) to San Pablo Bay and Suisun Bay (Ganssle 1966). They were also recorded in Tomales Bay (Bane and Bane 1971), Bodega Bay (Standing *et al.* 1975), and Moss Landing Harbor-Elkhorn Slough (Nybakken *et al.* 1977).

Judging from the larvae taken, the Pacific tomcod is a winter and spring spawner; however, the eggs of this species are still unknown (Matarese *et al.* 1981). Larvae occurred pelagically along the Oregon coast (Pearcy and Meyer 1974) and Washington coast (Waldron 1972), and the bulk of larvae were taken within 18 km of the shoreline (Richardson and Pearcy 1977). Some larvae were occasionally found within estuaries (Misitano 1977), including San Francisco Bay (this study).

Juveniles were found to be common in San Francisco Bay (Aplin 1967), San Pablo Bay, and Suisun Bay (Ganssle 1966). They were also observed in Tomales Bay at depths of 3–7 m (Bane and Bane 1971). The majority of the juvenile tomcod population inhabits the bottom of coastal waters off San Francisco Bay (this study). Analysis of juvenile tomcod stomachs included sand shrimps (Ganssle 1966), polychaete worms, algae, small crustaceans, and fish (Bane and Bane 1971).

Age of maturity of this species is not well documented. Bane and Bane (1971) captured mature female fish at 262 mm TL.

Pacific tomcod is not a commercial species, because of its small size (mostly less than 30 cm SL) (Matarese *et al.* 1981), but it is often taken by sport fishermen (Beardsley and Bond 1970, Hart 1973), and the flesh is of good eating quality (Bane and Bane 1971).

References

Aplin 1967, Bane and Bane 1971, Beardsley and Bond 1970, Ganssle 1966, Hart 1973, Isaacson 1965, Matarese *et al.* 1981, Miller and Lea 1972, Misitano 1977, Nybakken *et al.* 1977, Pearcy and Meyers 1974, Richardson and Pearcy 1977, Standing *et al.* 1975, Waldron 1972; Wilimovsky 1964.

Figure 15.—Gadidae: *Microgadus proximus*, Pacific tomcod.

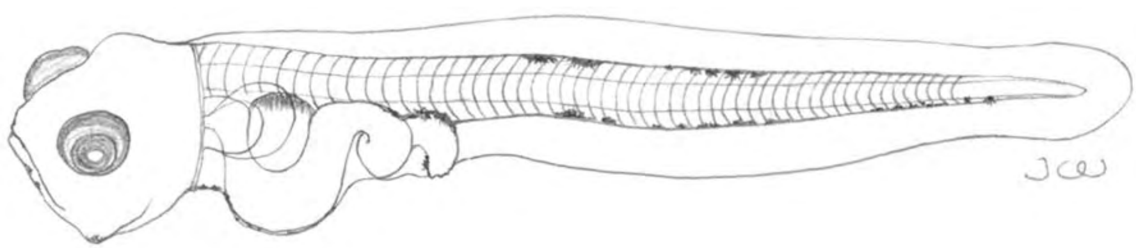


FIGURE 15-1.—Postlarva 3.7 mm TL.

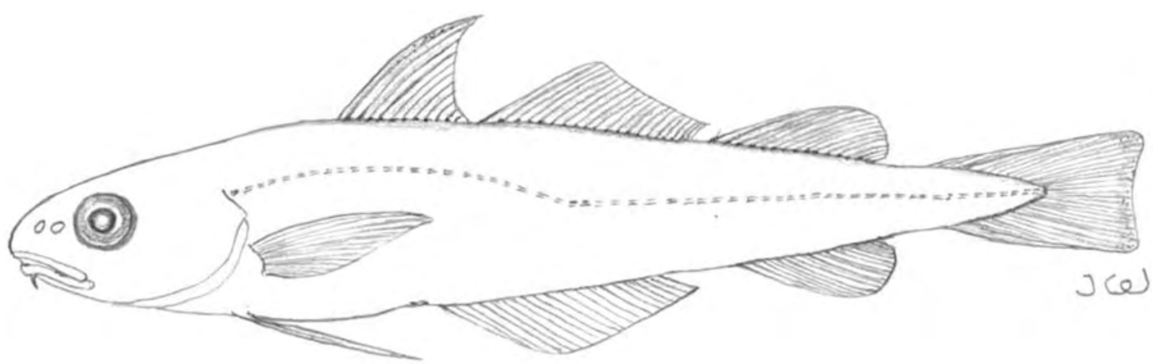


FIGURE 15-2.—Juvenile, 108 mm TL.

16. Ophidiidae – Cusk-Eels

Fifteen species of cusk-eels have been recorded along the Atlantic and Pacific coasts of the United States and Canada (Robins *et al.* 1980). Most of the species inhabit the Atlantic side, and Miller and Lea (1972) have reported only two species along the Pacific Coast: the spotted cusk-eel, *Chilara taylori*, and the basketweave cusk-eel, *Ophidium scrippsae*. Many *Otophidium* spp. are oviparous forms, producing pelagic eggs (Breder and Rosen 1966). Details of their reproductive biology are unknown. In this study, only spotted cusk-eel were observed.

References

Breder and Rosen 1966, Miller and Lea 1972, Robins *et al.* 1980.

SPOTTED CUSK-EEL, *Chilara taylori* (Girard)

SPAWNING

Season	Estimated to be in fall and winter (judging by the smallest specimens taken in this study).
Salinity	Sea water.

CHARACTERISTICS

LARVAE (Figure 16-1)

Snout to anus length	Ca. 39–42% of TL of larvae at 3.7–4.3 mm TL.
Gut	Straight.
Total myomeres	Ca. 82–87 or more.
Preanal myomeres	Ca. 19–25.
Postanal myomeres	Ca. 63 or more.
Pigmentation	A double row of large melanophores extends from dorsal to gut through tip of caudal fin; scattered melanophores in dorsal tail region.
Distribution	Inshore waters and embayments, such as Moss Landing Harbor and Horseshoe Cove, San Francisco Bay (this study).

JUVENILES (Figure 16-2)

Dorsal fin	198–216 (Miller and Lea 1972).
Anal fin	156–170 (Miller and Lea 1972).

Pectoral fin	25–26.
Mouth	Terminal.
Vertebrae	86–91 (Miller and Lea 1972).
Distribution	On or near bottom in offshore waters (Fitch and Lavenberg 1968). Occasionally taken at Moss Landing Harbor-Elkhorn Slough.

LIFE HISTORY

The spotted cusk-eel ranges from San Cristobal Bay, Baja California, to northern Oregon (Fitch and Lavenberg 1968). In the study area, this species was reported in Bodega Bay (Standing *et al.* 1975) and Moss Landing Harbor-Elkhorn Slough (Nybakken *et al.* 1977). Juveniles and adults were captured at the Potrero and Hunters Point Powerplants on San Francisco Bay. Larval, juvenile, and adult specimens were also observed in Horseshoe Cove, San Francisco Bay and in Moss Landing Harbor-Elkhorn Slough (this study).

There is little knowledge of the spawning habitats of this species. Judging by the time when small larvae (3.7–4.3 mm TL) were collected in this study, spawning occurred in fall and winter months, and the location of spawning could be mostly in the deeper water outside San Francisco Bay or in Monterey Submarine Canyon near Moss Landing Harbor.

Larvae are pelagic. They were found in the bays and estuaries (this study).

Small juveniles (50–76 mm TL) are also pelagic or bathpelagic in offshore waters (Fitch and Lavenberg 1968). Several juvenile cusk-eels (83–86 mm TL) were taken at the intake screens of the Moss Landing Powerplant, in Moss Landing Harbor, and at Horseshoe Cove, San Francisco Bay, during winter months (this study). Results of stomach analysis revealed that juvenile and adult spotted cuck-eel feed mainly on crustaceans (Fitch and Lavenberg 1968, this study).

Age of maturity of the spotted cusk-eel is poorly known. They are reported to be favorite foods of rockfish, California sea lion, and cormorant (Fitch and Lavenberg 1968).

Adults tend to be nocturnal. When disturbed, the cusk-eel buries its body, tail first, in the sand (Fitch and Lavenberg 1968). This behavior is very similar to that of striped cusk-eel, *Rissola marginata*, along the Atlantic coast (Hildebrand and Schroeder 1928, Wang and Kernehan 1979).

References

Fitch and Lavenberg 1968, Hildebrand and Schroeder 1928, Miller and Lea 1972, Nybakken *et al.* 1977, Standing *et al.* 1975, Wang and Kernehan 1979.

Specimen Verification

Specimens measuring 3.7 and 4.3 mm TL were confirmed by Elaine Sandnop, National Marine Fisheries Service, La Jolla, California.

Figure 16.—Ophidiidae: *Chilara taylori*, spotted cusk-eel.

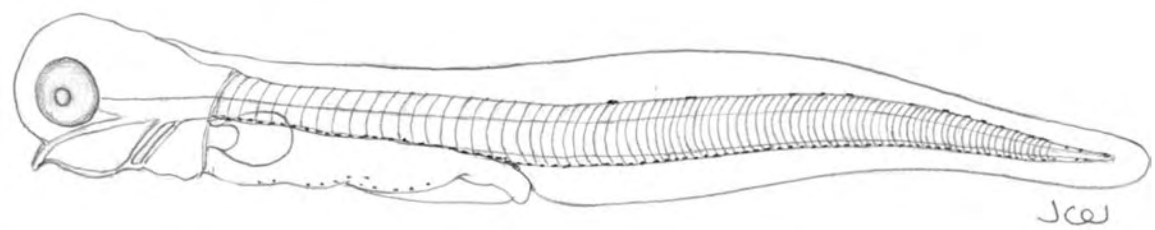


FIGURE 16-1.—Postlarva 4.6 mm TL.

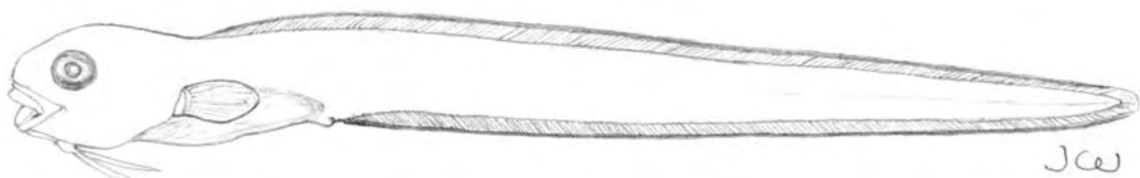


FIGURE 16-2.—Juvenile, 86 mm TL.

17. Bythitidae – Viviparous Brotulas

Members of the family Bythitidae are viviparous fishes. Taxonomically, the red brotula, *Brosmophycis marginata*, the only species known to the study area, was formerly classified in the family Ophidiidae (Bailey *et al.* 1970). Recently this species was placed in the family Bythitidae (Robins *et al.* 1980).

References

Bailey *et al.* 1970, Robins *et al.* 1980.

RED BROTULA, *Brosmophycis marginata* (Ayres)

SPAWNING

Location	Probably offshore.
Season	May (Hart 1973); estimated spring and summer.
Salinity	Seawater.
Fecundity	12,000–30,000 in specimens at 235–260 mm TL (Hart 1973).

CHARACTERISTICS

EGGS (ovoviviparous)

Diameter	Mature ovarian eggs, ca. 1.2 mm (Hart 1973).
Egg mass	Embedded in the ovaries of female fish.

LARVAE (Figure 17-1)

Length at birth (extrusion)	7.0 mm TL (Hart 1973).
Snout to anus length	Ca. 42–50% of TL of larvae at 6.5 mm TL.
Gut	Wavy or twisted, thick.
Air bladder	Small, oval, midway between pectorals and anus.
Total myomeres	63–65.
Preanal myomeres	19–20.
Postanal myomeres	43–45.
Pigmentation	Ca. 7–9 pairs of dark blotches on middorsum, midventrum, and postanal regions. Melanophores are also found at tip of lower jaw and on finfolds near caudal region.

Distribution	Pelagic. Offshore of Oregon coast (Richardson and Pearcy 1977). Locally, in Richardson Bay (Eldridge 1977); near Golden Gate Bridge and Angel Island.

JUVENILES

Dorsal fin	92–102 (Clemens and Wilby 1961); 99–110 (Follett 1970); 92–107 (Miller and Lea 1972).
Anal fin	73–81 (Follett 1970); 72–81 (Miller and Lea 1972); 70–74 (Hart 1973).
Pectoral fin	Ca. 20 (Hart 1973).
Mouth	Terminal, large, upper jaw extending behind eye, directed forward (Hart 1973).
Vertebrae	63–65 (Best 1957, Miller and Lea 1972).
Distribution	From shallows of San Francisco Bay (this study) to 183 miles off Oregon coast (Grinols 1965).

LIFE HISTORY

The red brotula has been reported from Ensenada Bay, Baja California (Fitch and Lavenberg 1968) to Petersburg, Alaska (Wilimovsky 1964). Larvae were observed by Richardson and Pearcy (1977) offshore of Yaquina Bay, Oregon. Locally, the larval stages of this species were reported in Richardson Bay (Eldridge 1977) and were found in the area between the Golden Gate Bridge and Angel Island in San Francisco Bay.

The red brotula is an ovoviviparous fish (Hart 1973). Larvae were collected from June through August (Eldridge 1977, this study). The period during which larvae are extruded is estimated to be spring (Hart 1973) and/or summer (this study). The larvae are pelagic and range from offshore (Richardson and Pearcy 1977) to estuaries (Eldridge 1977, this study). Early life history information of this species is very sketchy. Adults are reported to be common at depths of 20–26 m (Miller and Lea 1972) and have been reported at depths up to 183 m (Grinols 1965).

References

Best 1957, Clemens and Wilby 1961, Eldridge 1977, Fitch and Lavenberg 1968, Follett 1970, Grinols 1965, Hart 1973, Miller and Lea 1972,Richardson and Pearcy 1977, Wilimovsky 1954.

Specimen Credits

1. A specimen measuring 6.5 mm TL was loaned by Maxwell Eldridge, National Marine Fisheries Service, Tiburon, California.

2. Specimens measuring 7.7–10.1 mm TL were loaned by the CDFG, Stockton, California.

Figure 17.—Bythitidae: *Brosmophycis marginata*, red brotula.

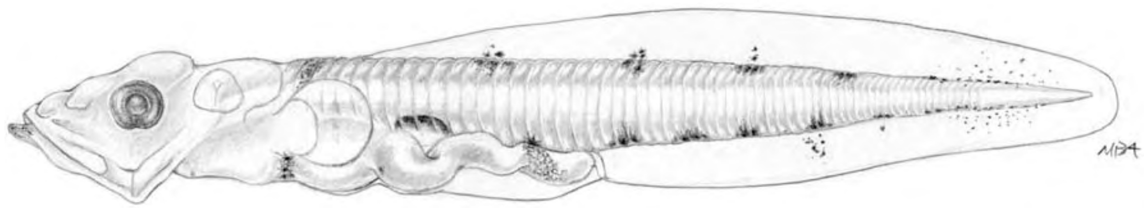


FIGURE 17-1.—Postlarva 6.5 mm TL.

18. Scomberesocidae – Sauries

The only species of Scomberesocidae found on the Pacific coast, the Pacific saury, *Cololabis saira*, was collected in the study area.

PACIFIC SAURY, *Cololabis saira* (Brevoort)

SPAWNING

Location	California Current (Frey 1971).
Season	All year, peaks occur in February through July (Frey 1971); most of the year (Hughes 1974).
Temperature	18°C (Hart 1973).
Salinity	Seawater.
Fecundity	990–1,800 for each spawn for a saury off Japan (Frey 1971).

CHARACTERISTICS

EGGS

Shape	Ovoid (Frey 1971).
Diameter	0.6–1.9 mm (Hatanaka 1956); ca. 2.0 mm (Hart 1973); mature eggs 1.8–2.0 mm (Hughes 1974).
Adhesiveness	Adhesive (Frey 1971), with ca. 20 filaments at 1 pole and a single thick filament about 90 degrees to the pole. Anchor on seaweeds and rocks (Aplin 1939, Okada 1955).

LARVAE (Figure 18-1)

Gut	Straight (this study).
Total myomeres	63–67 (from 2 specimens, this study).
Preanal myomeres	37–39 (from 2 specimens, this study).
Postanal myomeres	26–28 (from 2 specimens, this study).
Pigmentation	Heavy melanophores cover entire head and body, more dense in the dorsal half of body.
Distribution	Pelagic, locally found in Moss Landing Harbor-Elkhorn Slough (this study).

JUVENILES (Figure 18-2)

Dorsal fin	9 + 4 finlets (Clothier 1950); 9–12 + 4–6 (Miller and Lea 1972); 9–11 + 5–6 finlets (Hart 1973).
Anal fin	12–15 + 6 finlets (Clothier 1950); 12–15 + 4–7 finlets (Miller and Lea 1972); 12–14 + 5–7 (Hart 1973).
Pectoral fin	7–14 (Miller and Lea 1972); ca. 13 (Hart 1973).
Mouth	Small, short, lower jaw slightly projecting (Bane and Bane 1971); terminal, rather small, directed forward, upper jaw extending about half distance to rear of pupil (Hart 1973).
Vertebrae	62–64 (Clothier 1950); 63–67 (Miller and Lea 1972).
Distribution	Pelagic, near surface; surface of offshore waters of the Pacific (Hart 1973).

LIFE HISTORY

The distribution of the Pacific saury is from Baja California to Alaska and Japan (Ahlstrom and Casey 1956, Wilimovsky 1954, Frey 1971; Miller and Lea 1972). This species has been reported in Carquinez Strait (Messersmith 1966) and the Moss Landing and Monterey Bay areas (Kukowski 1972b).

Eggs have been found year-round in California waters, with a peak from February through July. The fish spawn at 2-month intervals from the third year throughout the rest of their life off Japan (Frey 1971). The ovoid eggs are ca. 2.0 mm in diameter (Frey 1971, Hart 1973). They become attached to seaweed and rocks (Aplin 1939, Okada 1955) and may also anchor on planktonic organisms (Frey 1971). In Japan, sauries 25.4 to 30.5 mm TL produce 1,000–1,800 eggs per spawn. The eggs hatch in 10 days (Frey 1971).

Larvae are pelagic (Hart 1973). A few specimens were taken in Moss Landing Harbor-Elkhorn Slough in April and July (this study), and it is assumed that the bulk of the larval saury population is offshore.

Juveniles are also pelagic and located near the surface (Schultz 1940). They are common along the coast of Baja California (Eberhardt 1954). Saury feed on zooplankton such as copepods, euphausiids, amphipods, and the larvae of common fish such as anchovies. They are eaten by marine mammals, squid, tuna, and albacore (Frey 1971).

The age of maturity and the growth rate of Pacific saury off California have not been studied (Frey 1971). The saury off Japan matures in its third year (Frey 1971), Saury are fished commercially by Japanese fishermen. Eberhardt (1954) reported that saury are easy to clean and delicious.

References

Ahlstrom and Casey 1956, Aplin 1939, Bane and Bane 1971, Clothier 1950, Eberhardt 1954, Frey 1971, Hart 1973, Hatanaka 1956, Hughes 1974, Kukowski 1972b, Messersmith 1966, Miller and Lea 1972, Okada 1955, Wilimovsky 1954.

Figure 18.—Scomberesocidae: *Cololabis saira*, Pacific saury.

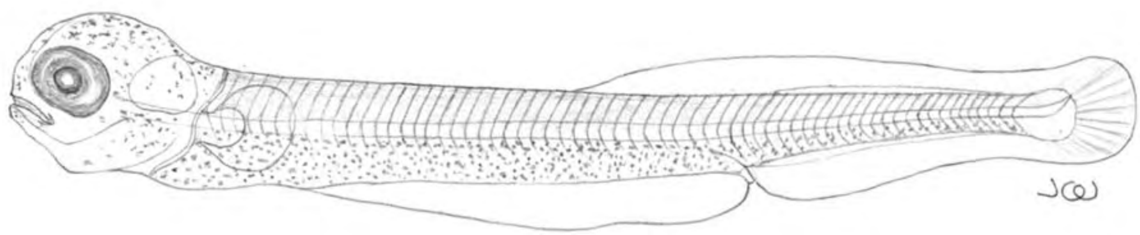


FIGURE 18-1.—Postlarva 7.8 mm TL.

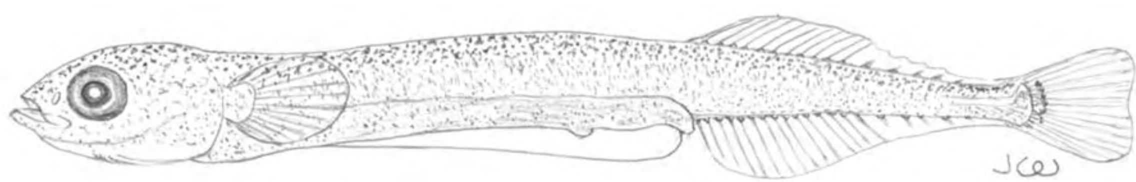


FIGURE 18-2.—Postlarva, 18.2 mm TL.

19. Cyprinodontidae – Killifishes

There are two species of killifish recorded in the coastal waters of California, the California killifish, *Fundulus parvipinnis*, a native species in southern California, and the rainwater killifish, *Lucania parva*, native to the Atlantic and Gulf of Mexico coasts and introduced to California in recent years (Hubbs and Miller 1965).

References

Hubbs and Miller 1965.

RAINWATER KILLIFISH, *Lucania parva* (Baird)

SPAWNING

Location	Shallow inshore water with dense vegetation of the Sacramento-San Joaquin Estuary. Particular locations include Aquatic Park (near KRC radio station, Lake Merritt, Oakland), Newark Slough, Corte Madera Creek, and lower reaches of Suisun Creek (this study).
Season	April or May–July or August in mid-Atlantic region (Hildebrand and Schroeder 1928, Kuntz 1916, Foster 1974, Wang and Kernehan 1979); May–July in Sacramento-San Joaquin Estuary (this study).
Temperature	17.8°C in the aquarium (Nichols 1916, Nichols and Breder 1927). Eggs collected in the field at 20°C; in the laboratory at 22–24°C (this study).
Salinity	Mostly freshwater to mesohaline (this study).
Substrate	Submerged aquatic vegetation (this study).
Fecundity	Maximum 104 (Hildebrand and Schroeder 1928); 7–46 ripe ova in the ovary (McLane 1955).

CHARACTERISTICS

EGGS (Figures 19-1, 19-2, 19-3, 19-4)

Shape	Spherical (Foster 1967).
Diameter	Average 1.23 mm (Foster 1967); 1.1–1.3 mm (Foster 1974); 1.10–1.25 mm.
Yolk	Yellowish, transparent (Kuntz 1916, Hildebrand and Schroeder 1928) Whitish, granular.

Oil globule	12–20 oil globules at animal pole (Kuntz 1916, Kuntz and Radcliffe 1917, Hildebrand and Schroeder 1928, Brinley 1938, Foster 1974); more than 10 oil globules, the largest, ca. 0.31–0.44 mm in diameter (Wang and Kernehan 1979); single large oil globule, ca. 0.40 mm in diameter, and ca. 10 small oil globules.
Chorion	Transparent, with coarse adhesive threads tangled on chorion (Kuntz 1916, Kuntz and Radcliffe 1917); transparent, with many fine filaments attached to chorion.
Perivitelline space	Very narrow (Foster 1974); ca. 1.0 mm in width.
Egg mass	Deposited singly or in small clusters on substrates.
Adhesiveness	Coarse adhesive threads (Kuntz 1916); chorion filaments are adhesive.
Buoyancy	Demersal.

LARVAE (Figure 19-5, 19-6, 19-7)

Length at hatching	5.0 mm TL (Kuntz 1916); 4.0 mm TL (Foster 1974); 4.0–5.5 mm TL (Wang and Kernehan 1979); ca. 4.0–4.5 mm TL.
Snout to anus length	Ca. 37–40% of TL of both prolarvae and postlarvae.
Yolk sac	Medium size, flat on ventral side. Yolk sac extends from thoracic to abdominal region.
Oil globule	Single or several scattered in the yolk sac.
Gut	Short and thick, bends ventrally in anal region.
Air bladder	Large, behind the base of pectoral fin.
Teeth	Small, pointed, in single row, apparent in postlarvae.
Size at completion of yolk-sac stage	6.0 mm TL (Foster 1974); ca. 6.0 mm TL.
Total myomeres	26 (Hudson and Hardy 1975); 26–27.
Preanal myomeres	8 (Hudson and Hardy 1975); 8–10.
Postanal myomeres	18 (Hudson and Hardy 1975); 17–18.
Last fin(s) to complete development	Pelvic.
Pigmentation	Darker melanophores in reticular network found in isthmus to abdominal region; light melanophores appear throughout head, body, and caudal fin.
Distribution	Planktonic in shallow water with vegetation in Sacramento-San Joaquin Estuary, distribution patchy.

JUVENILES (Figure 19-8)

Dorsal fin	9–14 (Moyle 1976, Hardy 1978a); 9–10 for San Francisco Bay population (Hubbs and Miller 1965).
Anal fin	8–13 (Moyle 1976, Hardy 1978a); 8–10 for San Francisco Bay population (Hubbs and Miller 1965).
Pectoral fin	10–15 (Moyle 1976, Hardy 1978a); 12–15 (Hubbs and Miller 1965, this study).
Mouth	Terminal to superior, small and oblique.
Vertebrae	28 (Garman 1895); 25–30 (Hardy 1978a); 27–28.
Distribution	Near bottom, in shallow inshore weedy areas of the Sacramento-San Joaquin Estuary.

LIFE HISTORY

The native distribution of the rainwater killifish is along the Atlantic coast from Cape Cod, Massachusetts, through Florida and the Gulf of Mexico, to the lower Rio Panuco system, Tamaulipas, Mexico (Hubbs and Miller 1965). Rainwater killifish have been introduced into several western states in recent years. Ruth (1964) and Brittan *et al.* (1970) reported the existence of this species in the San Francisco Bay area. In this study rainwater killifish were observed from the vicinity of the Pittsburg Powerplant in Suisun Bay to Neward Slough, south San Francisco Bay. The rainwater killifish population in the Sacramento-San Joaquin Estuary is very patchy. Whether they will migrate to freshwater to breed, as has been reported along the Atlantic coast (Gunter 1945, 1950; Beck and Massmann 1951), is uncertain at the present time.

The spawning period of the rainwater killifish in the Sacramento-San Joaquin Estuary is similar to that in the mid-Atlantic region, which occurs from April or May through July (Kuntz 1916, Hildebrand and Schroeder 1928, Wang and Kernehan 1979). Laboratory observations of this species showed that prior to spawning the fins of the male fish become brilliant orange-red in color. The males establish small territories that are associated with aquatic vegetation. After courtship, the female fish deposit a few eggs at a time over vegetation near water surface. The eggs have many fine adhesive filaments which attach to the substrate. A mop was used in the laboratory in place of vegetation, and eggs were found on both the surface and inner layers of the mop. During development of eggs, the male actively guards his territory, although he pays little attention to the eggs themselves. The eggs hatch in 12 days at 25°C in both mesohaline (18 ppt) and freshwater conditions (this study, Wang and Kernehan 1979); Foster (1967) reported a hatching time of 6 days at 24–25°C. Rainwater killifish eggs will also hatch in a cork-sealed test tube in approximately 2 weeks or slightly longer at room temperature (W. Gallagher 1979, personal communication). Eggs of different stages were found in the ovary, and only a few eggs are discharged during a spawning period, which suggests that females spawn more than once during the spawning season. Details of killifish reproductive behavior have been well-documented by Foster (1967).

Newly hatched larvae are lightly pigmented over most of their bodies, with heavy melanophores in the thoracic and yolk-sac regions. The young larvae initially remain on the bottom, but as development proceeds they begin to swim in the dense vegetation.

Juveniles are solitary, although they may form small, loose schools, and are usually found in aquatic vegetation. Some individuals have been found in inshore waters only a few millimeters deep, which may be an important survival strategy to avoid predation. The diet of juvenile rainwater killifish includes copepods, mosquito larvae, amphipods, and small insects (Harrington and Harrington 1961, this study).

Rainwater killifish reach sexual maturity in as little as 3–5 months, and the females are usually larger than the males (Foster 1967). This species has no commercial or sport value, although it probably has minor value as a forage fish.

References

Beck and Massmann 1951; Brinley 1938; Brittan 1970; Foster 1967, 1974; Gunter 1945, 1950; Hardy 1978a; Harrington and Harrington 1961; Hildebrand and Schroeder 1928; Hubbs and Miller 1965; Hudson and Hardy 1975; Kuntz 1916; Kuntz and Radcliffe 1917; McLane 1955; Moyle 1976; Nichols 1916; Nichols and Breder 1927; Ruth 1964; Wang and Kernehan 1979.

Figure 19.—Cyprinodontidae: *Lucania parva*, rainwater killifish.

FIGURE 19-1.—Egg, morula, 1.1 mm diameter.

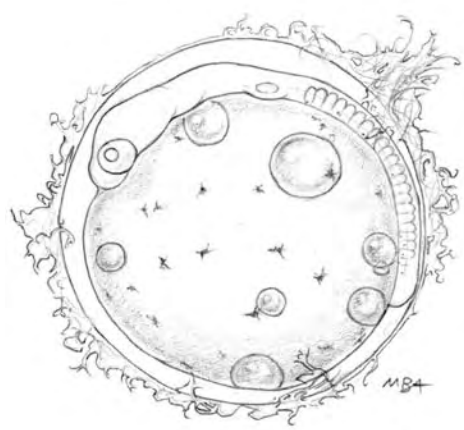


FIGURE 19-2.—Egg, early embryo, 1.1 mm diameter.

FIGURE 19-3.—Egg, late embryo, 1.1 mm diameter.

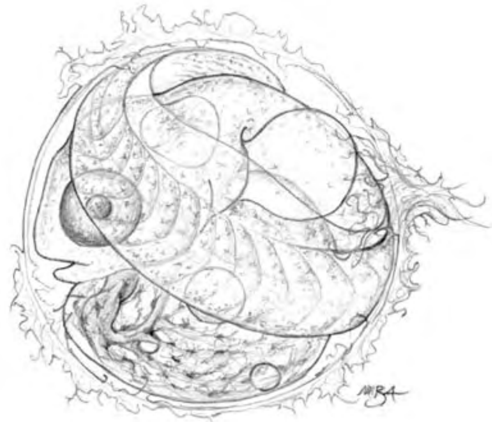


FIGURE 19-4.—Egg, late embryo, 1.1 mm diameter.

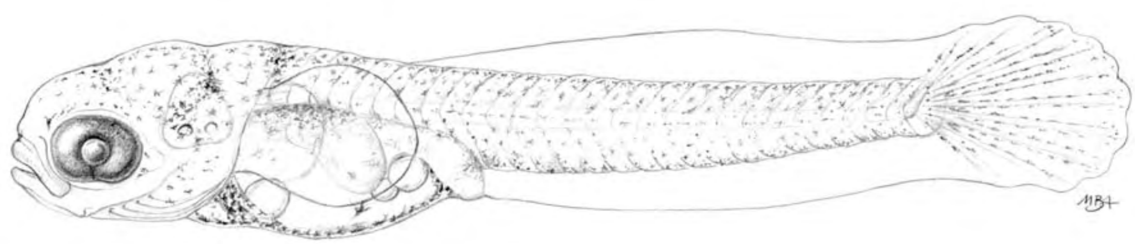


FIGURE 19-5.—Prolarva, 5 mm TL.

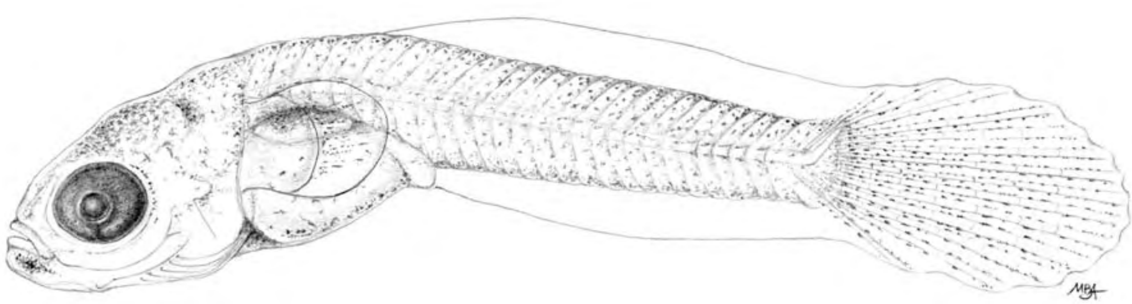


FIGURE 19-6.—Postlarva, 7 mm TL.

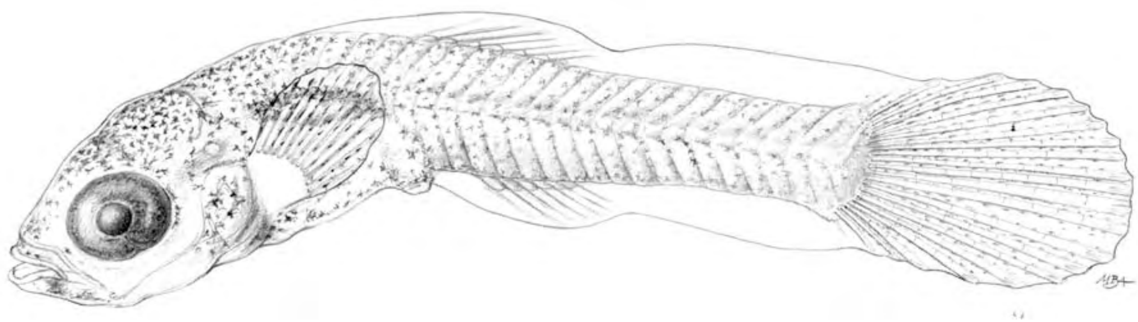


FIGURE 19-7.—Postlarva, 8.1 mm TL.

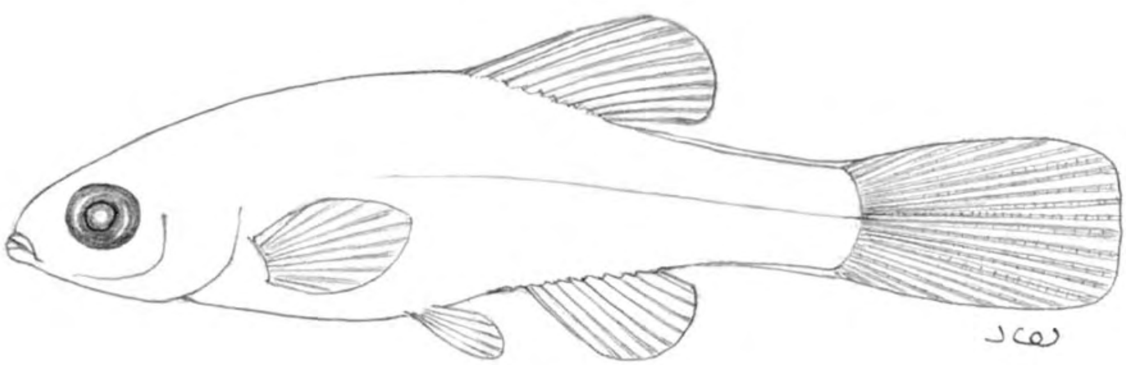


FIGURE 19-8.—Juvenile, 16.5 mm TL.

20. Poeciliidae – Livebearers

At least two species of livebearers have been introduced in California; the mosquitofish, *Gambusia affinis*, and the sailfin molly, *Poecilia latipinna*. Currently, only the mosquitofish is known to the Sacramento-San Joaquin Estuary, and the sailfin molly is distributed in warm southern California water and in the Salton Sea (Moyle 1976).

References

Moyle 1976.

MOSQUITOFISH, *Gambusia affinis* (Baird and Girard)

SPAWNING

Location	Sluggish water, from low to mid-elevation of the Sacramento-San Joaquin River system. General locations: land-locked ponds, reservoirs, irrigation ditches, flood control ditches, creeks, streams, and sloughs (this study).
Season	April–September (Moyle 1976); small juveniles were taken from early May through October from the field, and may spawn in the winter months in laboratory (this study).
Temperature	15.6°C (Self 1940); 15.5°C (Medlen 1952); up to 30°C (Okada 1959); in this study, it starts at ca. 15°C and goes up to 30°C or more (gravid fish were observed in the cooling ponds of the Pittsburg Powerplant).
Salinity	Mostly freshwater, but may occur in oligohaline water (this study).
Fecundity	Highly variable (Hardy 1978a); 1–300 (La Rivers 1962); average of a brood from 11 (Fowler 1907) to 300 (Beckman 1952); average of a brood is 20–100 (this study).

CHARACTERISTICS

EGGS (Figure 20-1) (Eggs obtained by caesarian removal)

Shape	Mostly spherical; may also be irregular if there is a congested condition in the ovary, particularly in late gestation.

Diameter	2.1 mm (Ryder 1882); 1.8 mm (Lippson and Moran 1974); 2.4–2.8 mm (Wang and Kernehan 1979); ca. 2.0 mm in early developmental stages and ca. 2.5–3.0 mm in the late embryo stage.
Yolk	Golden yellow (Kuntz 1914); bright yellowish, granular.
Oil globule	Numerous small oil globules (Ryder 1882, 1885; Kuntz 1914).
Chorion	Thin and transparent, with filaments attaching from chorion to the center of ovarian tissue (Ryder 1885, Kuntz 1914).
Perivitelline space	Very narrow.
Egg mass	Form small clusters; individual ovum attached to the center of the ovary (Ryder 1885, Kuntz 1914).
Adhesiveness	Chorion filaments are adhesive.
Buoyancy	Demersal (but embedded in the ovary).

LARVAE (Figure 20-2)

Length at birth	7.4 mm (Kuntz 1914); 8–10 mm TL (Hildebrand and Schroeder 1928); 7.0 mm TL (Regan 1961); 4.5–6.6 mm before birth (Wang and Kernehan 1979); ca. 4–5.5 mm for larvae in the ovary before birth and ca. 6–9 mm TL at the time of birth.
Snout to anus length	Ca. 40–45% of TL of larvae in the ovary and newly born specimens.
Yolk sac	Spherical, very large, extends from snout to abdominal region.
Air bladder	Small, oval, located above and behind pectoral fins.
Teeth	Small, pointed, in one row, apparent at birth.
Size at completion of yolk-sac stage	Ca. 6.0 mm TL.
Total myomeres	28–32.
Preanal myomeres	12–14.
Postanal myomeres	16–20.
Last fin(s) to complete development	Pelvic.
Pigmentation	Stellate melanophores are heavy on snout, head to middorsal region; pigments are light on ventral sideof the body and fin membranes. Pigmentation becomes

	more prominent on the edge of scale shortly after birth.

JUVENILES (Figure 20-3)

Dorsal fin	5 (Bailey *et al.* 1954); up to 11 (Garman 1895); 6–7 (Moyle 1976); 6–8.
Anal fin	9–11 (Hildebrand and Schroeder 1928); 9–10 (Moyle 1976); front anal fin ray modified into an intromittent organ or gonopodium (Hildebrand 1917, Hildebrand and Schroeder 1928, Turner 1941).
Pectoral fin	12–14 (Garman 1895); 12–13 (this study).
Mouth	Slightly superior, lower jaw projecting (Hildebrand and Schroeder 1928); small, oblique (Moyle 1976); terminal to superior, oblique.
Vertebrae	Trunk vertebrae 12–14, caudal vertebrae 17–20 (Garman 1895, Hollister 1940); 30–33.
Distribution	Sluggish water with vegetation, ranges broadly in the Sacramento-San Joaquin River system.

LIFE HISTORY

The mosquitofish is native to North America from southern Illinois through the Mississippi drainage to Texas, and along the Gulf of Mexico coast to the Rio Panuco basin, Mexico. On the Atlantic Coast, the range extends from New Jersey southward to Florida (Hildebrand and Schroeder 1928, Krumholz 1948, Rosen and Bailey 1963). Because mosquitofish feed on mosquito larvae and pupae, they have been introduced into the tropical and temperate regions of the entire world. The mosquitofish was introduced into California in 1922 (Moyle 1976). In this study, mosquitofish were observed in almost all backwaters and sluggish waters of the Sacramento-San Joaquin Estuary and River system, including foothill and mid-elevation reservoirs and ponds. Moyle and Nichols (1973) also reported this species in Sierra Nevada foothill waters. Pregnant female mosquitofish were observed all year, but judging from the numbers of small juveniles taken from the lower elevations of the Sacramento-San Joaquin Estuary and River system, the bulk of the local spawn occurs from April through October; spawning is at about 15.5°C (Medlen 1952). In February 1979, several female mosquitofish were collected at 10–12°C from the flood control ditch which runs through Hillcrest Community Park. The fish gave birth in the laboratory a few weeks later at 20–24°C. Apparently the embryos require a much longer development time during the cold winter.

Eggs are contained in a single ovary. Each egg is covered by a thin chorion and attaches to the central ovarian tissue by means of filaments (Kuntz 1914). Male fish use a gonodopodium (modified from anal fin rays) to contact the female's urogential tract and transfer sperm. As egg development proceeds, the female's abdominal region gradually swells.

The embryos hatch out of the chorions as larvae but remain within the ovary for several days before birth (this study). Larval development within the same brood is fairly constant, although some larvae will develop at a slower rate. When the female is ready to give birth, both mature and premature larvae will be discharged within a few minutes; consequently, some premature larvae will die (this study). The gestation period is 21–28 days (Krumholz 1948).

Newly born mosquitofish larvae have fully developed fin rays in all but the pelvic fin, and are able to swim immediately. Laboratory observations reveal, however, that premature and abnormal larvae remain on the bottom of the aquarium, and under natural conditions they would probably be preyed on by other fish. Juveniles tend to form small schools and use dense vegetation as a nursery and for protection. By the end of summer, juveniles and small adults outnumber large adults. Both juveniles and adults declined drastically in the late fall, probably because lack of food and unfavorable temperature. Juvenile mosquito larvae and pupae, plankton, algae, and diatoms (Harrington and Harrington 1961, Rees 1958, Moyle 1976).

Krumholz (1948) has reported that mosquitofish reach maturity 6 weeks after birth and usually live less than 1 year, although a few may live as long as 15 months. Mosquitofish are an important forage species for large predatory fish. They serve an even more important function as mosquito-control agents, however, and are used as such in California and throughout the world (Hoy *et al*. 1972). Their success in controlling mosquitos can be attributed to many factors. Mosquitofish are able to tolerate temperatures ranging from 4–37°C (Krumholz 1948, Carlander 1969). Their ability to breathe at the water's surface allows them to survive in extremely eutrophic ponds, lakes, and ditches. They are opportunistic feeders, being able to eat not only mosquito larvae and pupae but almost anything else they can find, including algae (Moyle 1976). Since mosquitofish are livebearers, they do not require any particular spawning habitat. They will readily breed under both natural and artificial conditions (Hardy 1978a). Above all, they are hardy and prolific.

References

Bailey *et al.* 1954; Beckman 1952; Carlander 1969; Fowler 1907; Garman 1895; Hardy 1978a; Harrington and Harrington 1961; Hildebrand and Schroeder 1928; Hollister 1940; Krumholz 1948; Kuntz 1914; La Rivers 1962; Lippson and Moran 1974; Medlen 1952; Moyle 1976; Moyle and Nicols 1973; Okada 1959–1960; Rees 1958; Regan 1961; Ryder 1882, 1885; Self 1940; Wang and Kernehan 1979.

Figure 20.—Poeciliidae: *Gambusia affinis*, mosquitofish.

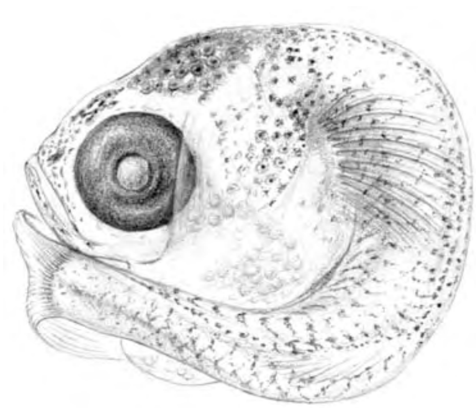


FIGURE 20-1.—Dissected embryo, 3.2 mm diameter.

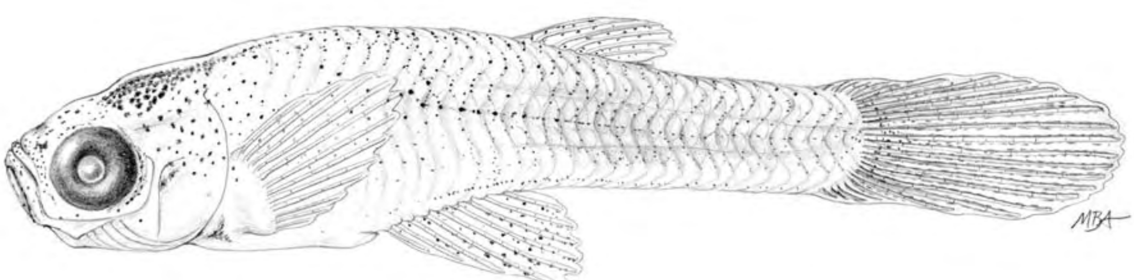


FIGURE 20-2.—Newly born postlarva, 9.5 mm TL.

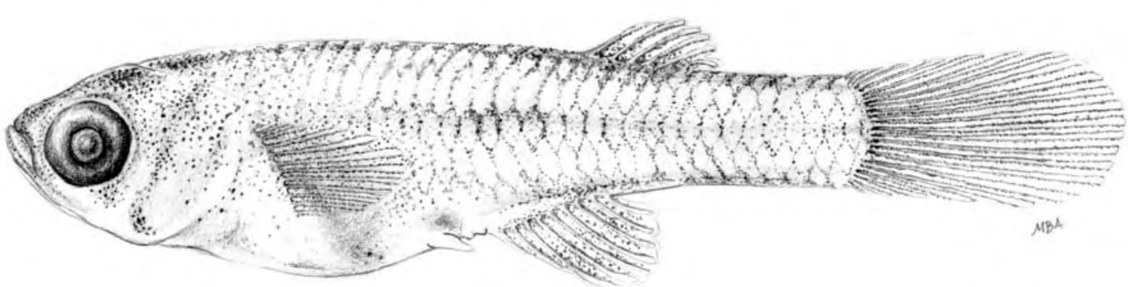


FIGURE 20-3.—Juvenile, 11.6 mm TL.

21. Atherinidae – Silversides

Three species of atherinids are known to the Sacramento-San Joaquin Estuary: topsmelt, *Atherinops affinis,* an estuarine species; jacksmelt, *Atherinopsis californiensis,* a coastal marine species; and inland silverside, *Menidia beryllina,* an introduced freshwater species.

California grunion, *Leuresthes tenuis*, a coastal marine fish, was reported in San Francisco Bay by Miller and Lea (1972). However, this species was not collected in this study. The description of California grunion in this manual was developed from specimens taken from Moss Landing and southern California.

References

Miller and Lea 1972.

TOPSMELT, *Atherinops affinis* (Ayres)

SPAWNING

Location	Alviso salt pond (Carpelan 1955). Along Pacific coast, San Francisco Bay and up to mesholine portion of the estuary. Particular locations observed in this study include Aquatic Park, Lake Merritt, vicinity of Oleum Powerplant, intake pond of Hunters Point Powerplant, San Mateo Bridge in south San Francisco Bay, Tomales Bay, and Elkhorn Slough.
Season	March–August (Carpelan 1955); spring–early fall (Feder *et al.* 1974); April–October.
Temperature	Ca. 20°C (Carpelan 1955); ca. 10–25°C.
Salinity	Up to twice that of ocean water or up to 72 ppt (Carpelan 1955); mesohaline to seawater.
Substrate	Marine plants (Bane and Bane 1971); algae, hydroids, and submerged plants.

CHARACTERISTICS

EGGS (Figure 21-1)

Shape	Spherical.
Diameter	Ca. 1.5–1.7 mm.
Yolk	Amber color, granular.
Oil globule	Usually single and large.

Chorion	Transparent, thick, ca. 2–8 filaments attached to chorion in random pattern.
Perivitelline space	Very narrow.
Egg mass	Deposited singly in the vicinity of vegetation, where the chorion filaments become entangled with the substrate and can form large clusters.
Adhesiveness	None.
Buoyancy	Demersal.

LARVAE (Figures 21-2, 21-3, 21-4)

Length at hatching	Ca. 4.3–4.9 mm TL.
Snout to anus length	Ca. 30–35% of TL for prolarvae, increasing to 35–43% of TL for postlarvae.
Yolk sac	Sperical, thoracic.
Gut	Very short.
Air bladder	Small, oval, near pectoral fin.
Teeth	Small, pointed in postlarvae.
Size at completion of yolk-sac stage	Ca. 7.0 mm TL.
Total myomeres	42–48.
Preanal myomeres	13–16.
Postanal myomeres	27–33.
Last fin(s) to complete development	Spiny dorsal fin.
Pigmentation	Very large stellate melanophores extend from snout to cephalic and middorsal regions (1 row of melanophores in middorsal region). Few melanophores on midventral region. Large melanophores are also found on dorsal and side of gut. A series of melanophores along postanal region. Dashed melanophores along lateral line region.
Distribution	Surface of water column of inshore and open waters in San Pablo Bay, San Francisco Bay, and coastal Pacific.

JUVENILES (Figure 21-5, 21-6)

Dorsal fin	V–IX, I, 8–14 (Miller and Lea 1972, Moyle 1976).
Anal fin	I, 19–25 (Miller and Lea 1972; Moyle 1976)
Pectoral fin	13 (Miller and Lea 1972, Moyle 1976); 13–15.

Mouth	Small, oblique (Moyle 1976); terminal, small, oblique.
Vertebrae	45–52 (Miller and Lea 1972); 45–49.
Distribution	Shallow inshore waters from coast up to Suisun Bay.

LIFE HISTORY

The range of the topsmelt extends from the Gulf of California to Vancouver Island, British Columbia (Miller and Lea 1972, Hart 1973). Of the three subspecies described by Schultz (1933) as being found within this range, the San Francisco topsmelt, *Atherinops affinis affinis* is the only one inhabiting the Sacramento-San Joaquin Estuary. Topsmelt are particularly abundant in the shallow waters of south San Francisco Bay; young-of-the-year are common in the mesohaline to oligohaline portions of the estuary.

Topsmelt have a prolonged spawning period from April through October, with a peak in May and June. Observations of various sized ova within individual ovaries indicate that eggs may be deposited more than once during a single spawning season.

Spawning takes place in vegetated areas where elongate filaments on the eggs become entangled with the substrate. Hatching may occur over a wide range of salinities (Carpelan 1955). In this study, spawning was observed in Aquatic Park and near Dumbarton Bridge of south San Francisco Bay. Along the coast, the pelagic larvae stay in the upper few inches of kelp canopy (Feder *et al.* 1974). Within the estuary the larvae swim in small schools near the surface of both shallow and open water. Topsmelt larvae are particularly abundant in tidal basins (*e.g.*, the Aquatic Park in Berkeley, Lake Merritt in Oakland), and in the sluggish waters of south San Francisco Bay (*e.g.*, near Robert Crown Memorial Park, Hunters Point, San Mateo Bridge, Dumbarton Bridge).

Juvenile topsmelt generally move into the open water of the estuary and coastal kelp beds. Some may ascend into Suisun Bay in the summer and early fall as the salt wedge moves to the upper reaches of the estuary. Juveniles feed on small crustaceans (Feder *et al.* 1974), diatoms, filamentous algae, detritus, chironomid larvae, and amphipods (Moyle 1976). Topsmelt mature in their second year and may live 6–9 years (Schultz 1933, Feder *et al.* 1974). Topsmelt are among the most abundant atherinids in San Francisco Bay and have been used both as food and as bait fish.

References

Bane and Bane 1971, Carpelan 1955, Feder *et al.* 1974, Hart 1973, Miller and Lea 1972, Moyle 1976, Schultz 1933.

JACKSMELT, *Atherinopsis californiensis* (Girard)

SPAWNING

Location	Shallow coastal waters in bays and estuaries such as San Pablo Bay (Ganssle 1966), San Francisco Bay, San Pablo Bay, Moss Landing Harbor, Tomales Bay.
Season	October–March, with peak in November–March (Clark 1929); throughout year in southern California (Feder *et al.* 1974); September–April (Ganssle 1966); October–early August.
Temperature	10°C and greater.
Salinity	Seawater–polyhaline; may occur in mesohaline water.
Substrate	Seaweed (Baxter 1966), algae, plants, and hydroids.

CHARACTERISTICS

EGGS (Figure 21-7)

Shape	Spherical.
Diameter	Mature eggs 0.9–2.2 mm (Clark 1929); fertilized eggs 1.9–2.5 mm.
Yolk	Yellowish orange (Bane and Bane 1971); yellowish, orange, rusty brown, granular.
Oil globule	Many oil globules, tending to consolidate into one oil globule prior to hatching.
Chorion	Transparent, thick, hard; 15–16 filaments 1–2 cm long attached to chorion in random pattern.
Perivitelline space	Very narrow.
Egg mass	Released in the vicinity of aquatic vegetation and hydroids; the filaments become entangled with substrates and form large clusters.
Adhesiveness	None.
Buoyancy	Demersal.

LARVAE (Figures 21-8, 21-9, 21-10, 21-11)

Length at hatching	Ca. 7.5–8.6 mm TL.
Snout to anus length	Ca. 30–33% of TL of prolarvae, increasing to ca. 40 % of TL in postlarvae.
Yolk sac	Spherical, in thoracic region.

Oil globule	Single, ca. 0.4–0.6 mm in diameter, usually located in anterior yolk sac.
Gut	Very short, bending ventrally in anal region.
Air bladder	Oval, small, behind pectorals.
Teeth	Small, pointed.
Size at completion of yolk-sac stage	Ca. 9.5–10.0 mm TL.
Total myomeres	59–53.
Preanal myomeres	12–14.
Postanal myomeres	37–39.
Last fin(s) to complete development	Spiny dorsal fin.
Pigmentation	A few very large stellate melanophores on snout and cephalic regions, melanophores on middorsal region in single row, large melanophores on side of gut, dashed melanophores in lateral line region.
Distribution	Pelagic, on surface of water column, inshore to open water, ranging from seawater to mesohaline.

JUVENILES (Figure 21-12)

Dorsal fin	V–IX, I, 11–14 (Miller and Lea 1972).
Anal fin	I, 21–26 (Miller and Lea 1972).
Pectoral fin	15.
Mouth	Terminal, small, oblique.
Vertebrae	50–54 (Miller and Lea 1972).
Distribution	Shallow coastal waters (Boothe 1967); San Francisco Bay (Baxter 1966, Aplin 1967); San Pablo Bay (Ganssle 1966); Carquinez Strait (Messersmith 1966); mostly from San Francisco Bay to San Pablo Bay, occasionally entering Suisun Bay, Tomales Bay, Moss Landing Harbor, and Ekhorn Slough.

LIFE HISTORY

Jacksmelt range from Santa Monica Bay, Baja California, to Yaquina Bay, Oregon (Miller and Lea 1972). They are usually found within a few miles of shore (Boothe 1967). In the Sacramento-San Joaquin Estuary, jacksmelt are commonly found in a salinity range of seawater to mesohaline (Ganssle 1966, Messersmith 1966, Aplin 1967).

Large clumps of jacksmelt eggs have been observed at the intake screens of the Potrero, Hunters Point, Oleum and Moss Landing Powerplants during winter and spring months, indicating that embayments and estuaries are important spawning grounds for this species. Egg masses were observed tangled with hydroids on the ocean beach near Rodeo Lagoon and attached to eel grass in Tomales Bay. Eggs collected which were in the early embryo stages hatched in the laboratory within 7 days at 10–12°C in polyhaline water. It was also noticed that jacksmelt eggs hatched in a salinity as low as 5 ppt. Jacksmelt can spawn several times during a spawning season (Clark 1929).

In the laboratory, newly hatched larvae remained on the bottom for a short moment and then swam actively near the surface.

Juveniles form large schools, and often mix with topsmelt (Bane and Bane 1971). They are common in the open waters of San Pablo Bay (Ganssle 1966) and San Francisco Bay (Baxter 1966, Aplin 1967), as will as shallow coastal waters (Boothe 1967). In the Moss Landing Harbor area, samples collected in the harbor and in Elkhorn Slough contained many more jacksmelt larvae than juveniles in the winter and spring months. This suggests that coastal embayments and estuaries are more important for spawning than for use as nursery grounds for this species.

Major food items for juvenile jacksmelt include algae, detritus, and small crustaceans (Bane and Bane 1971). Stomach analyses show that amphipods are also a common food item, indicating that juvenile jacksmelt may feed on the bottom.

Jacksmelt mature at 2–3 years or about 20 cm TL, and may live 9–10 years (Clark 1929). Commercially, the jacksmelt is harvested along with topsmelt for human consumption. Jacksmelt also serve as prey for many other species of fishes and birds (Bane and Bane 1971).

References

Aplin 1967, Bane and Bane 1971, Baxter 1966, Boothe 1967, Clark 1929, Ganssle 1966, Messersmith 1966, Miller and Lea 1972.

CALIFORNIA GRUNION, *Leuresthes tenuis* (Ayres)

SPAWNING

Location	Coastal sandy beaches, from southern California to Point Conception; may extend further.
Season	March–August (Thompson and Thompson 1919).
Temperature	24.8–26.8°C (Hubbs 1965).
Salinity	Seawater.
Substrate	Sandy beach.

Fecundity	1,400–2,200 per spawn (Thompson and Thompson 1919); ca. 3,000 per spawn (Fitch and Lavenberg 1971).

CHARACTERISTICS

EGGS (Figure 21-13)

Shape	Spherical.
Diameter	Mature eggs 1.0–1.1 mm (Clark 1925); 1.5–1.6 mm (David 1939); 1.8–2.2 mm (Moffatt and Thomson 1978); 1.6–1.9 mm.
Yolk	Yellow-green, clear (David 1939).
Oil globule	23–115 small oil globules, the number decreasing as developmental stages proceed, eventually consolidating in one large oil globule, ca. 0.5 mm in diameter in yolk-sac larvae (David 1939).
Chorion	Clear, no chorion filaments (Clark 1925, David 1939, Hubbs 1965); transparent, smooth.
Perivitelline space	Ca. 0.2–0.5 mm (David 1939).
Egg mass	Deposited in clusters (David 1939).
Adhesiveness	None (Hubbs 1965).
Buoyancy	Demersal (David 1939).

LARVAE (Figure 21-14, 21-15, 21-16, 21-17, 21-18, 21-19, 21-20, 21-21)

Length at hatching	6.5–6.7 mm TL (David 1939).
Snout to anus length	Ca. 30–35% of TL of prolarvae and early postlarvae, increasing to 35–40% of TL in late postlarvae.
Yolk sac	Spherical to oval, in thoracic region.
Oil globule	Single, usually located in anterior yolk sac (David 1939).
Gut	Very short (this study).
Air bladder	Oval, small, near and behind pectorals (this study).
Teeth	None (this study).
Size at completion of yolk-sac stage	Ca. 7.0 mm TL.
Total myomeres	44–45 (David 1939); 44–48.
Preanal myomeres	9–12.

Post myomeres	32–36 (this study).
Last fin(s) to complete development	Spiny dorsal fin.
Pigmentation	Very large stellate melanophores on snout and cephalic region, a single row of melanophores along middorsal region, dashed melanophores in lateral line region; melanophores are also found in postanal region and caudal regions in late postlarvae. No pigments on midventral region.
Distribution	Pelagic in southern California coastal waters, and occasionally found near Point Conception and vicinity of Moss Landing Harbor.

JUVENILES (Figure 21-22)

Dorsal fin	V–VII; I, 9–10 (Miller and Lea 1972).
Anal fin	I, 21–24 (Miller and Lea 1972).
Pectoral fin	13–15.
Mouth	Terminal or slightly subterminal, premaxillary protractive (Miller and Lea 1972).
Vertebrae	47–50 (Miller and Lea 1972); 46–47.
Distribution	This species was reported in San Francisco Bay by Miller and Lea (1972); postlarvae and juveniles are found in Moss Landing Harbor and Elkhorn Slough, Morro Bay, and southward (Fitch and Lavenberg 1971), but the bulk of the juvenile grunion population is concentrated along the coast of southern California (Clark 1925; David 1939).

LIFE HISTORY

According to Miller and Lea (1972), the California grunion ranges from Magdalena Bay northward to San Francisco Bay. However, this species has not been observed in San Francisco Bay, Tomales Bay, or Bodega Bay in the past two decades (Aplin 1967, Ganssle 1966, Bane and Bane 1971, Standing *et al.* 1975). According to Lillian Dempster (1980, personal communication), Miller and Lea (1972) could have made an erroneous range report based on observations on grunion being sold in the San Francisco fish market that had actually been shipped in from

Monterey Bay. Fitch and Lavenberg (1971) commented that grunions were seldom seen north of Morro Bay.

However, on several occasions during 1978–1980 grunions were collected in Moss Landing Harbor and Elkhorn Slough. Thus, the present northern range limit of this species may be somewhere between Moss Landing and San Francisco Bay.

Spawning occurs on sandy beaches in spring and summer, shortly after a full or new moon. The fish are carried to the high tide mark by the surf, the females deposit their eggs in the sand, and the males extrude milt into the surrounding sand. The eggs incubate in the warm sand and hatch approximately 15 days later during the following series of high tides. If the eggs are not exposed by these high tides, they may remain viable until the next series of high tides, up to about 22–25 days after spawning (Fitch and Lavenberg 1971). California grunion may produce 4–8 batches of eggs during a single spawning period (Clark 1925). Their spawning habits, synchronizing with the lunar cycle and tides, and their egg burying make this species unique among marine fishes.

After incubating, the eggs are washed into the surf by the high tide, where they hatch. The larvae immediately begin swimming on the surface along the coast (David 1939).

Juvenile grunion school in shallow coastal water, usually a few miles from shore. They feed on planktonic organisms (Fitch and Lavenberg 1971).

The California grunion is a highly prolific fish (about 3,000 eggs per batch); reproduction begins at age 1, and females continue to spawn for 2 more years (Clark 1925). Grunion are important as a sport fish during their spawning run.

The spawning behavior and early life history of California grunion are well documented by Thompson and Thompson (1919), Clark (1925), David (1939), and Hubbs (1965). In recent years, Moffatt and Thomson (1978) have published papers on the subject of the evolution and adaptability of California grunion to changes in the environment.

References

Aplin 1967; Bane and Bane 1971; Clark 1925; David 1939; Fitch and Lavenberg 1971; Ganssle 1966; Hubbs 1965; Miller and Lea 1972; Moffatt and Thomson 1978; Standing *et al.* 1975; Thompson and Thompson 1919.

Specimen Credit

Eggs and larvae were obtained from John Lindsay, Lockhead Center for Marine Research, Carlsbad, California.

INLAND SILVERSIDE, *Menidia beryllina* (Cope)

SPAWNING

Location	Shallow weedy freshwaters in the Delta, sloughs, tributaries of the Bay, ponds, and reservoirs. Particular locations: Wilson Slough, vicinity of Contra Costa and Pittsburg Powerplants, Antioch Municipal Reservoir, Clifton Court Forebay, and San Luis Reservoir
Season	May–August (Moyle 1976), April–September.
Temperature	13.2–34.2°C; optimum temperature 20–25 °C (Hubbs *et al.* 1971).
Salinity	Freshwater and oligohaline (Hubbs *et al.* 1971).
Substrate	Aquatic vegetation, inundated terrestrial plants, and tree roots (Hubbs *et al.* 1971, Fisher 1973), cattail, tules, and dead plant leaves.

CHARACTERISTICS

EGGS (Figures 21-23, 21-24, 21-25)

Shape	Spherical.
Diameter	0.8–1.2 mm (this study) 0.8–0.9 mm (Wang and Kernehan 1979).
Yolk	Pale yellow, coarse, granular.
Oil globule	1–3 oil globules, each ca. 0.2–0.3 mm in diameter, tend to consolidate into a single oil globule prior to hatching.
Chorion	Transparent, with 1–3 chorion filaments, ca. 1–2 cm long, attached to chorion next to each other; one large and five or more thin filaments (Wang and Kernehan 1979).
Perivitelline space	0.1–0.2 mm in width.
Egg mass	Single eggs entangled on substrate by chorion filaments or small clusters.
Adhesiveness	Adhesive.
Buoyancy	Demersal.

LARVAE (Figure 21-26, 21-27, 21-28, 21-29)

Length at hatching	3.5–4.2 mm TL.
Snout to anus length	Ca. 26–30% of TL of prolarvae and early postlarvae and 28–34% of TL of 8.0–11.0 mm postlarvae.

Yolk sac	Spherical, in jugular-thoracic region.
Oil globule	Mostly single, ca. 0.2–0.3 mm in diameter.
Gut	Extremely short (Taber 1969); very short, bending ventrally in anal region.
Air bladder	Well developed (Taber 1969); small, oval, midway between pectoral fins and anus.
Teeth	Small, pointed.
Size at completion of yolk-sac stage	Ca. 4.0–4.5 mm TL.
Total myomeres	34–38.
Preanal myomeres	6–10.
Postanal myomeres	28–32.
Last fin(s) to complete development	Spiny dorsal fin.
Pigmentation	3–5 large stellate melanophores on cephalic region. Few melanophores or none on middorsal region. Pigments are also found along midventral and postanal regions, and dashed melanophores along lateral line region.
Distribution	Surface of water column (Taber 1969); surface and upper water column of freshwater and oligohaline portions of the estuary; also known in San Luis Reservoir.

JUVENILES (Figure 21-30)

Dorsal fin	IV–V, I, 8–9 (Moyle 1976).
Anal fin	I, 15–18 (Moyle 1976); I, 15–20 rays (Pflieger 1975); I, 15–19.
Pectoral fin	13–14.
Mouth	Oblique, small (Moyle 1976); terminal, small, oblique.
Vertebrae	37–42.
Distribution	Mostly in shallow weedy areas of freshwater-oligohaline portion of the estuary; also found in ditches, reservoirs, and irrigation systems. Currently known as far as San Luis Reservoir.

LIFE HISTORY

The inland silverside is native to brackish waters along the Gulf of Mexico coast up into the lower Mississippi Basin and north to Oklahoma and Tennessee (Gomez and Lindsay 1972; Miller and Robison 1973; Pflieger 1975). It is also known along the Atlantic coast from Mexico to Cape Cod (Robins 1969). In 1967, inland silverside were introduced into Blue Lake and Clear Lake, California (Cook and Moore 1970). The species experienced a population explosion in Clear Lake and rapidly spread into the adjacent drainages, including Cache Creek and Putah Creek, and from there through the irrigation network to the Delta, where they have become well established. The inland silverside has been one of the most common species collected by beach seine in the Delta, Suisun Bay, and Montezuma Slough during the past 4 years. They have also been observed in the lower reaches of Sonoma Creek and the Napa River, and in land-locked ponds such as the Antioch Reservoir. The species is currently known as far south as the San Luis Reservoir, and it was probably transported there via the California Aqueduct system.

The successful establishment of this species in the Sacramento-San Joaquin Estuary and adjacent waters is probably due in part to their tolerance of various salinities and to the surface feeding habitats of the inland silverside larvae, which reduces competition from other fish species.

Moyle (1976) noted that inland silverside spawn from April through September, with peaks in May and in August. In the Delta, ripe females were collected from April through September. The ovaries of these females had at least 2 or 3 distinct sizes of ova present at the same time, indicating that inland silverside spawn more than once a season (Mense 1967, Hubbs *et al.* 1971). The eggs have 1–3 filaments, attached to the chorion, which become entangled with vegetation and suspend the eggs in the water column.

The eggs hatch in 4–30 days, depending on the temperature (Moyle 1976). Newly hatched larvae have well-developed air bladders (Taber 1969) and are planktonic, swimming in the neuston. This trait is common to the atherinids, also including topsmelt, jacksmelt, and other silverside larvae found along the Atlantic coast (Lindsay *et al.* 1978).

Juvenile inland silverside generally inhabit vegetated inshore waters. They have been collected by beach seining in sluggish areas or backwaters and seem to avoid fast currents and the intakes of powerplants. Their diet consists primarily of zooplankton, including large cladocerans and instars of chironomid midges and chaoborid gnats (Moyle 1976).

Inland silverside generally reach maturity at age 1, spawn, and die, although a few females are able to survive an additional year (Mense 1967, Moyle 1976).

This fish has been used as a forage species for game fishes and as a biological control for reducing gnat and midge populations in Clear Lake. The shiny, silvery body of the inland silverside suggests that they would also be an excellent bait fish.

References

Cook and Moore 1970, Fisher 1973, Gomez and Lindsay 1972, Hubbs *et al.* 1971, Lindsay *et al.* 1978, Mense 1967, Miller and Robison 1973, Moyle 1976, Pflieger 1975, Robins 1969, Taber 1969, Wang and Kernehan 1979.

Characteristic Comparison: Silversides

Characteristic	Topsmelt	Jacksmelt	California Grunion	Inland Silverside
Spawning				
Location	San Francisco Bay and San Pablo Bay; Moss Landing Harbor	San Francisco Bay and San Pablo Bay; Moss Landing Harbor	Southern California coast; some spawning occasionally occurs north of Pt. Concepcion	Freshwater impoundments, possibly oligohaline waters of the Sacramento-San Joaquin Estuary
Eggs				
Diameter (mm)	1.5–1.7	1.9–2.5	1.5–2.2	0.8–1.2
Chorion filaments	5–8	15–16	None	1–3
Larvae				
Total myomeres	42–48	49–53	44–48	34–38
Preanal myomeres	13–16	12–14	9–12	6–10
Postanal myomeres	27–33	38–39	32–36	28–32
Pigmentation	Large dark stellate melanophores on head and snout; single row of melanophores on middorsal, midventral, and postanal regions; dashed melanophores on lateral line	Large stellate melanophores on head and snout; single row of melanophores on middorsum; dashed melanophores on lateral line no pigmentation on mid-ventral and postanal regions	Large stellate melanophores on head and snout; single row of melanophores on middorsal region; dashed melanophores on lateral line; a few melanophores on postanal region; no pigmentation on midventral region	Large stellate melanophores on head; melanophores along midventral and postanal regions; dashed melanophores on lateral line; no pigmentation on middorsal region except occasionally on caudal peduncle
Juveniles				
Dorsal fin	V–IX; I, 8–14	V–IX; I, 11–14	V–VIII; I, 9–10	IV–V; I, 8–9
Anal fin	I, 19–25	I, 21–26	I, 21–24	I, 15–18
Pectoral fin	13–15	15	13–15	13
Teeth	Forked, pointed	Small, pointed	None	Small, pointed
Vertebrae	45–52	50–54	47–50	37–42
Scales between insertion of D1 and origin of D2	5–8	10–12	7–9	4–5
Type of scale	Ctenoid, smooth posterior edge	Ctenoid, smooth posterior edge	Ctenoid, rough posterior edge	Cycloid, smooth posterior edge
Insertion of spiny dorsal vs. origin of anal fin	Over-under	Spiny dorsal anterior	Spiny dorsal posterior	Spiny dorsal anterior

Figure 21.—Atherinidae: *Atherinops affinis*, topsmelt.

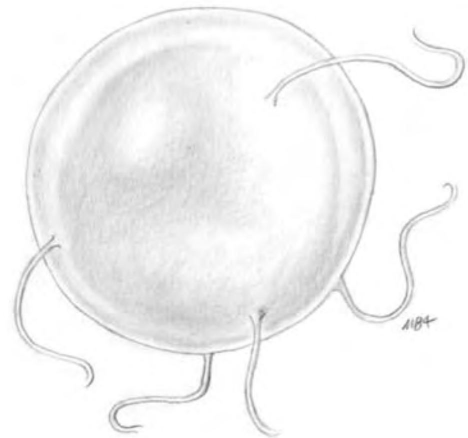


FIGURE 21-1.—Egg, dead, 1.4 mm diameter.

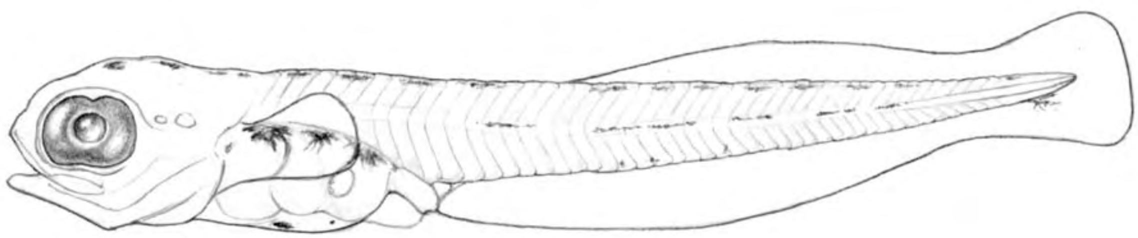


FIGURE 21-2.—Postlarva, 5 mm TL.

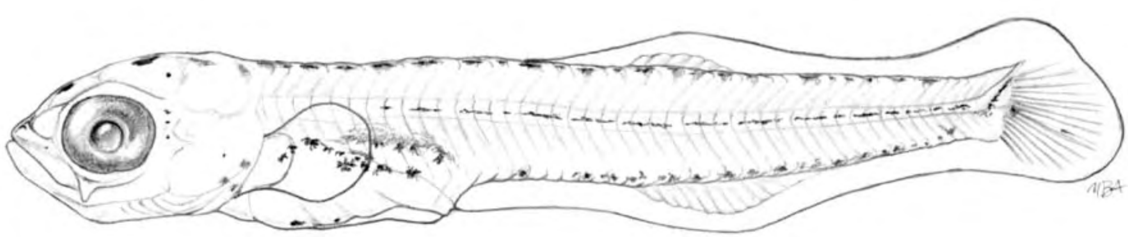


FIGURE 21-3.—Postlarva, 10 mm TL.

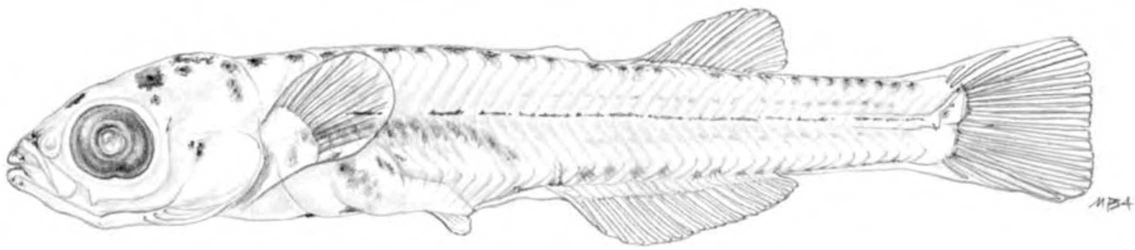


FIGURE 21-4.—Postlarva, 14 mm TL.

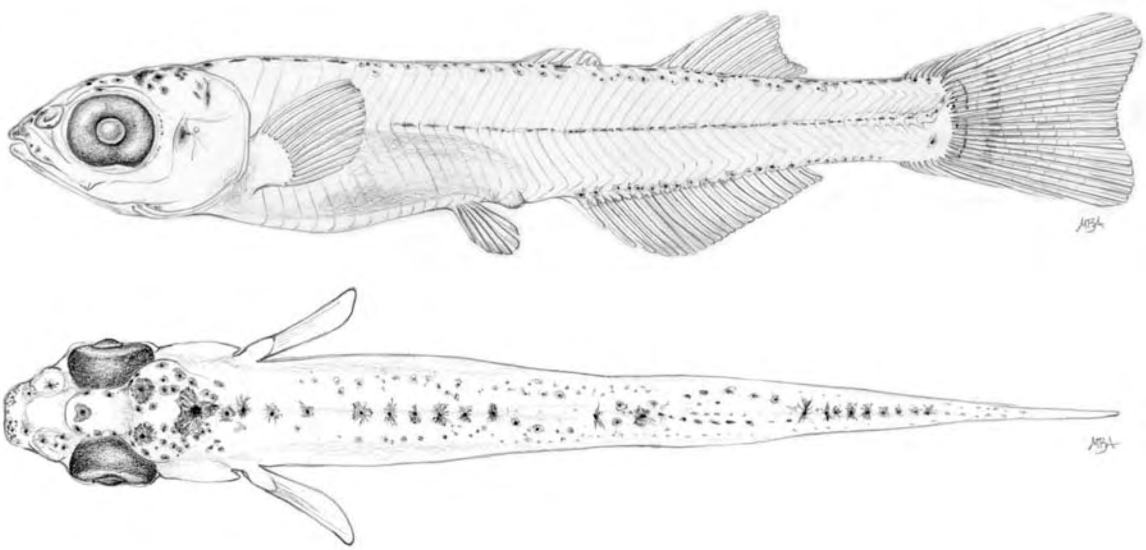


FIGURE 21-5, 21-6.—Juvenile, lateral and dorsal views, 18.7 mm TL.

Atherinidae: *Atherinopsis californiensis*, jacksmelt.

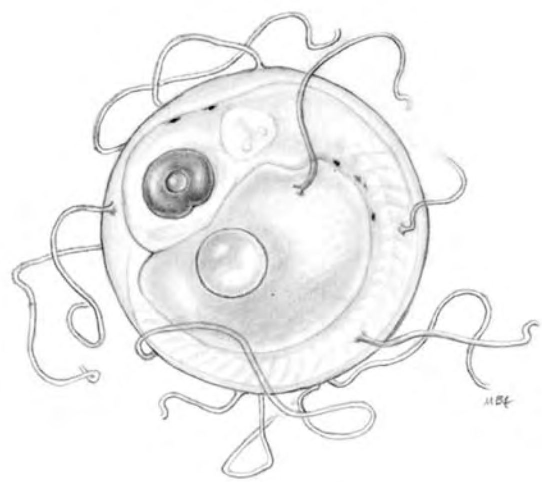


FIGURE 21-7.—Egg, late embryo, 1.8 mm diameter.

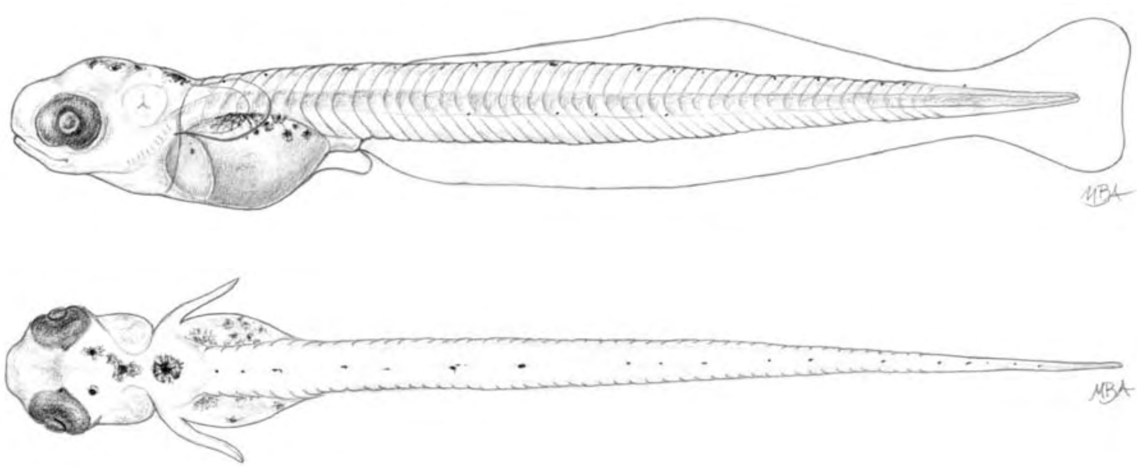


FIGURE 21-8, 21-9.—Prolarva, lateral and dorsal views, 9.3 mm TL.

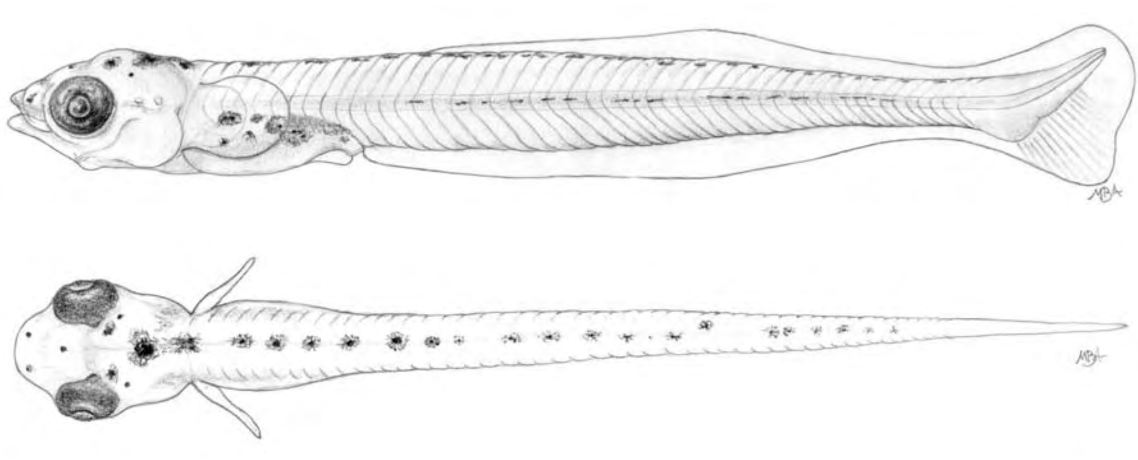


FIGURE 21-10, 21-11.—Postlarva, lateral and dorsal views, 12.8 mm TL.

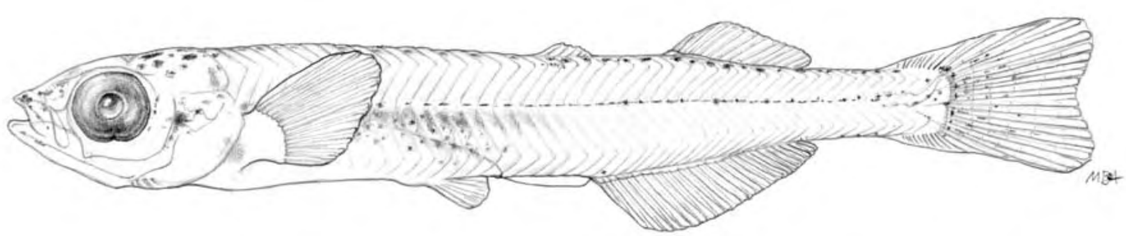


FIGURE 21-12.—Juvenile, 35 mm TL.

Atherinidae: *Leuresthes tenuis*, California grunion.

FIGURE 21-13.—Egg, late embryo, 1.6 mm diameter.

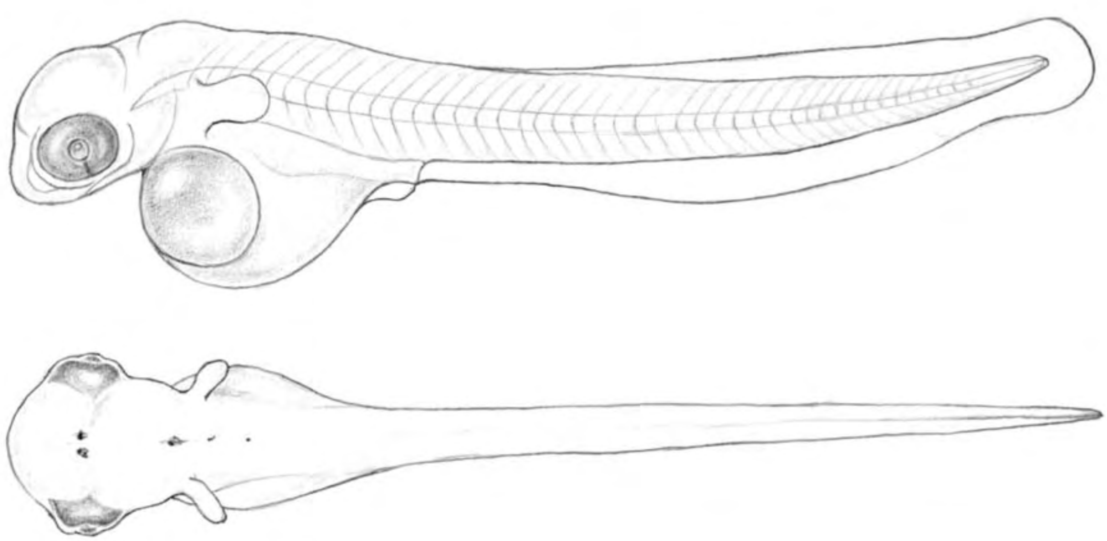


FIGURE 21-14, 21-15.—Prolarva, lateral and dorsal views, 7.8 mm TL.

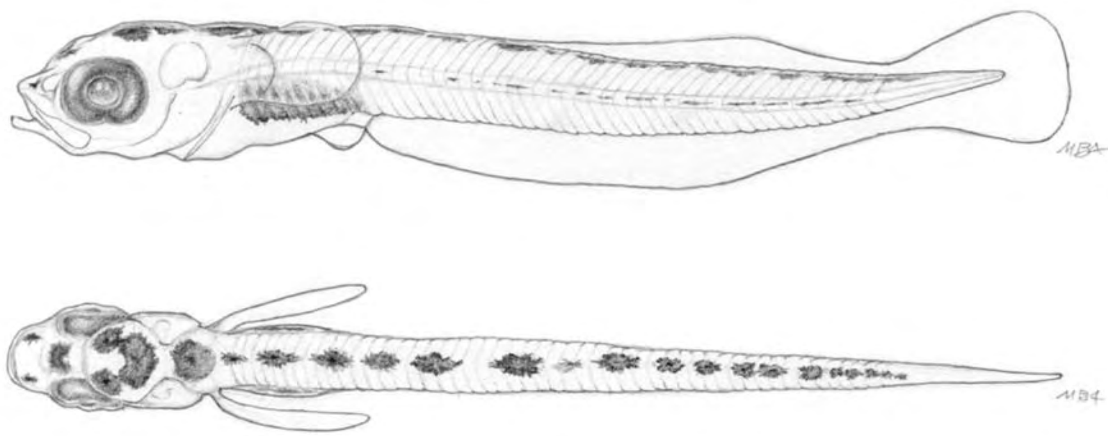


FIGURE 21-16, 21-17.—Postlarva, lateral and dorsal views, 7.8 mm TL.

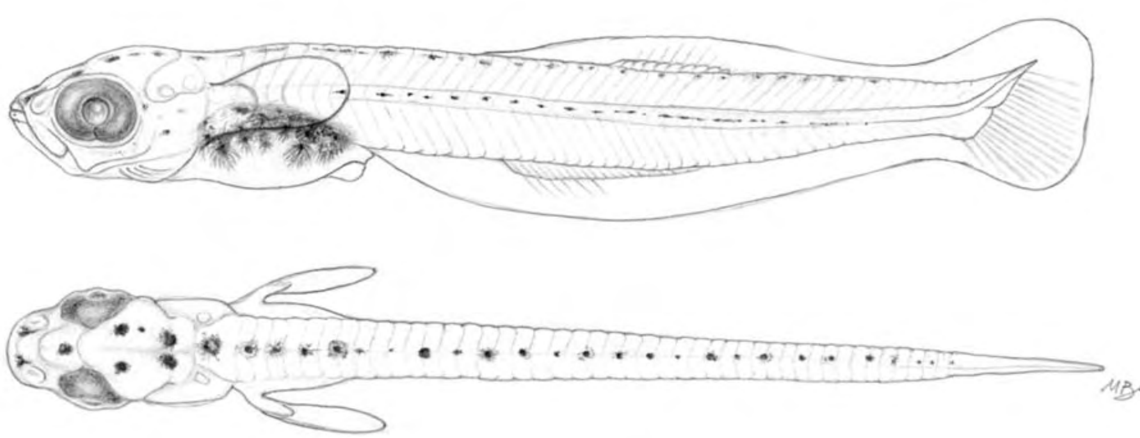


FIGURE 21-18, 21-19.—Postlarva, lateral and dorsal views, 10 mm TL.

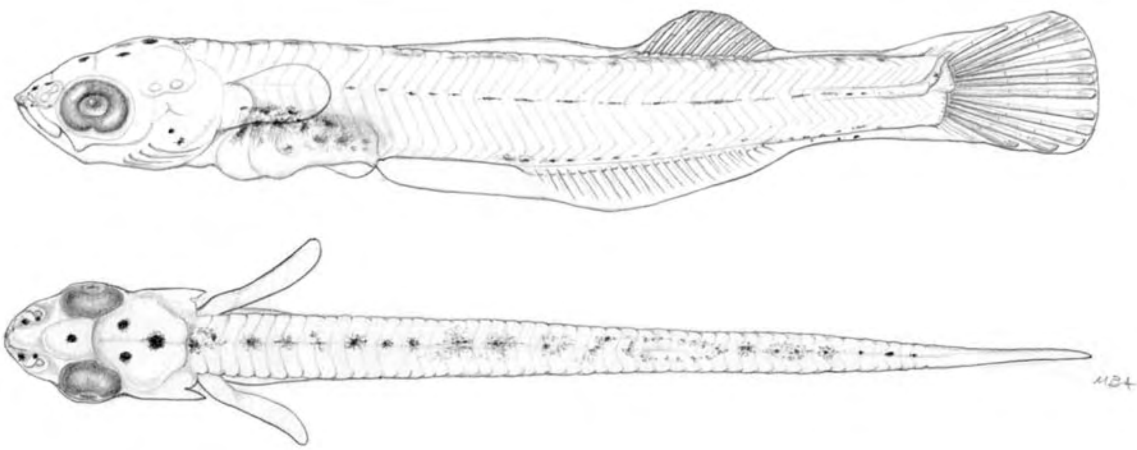


FIGURE 21-20, 21-21.—Postlarva, lateral and dorsal views, 13 mm TL.

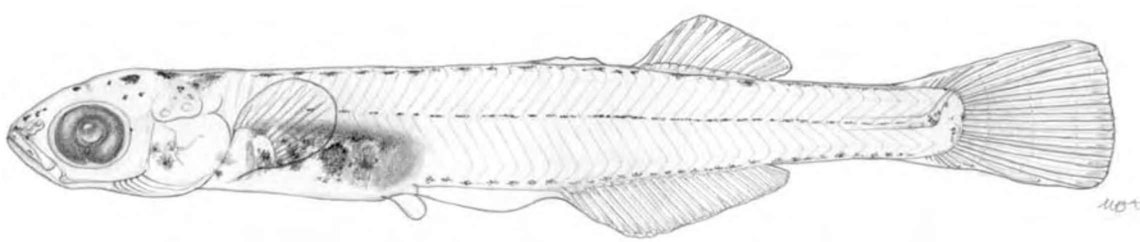


FIGURE 21-22.—Postlarva, 15 mm TL.

Atherinidae: *Menidia beryllina*, inland silverside.

FIGURE 21-23.—Egg, gastrula, 1.1 mm diameter.

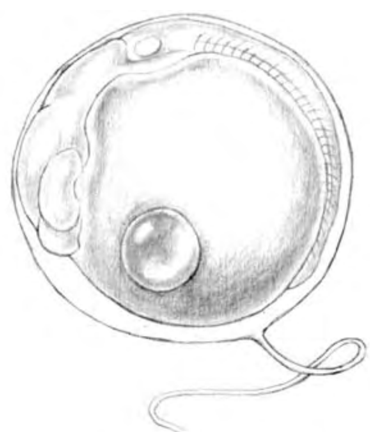


FIGURE 21-24.—Egg, early embryo, 1.1 mm diameter.

FIGURE 21-25.—Egg, late embryo, 1.1 mm diameter.

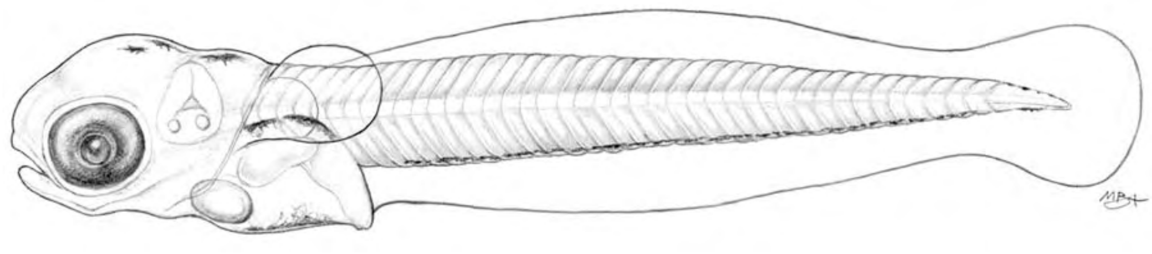


FIGURE 21-26.—Prolarva, 4.3 mm TL.

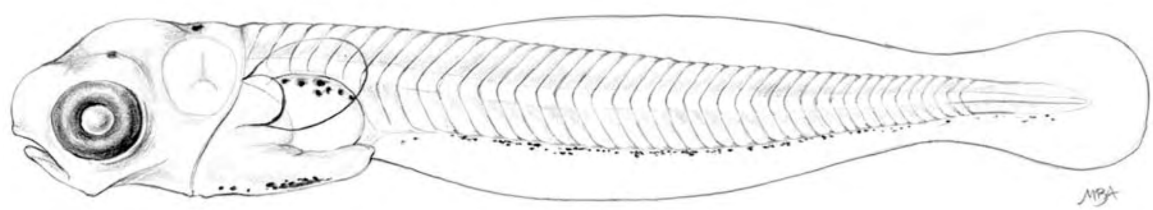


FIGURE 21-27.—Postlarva, 5.0 mm TL.

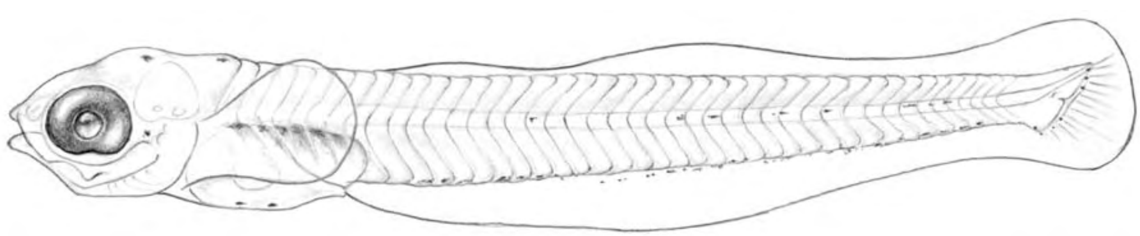


FIGURE 21-28.—Postlarva, 8 mm TL.

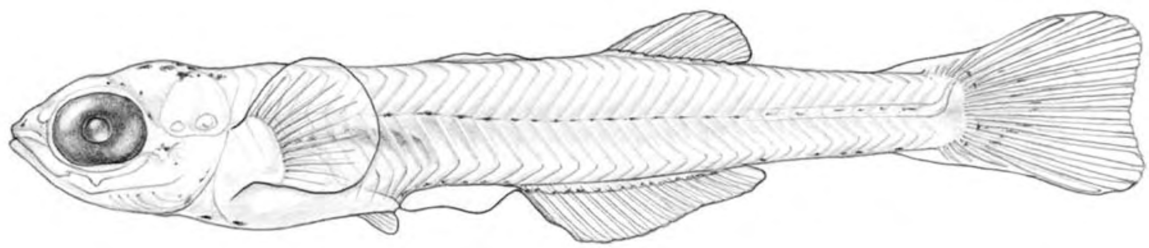


FIGURE 21-29.—Postlarva 10.5 mm TL.

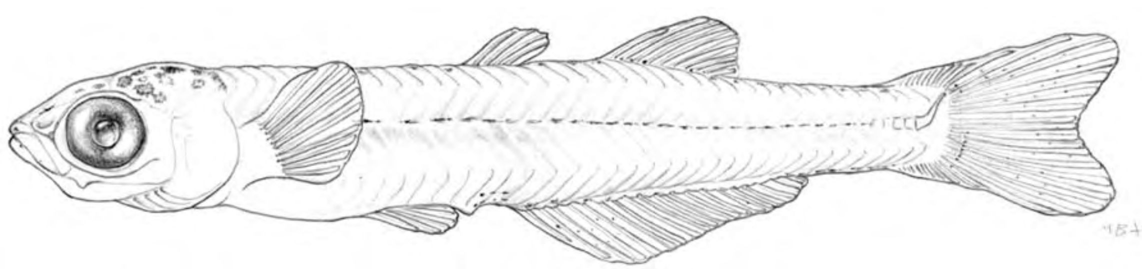


FIGURE 21-30.—Juvenile, 15.5 mm TL.

22. Gasterosteidae – Sticklebacks

Six species of sticklebacks are recognized in North America (Robins *et al.* 1980). Two of them are found in California: tube-snout, *Aulorhynchus flavidus*, a coastal marine species associated with giant kelp beds (this species was formerly in the family of Aulorhynchidae) and the threespine stickleback, *Gasterosteus aculeatus*, a widely distributed small fish. Both freshwater and anadromous forms are found in the study area. The sticklebacks are a very complicated taxonomic group; Nelson (1971) has referred to them as the *Gasterosteus aculeatus* complex.

Reference

Robins *et al.* 1980; Nelson 1971.

TUBE-SNOUT, *Aulorhynchus flavidus* Gill

SPAWNING

Location	Coastal waters of Pacific in subtidal areas, (depths 5–36 m); mostly 11–18 m (Limbaugh 1962).
Season	Occurrence of eggs and young throughout the year in southern California (Limbaugh 1962); April–June in British Columbia (Hart 1973); February–June (Fitch and Lavenberg 1968); larvae were taken from late February to late July.
Temperature	12°C (Marliave 1975).
Salinity	Seawater and in polyhaline range, such as 29 ppt (Marliave 1975).
Fecundity	Ca. 400 and greater (Fitch and Lavenberg 1975).

CHARACTERISTICS

EGGS

Shape	Spherical to oval (Limbaugh 1962).
Diameter	2.0 mm (Limbaugh 1962).
Yolk	Pale honey-tan to brownish-orange to dark reddish-amber (Orton 1955); pink (Hart 1973).
Oil globule	Single large oil globule, with several small oil globules (Limbaugh 1962).
Chorion	Firm and thick; ca. 0.08 mm (Marliave 1975).
Perivitelline space	–

Egg mass	Deposited in small clusters (Limbaugh 1962); in globular clusters (Hart 1973).
Adhesiveness	Adhesive to each other but not to substrate (Limbaugh 1962).
Buoyancy	Slightly negative (Marliave 1975).

LARVAE (Figure 22-1, 22-2)

Length at hatching	5.5–7.0 mm TL (Limbaugh 1962); 8.0 mm TL (Marliave 1975).
Snout to anus length	Ca. 60% of TL of prolarvae at 6.5–6.9 mm TL; 65% of postlarvae at 15.2 mm TL.
Yolk sac	Pale yellowish to a slightly greenish-yellow (Limbaugh 1962); large, elongate, extends from thoracic to abdominal region.
Oil globule	Single, large, located in anterior portion of yolk sac.
Gut:	Straight and thick.
Air bladder	Oval and near pectoral fin (Marliave 1975).
Teeth	Small, pointed, apparent in postlarval stage.
Total myomeres	52–54.
Preanal myomeres	28–30.
Postanal myomeres	24–26.
Last fin(s) to complete development	Spiny dorsal fin.
Pigmentation	A series of larger stellate melanophores on the dorsal surface of gut and smaller melanophores on the dorsal surface of gut and smaller melanophores along midventral region; scattered melanophores are also found in postanal region. Just behind anal region a series of dashed melanophores located above, below, and on side of notochord. These serial melanophores extend to the caudal region in the late postlaval stage.
Distribution:	Planktonic drifting (Marliave 1975); found to be planktonic in Elkhorn Slough and Moss Landing Harbor.

JUVENILES

Dorsal fin	XXIII–XXVI, 9–11 (Miller and Lea 1972); XXIV–XXVII, 9–10 (Hart 1973).
Anal fin	I, 9–10 (Miller and Lea 1972); I, 9 (Hart 1973).
Pectoral fin	Ca. 10 (Hart 1973); 10.

Mouth	Terminal, duck-billed or tube-like.
Vertebrae	53–55 (Clothier 1950); 54–56 (Miller and Lea 1972).
Distribution	Shallow coastal bottom waters, associated with the distribution of giant kelp (Marliave 1975). Shallow embayments and sloughs.

LIFE HISTORY

The tube-snout is found in coastal waters from Point Rompiente, Baja California, to Sitka, Alaska (Jordan and Evermann 1896–1900, Fitch 1952, Miller and Lea 1972). In the San Francisco area this species was first recorded by Bean (1881) and later by Ruth (1964). In this study, the tube-snout was not collected in San Francisco Bay, but was found in Elkhorn Slough and Moss Landing Harbor.

Spawning probably occurs throughout the year in southern California (Limbaugh 1962), and in the northern range spawning is reported in spring and summer (Hart 1973). Male fish construct a nest at an average depth of about 10–20 m (Limbaugh 1962). The nests are made generally of *Macrocystis*, though other kelps and seaweeds are used. The male tube-snout binds the kelp together with strong, silvery, weblike strands extruded from his urogenital region (Limbaugh 1962). The egg masses are laid so that they encircle the stipe and base of the pneumatocysts of the kelp. The eggs are very adhesive to each other but not to the substrate on which they are spawned. The males guard the nesting area. Tube-snout eggs have been hatched in the laboratory in 10–14 days at 12°C and 29 ppt salinity (Marliave 1975). The spawning habits of the tube-snout have led to the theory that this species deliberately selects the delicate growing tips of algae as spawning sites (Marliave 1975). During storms, the growing tips are often torn from the plant, and therefore the egg mass attached to algal tip can be dispersed from the spawning site. This dispersal mechanism enchances the chances of a wider distribution for the species (Marliave 1976).

Larvae have a very short planktonic life. In the laboratory, newly hatched larvae will stay on the surface for a short time and then descend to the bottom within hours (Marliave 1975). In the ocean the planktonic life of the larvae is probably as short as the laboratory observations, reinforcing the importance of the egg dispersal mechanism theory.

The habitat of the juvenile tube-snout is assumed to be the same as that of the adult. They are found inshore, in sheltered bays, generally in water no more than 100 feet deep. The preferred depth seems to be approximately 30–40 feet (Limbaugh 1962). Juveniles feed strictly on living organisms, including small planktonic crustaceans and small fish larvae (Limbaugh 1962, Hart 1973).

The tube-snout matures, spawns, and dies within one year (Fitch and Lavenberg 1975). This species has no sport or commercial value, but they are important as forage for kelp bass, lingcod, and other predators which live in the kelp bed community (Fitch and Lavenberg 1975).

References

Bean 1881, Clothier 1950, Fitch 1952, Fitch and Lavenberg 1975, Hart 1973, Jordan and Evermann 1896–1900, Limbaugh 1962, Marliave 1975, 1976, Miller and Lea 1972, Orton 1955, Ruth 1964.

THREESPINE STICKLEBACK, *Gasterosteus aculeatus* (Linnaeus)

SPAWNING

Location	Shallow weedy areas of the Sacramento-San Joaquin Estuary, adjacent coastal streams, bays, and sloughs. Particular locations where spawning was observed include San Ramon Creek below the spill pool of San Ramon; Walnut Creek near Civic Drive; Hillcrest Community Park; Wilton Slough; Suisun Creak near Lake Curry; Aquatic Park near Berkeley; Pine Gulch Creek near Bolinas; Walker Creek of Tomales Bay, and Upper Elkhorn Slough.
Season	May–July (Kuntz and Radcliffe 1917); February–August (Vrat 1949); April–July (Moyle 1976); March–October.
Temperature	15.8–18.5°C (Vrat 1949); male fish exhibits breeding color at ca. 12°C. Spawning occurs at ca. 15°C and more larvae are observed at 18°C and greater.
Salinity	Freshwater and brackish water (Bigelow and Schroeder 1953; Altman and Dittmer 1962); freshwater to mesohaline.
Substrates	Twigs and debris (Scott and Crossman 1973); strands of algae and pieces of aquatic plants (Moyle 1976); fragments of aquatic plants, algae, and debris.
Fecundity	Each female deposits 50–300 eggs in several spawnings (Moyle 1976); 50 (Tinbergen 1952); 292 (Hagan 1967); less than 100 (Livingstone 1951); 100–150 per batch (Bigelow and Schroeder 1953); up to 600 eggs in one nest (probably spawned by several females) (Scott and Crossman 1973); mostly less than 100 and more than 50 per batch.

CHARACTERISTICS

EGGS (Figure 22-3, 22-4, 22-5)

Shape	Spherical (Kuntz and Radcliffe 1917, Vrat 1949).
Diameter	1.5–1.9 mm (Vrat 1949); 1.5–1.7 mm (Kuntz and Radcliffe 1917, this study).

Yolk	Yellowish to light tan, semi-opaque (Kuntz and Radcliffe 1917, Brinley 1938, Swarup 1958); yellowish, smooth.
Oil globule	Numerous oil globules (Kuntz and Radcliffe 1917). Several large oil globules ca. 0.3–0.4 mm in diameter and many smaller ones. All oil globules gradually consolidate into one oil globule as development proceeds.
Chorion	Transparent (Vrat 1949); tough (Swarup 1958); thick and elastic.
Perivitelline space	Very narrow, ca. 0.05–0.01 mm in width.
Egg mass	Deposited in clusters (Vrat 1949); each batch is in a small cluster.
Adhesiveness	Highly adhesive to each other but not to substrates (Vrat 1949, Bigelow and Schroeder 1953).
Buoyancy	Demersal (Brinley 1938, Battle 1944).

LARVAE (Figure 22-6, 22-7, 22-8, 22-9, 22-10)

Length at hatching	4.2–4.5 mm TL (Kuntz and Radcliffe 1917); 4.7–4.9 mm SL (Vrat 1949); ca. 5.0–5.5 mm TL.
Snout to anus length	Ca. 54–59% of TL for both prolarvae and postlarvae.
Yolk sac	Large, spherical to oval, extends form jugular to abdominal region.
Oil globule	Single, located in anterior portion of the yolk sac.
Air bladder	Large, elongate, just behind the pectoral fin.
Teeth	Small, pointed teeth in one row, apparent in postlarvae.
Size at completion of yolk-sac stage	Ca. 6.5 mm TL.
Total myomeres	29–32.
Preanal myomeres	15–17.
Postanal myomeres	14–16.
Last fin(s) to complete development	Spiny dorsal fin.
Pigmentation	Pigmentation is heavy for larval threespine stickleback. In prolarvae there are dense melanophores on cephalic and middorsal regions. Melanophores are also found in midventral and postanal regions. In postlarvae, heavy melanophores are all over the head and body and form 7–9 darker blotches on the side of body.

Distribution	Planktonic, in pools which have aquatic vegetation, or among vegetation near inshore.

JUVENILES (Figure 22-11)

Dorsal fin	II–III, I, 10–13 (Miller and Lea 1972); III–VI, 10–14 (Scott and Crossman 1973); III, 11–12 (Hart 1973).
Anal fin	I, 7–12 (Miller and Lea 1972); I, 8–10 (Scott and Crossman 1973); I, 8–9 (Hart 1973).
Pectoral fin	10 (Hart 1973) 10–11.
Mouth	Terminal and slanting upward (Moyle 1976); terminal, small, oblique.
Vertebrae	30–33 (Miller and Lea 1972); 29–33 (Scott and Crossman 1973); 31–33.
Distribution	Widely distributed in the Sacramento-San Joaquin Estuary and river system in landlocked condition. It has been observed in Millerton Lake and Kerckhoff Lake. They are also common in Tomales Bay, Moss Landing Harbor and Elkhorn Slough, and coastal streams.

LIFE HISTORY

Threespine stickleback are widely distributed throughout the northern hemisphere (Livingston 1951, Scott and Crossman 1973). Although threespine stickleback are most often taken in estuarine waters (Bigelow and Schroeder 1953), specimens are often found in the ocean, and spawning often occurs in freshwater. In the Pacific this species is known from Baja California (Barraclough 1967) to the Bering Sea (Wilimovsky 1954, 1964) and to Japan (Okada 1955). In California, they have been recorded from coastal streams, the Central Valley, and many reservoirs (Moyle 1976). In this study, the threespine stickleback was observed throughout the Sacramento-San Joaquin Estuary and river system and in adjacent bays, sloughs, and coastal streams.

The threespine stickleback is probably one of the most studied fish by fishery biologists and behaviorists. As a result of their fascinating social and mating behavior, an enormous amount of descriptive material can be found in the literature. The following description is a summary of the early life history of this species.

Spawning occurs from March through October. Male fish develop brilliant dark green and orange-red spawning coloration as early as March, when the water temperature reaches about 12–15°C. Male fish will retain their breeding color for a month after spawning season. In the laboratory, the male stickleback will exhibit spawning colors off and on throughout the year if kept at room temperature. As the spawning period approaches the male fish builds a nest. A nest may be an irregular cocoon shape, with an opening at each end, or just a simple pad with a hollow sandy pit below the pad. Nests are built with a combination of plant fragments and renal secretions (Greenbank and Nelson 1959). After the courtship ritual, the female fish deposits her eggs in the nest and then is driven away by the male. The male then enters the nest, fertilizes the eggs and loosens the top of the nest to enhance ventilation. Eggs, in small clusters, are highly adhesive to each other but not to the substrate (Vrat 1949). Eggs are embedded in the nest or underneath the pad. The male often assumes a head-stand posture at one end of the nest and circulates water over the eggs by fanning his pectoral fins (Moyle 1976). He is also known to clean the eggs with his mouth. When the hatching time approaches, he tears down the nest (Bigelow and Schroeder 1953). The egg clusters are crushed and the individual eggs scattered. This may be an important spawning strategy: the individual eggs may have a better chance to hatch out than the clustered eggs, in which the inner layer eggs will often die of suffocation. Eggs will hatch in 7 days at 19°C (Breder and Rosen 1966); in this study, eggs hatched out in the laboratory in seven days at 18–20 °C.

The threespine stickleback is a multiple spawner during the breeding season. Under ideal laboratory control conditions (21–23°C, proper aeration and feeding, and ample breeding space and substrates), a pair can spawn six times within an interval of 10–15 days. Some males will desert the nest during the incubation period, and therefore hatching success is dependent on the male.

Newly hatched larvae were guarded continuously by the male for several days. The larvae stay near the bottom after hatching. As the larvae achieve full swimming ability, they disperse into shallow water with dense vegetation. They school with fish of similar size, of their species and of different species. This may explain why so few threespine stickleback larvae were collected in the open water plankton tows.

Juveniles, equipped with armed plates and spines, emerge from the vegetation into open pools and form loose aggregations. In some creeks, such as San Ramon Creek, the channelized section of Walnut Creek, Newark Slough, the lower stretch of Alameda Creek, and Pine Gulch Creek, threespine stickleback are so plentiful that they dominate the fish community. The number of juveniles reaches a peak in late summer and then drastically declines in the fall. It is unknown at the present time whether juveniles the eastern Pacific migrate toward the sea, as described by Igarashi (1970) in Japan, or if massive mortality occurs because of overcrowding. Moyle (1976) states that the ecological relationship between freshwater forms and anadromous forms ranges from complete separation to complete interbreeding. The behavior of each group can vary to a large extent as well.

Juvenile stickleback are active feeders. Food items include aquatic insects, insect larvae, eggs, and larval fish for the freshwater form (Hagen 1967) and mostly free-swimming crustaceans for the anadromous form (Barraclough and Fulton 1967, 1968; Barraclough *et al.* 1968; Moyle 1976). Stickleback are eaten by salmonids, other predator fishes, and seabirds (Hart 1973, Scott and Crossman 1973, Moyle 1976).

In California, most threespine stickleback reach maturity within one year, and some individuals may live up to 2–3 years (Moyle 1976). This study fully supports Moyle's observations. Large recruitment was observed in the late summer, consisting of young both from older fish and from the young of the year. The threespine stickleback has no commercial value, but as mentioned before, it is an important species to biologists.

References

Altman and Dittmer 1962; Barraclough 1967; Barraclough and Fulton 1967, 1968; Barraclough *et al.* 1968; Battle 1944; Bigelow and Schroeder 1953; Breder and Rosen 1966; Brinley 1938; Greenbank and Nelson 1959; Hagen 1967; Hart 1973; Igarashi 1970; Kuntz and Radcliffe 1917; Livingstone 1951; Miller and Lea 1972; Moyle 1976; Okada 1955; Scott and Crossman 1973; Swarup 1958; Tinbergen 1952; Vrat 1949; Wilimovsky 1954, 1964.

Characteristic Comparison: Sticklebacks

Characteristic	**Tube-Snout**	**Threespine Stickleback**
Eggs		
Shape	Spherical to oval	Spherical
Diameter (mm)	2.0	1.5–1.7
Spawning location	Beds of giant kelp	Bays, estuaries, freshwater
Salinity	Seawater	Freshwater-brackish water
Larvae		
Snout	Elongate	Short
Pigmentation	Series of melanophores located behind the anal region surrounding the notochord	Pigmentation generally heavy over entire body
Juveniles		
Dorsal fin	XXIII–XXVII, 9–11	II–III, I, 10–14
Anal fin	I, 9–10	I, 7–12
Pectoral fin	10	10–11
Vertebrae	53–56	29–33
Mouth	Tube-like	Normal

Figure 22.—Gasterosteidae: *Aulorhnchus flavidus*, tube-snout.

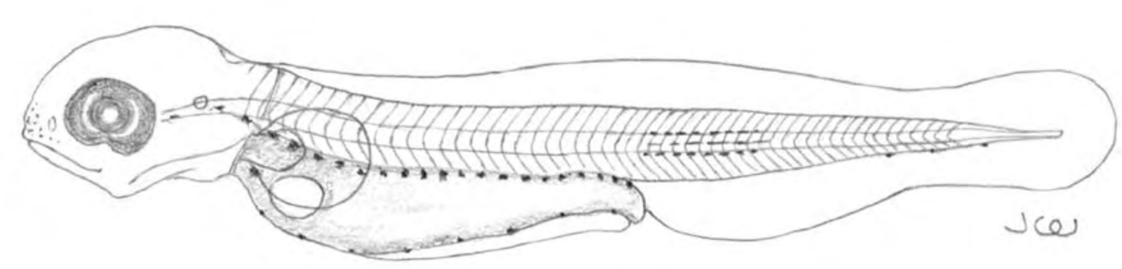


FIGURE 22-1.—Prolarva, 6.5 mm TL.

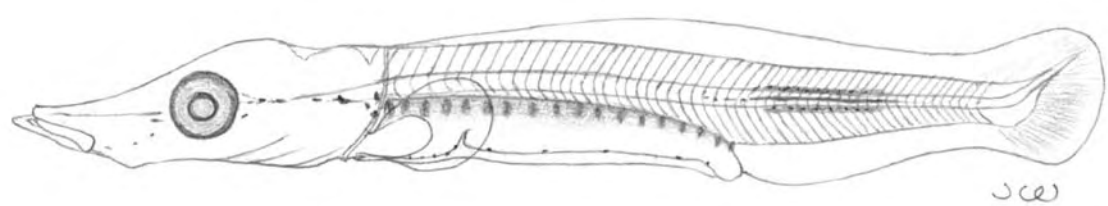


FIGURE 22-2.—Postlarva, 14.3 mm TL.

Gasterosteidae: *Gasterosteus aculeatus*, threespine stickleback.

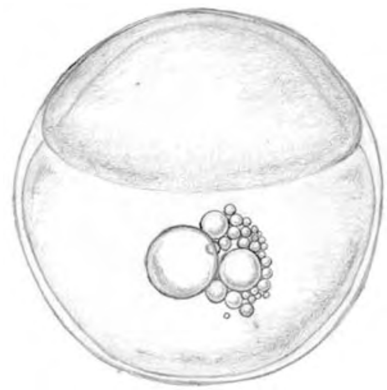


FIGURE 22-3.—Egg, morula, 1.7 mm diameter.

FIGURE 22-4.—Egg, late embryo, 1.7 mm diameter.

FIGURE 22-5.—Egg, late embryo, 1.7 mm diameter.

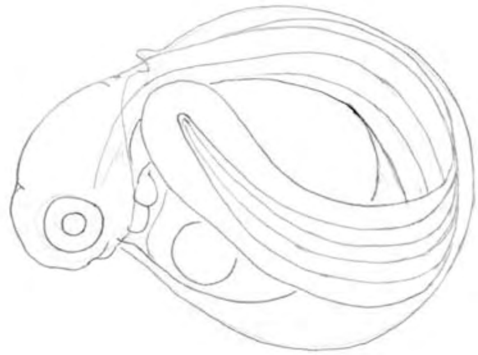


FIGURE 22-6.—Hatching.

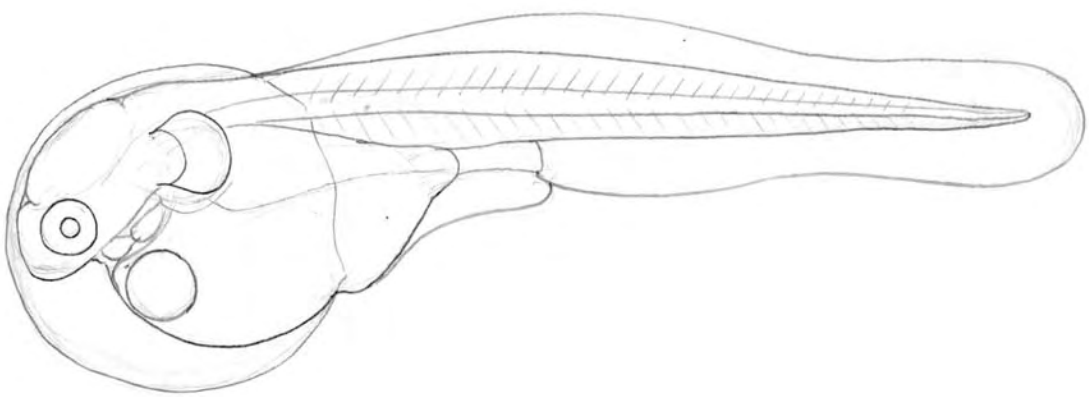


FIGURE 22-7.—Hatching

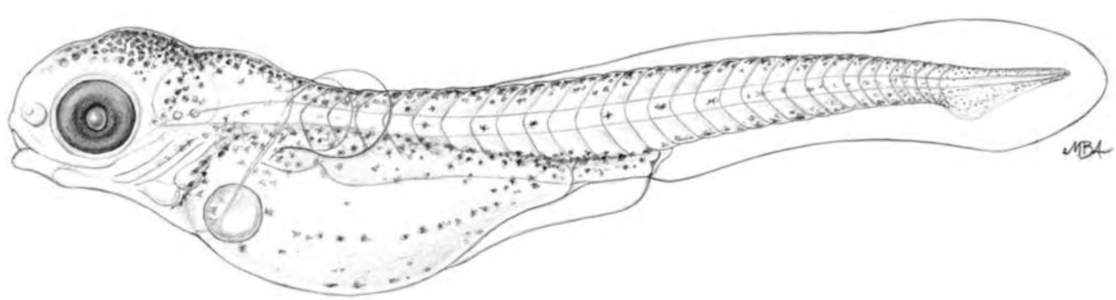


FIGURE 22-8.—Prolarva, 6.6 mm TL.

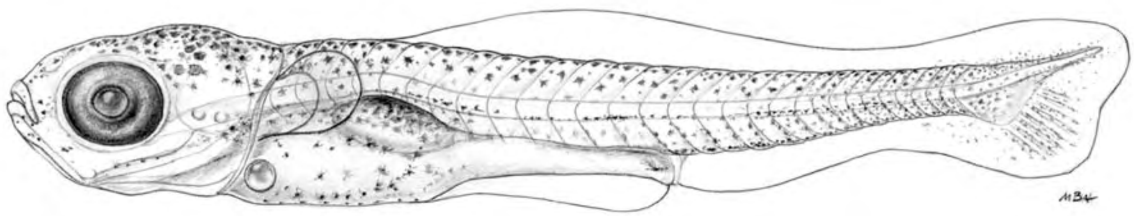


FIGURE 22-9.—Postlarva. 6.6 mm TL.

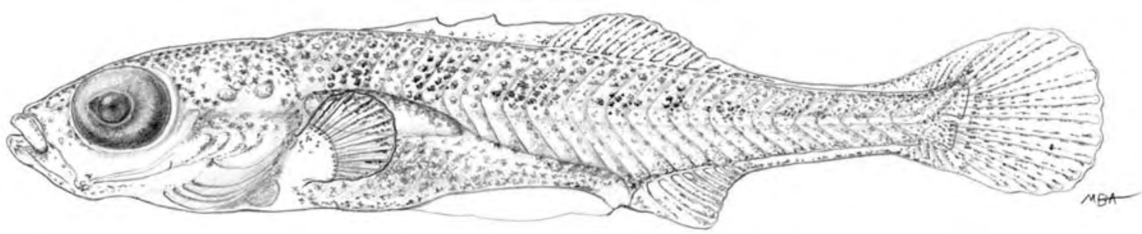


FIGURE 22-10.—Postlarva, 9.2 mm TL.

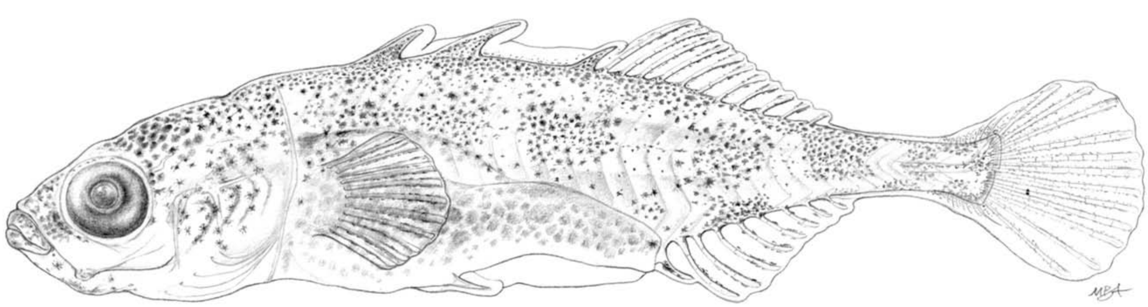


FIGURE 22-11.—Juvenile, 14.5 mm TL.

23. Syngnathidae – Pipefishes and Seahorses

Two species of pipefishes are known to the study area: the kelp pipefish, *Syngnathus californiensis*, and the bay pipefish, *Syngnathus leptorhynchus* (Miller and Lea 1972, Fritzsche 1980). Specimens used for descriptions in this manual have been collected from San Francisco Bay, San Pablo Bay, and Suisun Bay, and are believed to be the bay pipefish. A few specimens of kelp pipefish were taken in Moss Landing Harbor-Elkhorn Slough. These latter specimens are not discussed.

References

Fritzsche 1980, Miller and Lea 1972.

BAY PIPEFISH, *Syngnathus leptorhynchus* (Girard)

SPAWNING

Location	Shallow water with eelgrass, algae, and other types of vegetation in the estuary and embayments.
Season	Males carry young in August (Clemens and Wilby 1961); males carry eggs in May and young in August (Hart 1973); mating in May and June (Moyle 1976); eggs and larvae were found in the male pouch from February through November.
Temperature	Ca. 15°C (judging by the time at which male fish were found to be incubating eggs).
Salinity	Seawater to mesohaline.
Fecundity	Up to 225 eggs deposited in the males pouch (Bane and Bane 1971); 2–3 distinctive developmental stages of eggs were found in a male's pouch, which could have been from different female fish.

CHARACTERISTICS

EGGS (removed from male pouch; Figure 23-1)

Shape	Spherical to oval.
Diameter	Ca. 1.0–1.5 mm.
Yolk	Bright yellow, smooth.
Oil globule	One or a few large oil globules (0.4–0.5 mm in diameter) with several to many small oil globules (less than 0.01 mm in diameter).

Chorion	Transparent to translucent.
Perivitelline space	Very narrow.
Egg mass	Adhesive.
Buoyancy	Demersal (in male brood pouch).

LARVAE (removed from male pouch)

Length at hatching	Ca. 4.5–5.0 mm TL.
Snout to anus length	Ca. 35–40% of TL of larvae at 4.5–5.0 mm TL.
Yolk sac	Very large, spherical, bright yellow, in thoracic region.
Oil globule	Many oil globules.
Gut	Straight.
Air bladder	Small, shallow, near pectorals.
Teeth	None.
Size at completion of yolk-sac stage	Ca. 10 mm TL at the time of birth.
Total myomeres	57–63.
Preanal myomeres	16–19.
Postanal myomeres	39–44.
Last fin(s) to complete development	Anal (only female fish has anal fin).
Pigmentation	Newly hatched larvae in the pouch have little pigmentation. Melanophores gradually covered head and body and formed ca. 20+ vertical blotches.

JUVENILES (Figure 23-2)

Dorsal fin	28–37 (Herald 1941); 35–44 (Bane and Bane 1971); 28–44 (Miller and Lea 1972).
Anal fin	3–5 (Miller and Lea 1972); 5 in female fish (Hart 1973).
Pectoral fin	Ca. 15 (Hart 1973).
Mouth	Terminal, minute, directed somewhat upward (Hart 1973); mouth, small, snout tubular (Bane and Bane 1971).
Vertebrae	56–64 (Miller and Lea 1972).
Distribution	Shallow waters with eel grass, kelp beds, filamentous algae, pilings, and other substrates; in San Francisco Bay up to Suisun Bay; Moss Landing Harbor–Elkhorn Slough; Tomales Bay.

LIFE HISTORY

The bay pipefish ranges from Bahia Santa Maria, Baja California, to southeastern Alaska (Herald 1941, Wilimovsky 1954 Fritzsche 1980) and is known to inhabit both marine and estuarine environments. Specimens have been observed from San Francisco Bay (Ganssle 1966) up to the freshwater portion of Suisun Bay (this study). The bay pipefish has often been referred to as a subspecies of the kelp pipefish, *Syngnathus californiensis* (Herald 1941). Both Miller and Lea (1972) and Fritzsche (1980) reconfirmed the bay pipefish as a separate species, *Syngnathus leptorhynchus*.

Clemens and Wilby (1961) reported that bay pipefish spawn from May through August. In this study, the eggs and larvae were observed in the male pouches from February through November. The presence of eggs in various development stages in the same pouch suggests that a male may accept egg deposits from more than one female fish, at different times (R.A. Fritzsche 1981, personal communication; this study).

The incubation of the eggs and development of the larvae are completed in the male pouch in 8–15 days (Bane and Bane 1971) or 2–3 weeks, depending on the water temperatures (Moyle 1976). When the offspring are ready to be released, they have developed into the early juvenile stage.

Juvenile and adult bay pipefish are slow swimmers, and are usually observed in a horizontal or oblique position when kept in an aquarium. In the field, they are often found associated with eel grass in the intertidal areas; they are also captured by plankton nets in the open water of Suisun Bay. Pipefish have small tubular mouths and feed on live crustaceans (Moyle 1976). The bay pipefish has no major commercial or sport value. Some syngnathids are dried and used for medical purposes by the Chinese and sold locally in Chinatown, San Francisco.

References

Bane and Bane 1971; Clemens and Wilby 1961; Fritzsche 1980; Hart 1973; Herald 1941; Miller and Lea 1972; Moyle 1976; Wilimovsky 1954.

Figure 23.—Syngnathidae: *Syngnathus leptorhynchus*, bay pipefish.

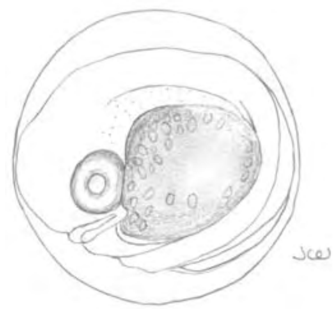


FIGURE 23-1.—Dissected egg, 1.4 mm diameter.

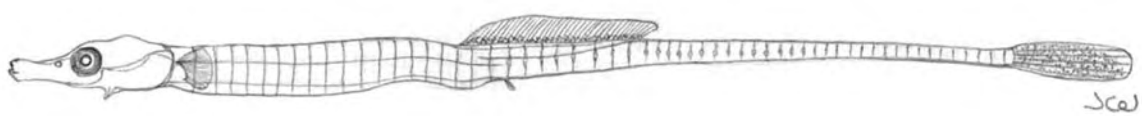


FIGURE 23-2.—Juvenile, 47 mm TL.

24. Percichthyidae – Temperate Basses

Two members of this family have been introduced into California: the striped bass, *Morone saxatilis*, and the white bass, *Morone chrysops*. Striped bass are one of the most abundant fish found in the Sacramento-San Joaquin River system. White bass were introduced into Nacimiento Reservoir in San Luis Obispo County (von Geldern 1966), but do not inhabit the Sacramento-San Joaquin River system and are not discussed.

References

von Geldern 1966.

STRIPED BASS, *Morone saxatilis* (Walbaum)

SPAWNING

Location	Delta region (Scofield 1931); lower Sacramento and San Joaquin Rivers, Piper Slough, Three Mile Slough, Three Mile Slough-Big Creek (Hatton 1940); Fisherman's Cut, Middle River, lower Mokelumne, vicinity of Marysville of Sacramento River, and vicinity of San Joaquin City of San Joaquin River (Woodhull 1947); mouth of Middle River, lower part of Old River, False River, Rio Vista to Verona, and Suisun Slough (Chadwick 1958); Rio Vista to Butte City of Sacramento River, Antioch to Venice Island, and Stockton to Mossdale of San Joaquin River (Farley 1966); lower reaches of the Sacramento and San Joaquin Rivers, Suisun Bay.
Season	April–May (Scofield 1931); April–June (Erkkila *et al.* 1950, Calhoun *et al.* 1950, Chadwick 1958, Moyle 1976); mostly in May (Farley 1966); April–July.
Temperature	14.4–23.9°C (Scofield 1931, Calhoun *et al.* 1950); ca. 19.5–20.0°C (Woodhull 1947); 15.6–19.4°C (Raney 1952); 14.4–15.6°C (Chadwick 1958); started at 14.4–15.0°C with most eggs collected at 16.1–20.6°C (Farley 1966); 15.6–20.0°C (Moyle 1976); bulk of spawn at 15.0–18.0°C.
Salinity	Brackish water. (Woodhull 1947); freshwater (Raney 1952); mostly in tidal freshwater.
Substrates	None.
Fecundity	11,000–2,000,000 (Moyle 1976); up to 5,300,000 (Hollis 1967); wide difference of estimation because

of mature and immature eggs and different sizes of female fish (Hardy 1978b).

CHARACTERISTICS

EGGS (Figure 24-1, 24-2, 24-3, 24-4)

Shape	Spherical (Pearson 1938, Woodhull 1947).
Diameter	3.2 mm (Murawski 1969) to 4.3 mm (Albrecht 1964). For California population: mean diameter 3.3 mm (Woodhull 1947); range 3.4–4.2 mm.
Yolk	Heavily granulated (Pearson 1938); lightly granulated (Hardy 1978b); smooth to granulated.
Oil globule	Single, 0.56 mm in diameter (Pearson 1938); 0.40–0.85 mm in diameter (Pearson 1938); sometimes with several additional globules (Hardy 1978b); single, and located opposite of blastoderm; the embryo is suspended in upside down position.
Chorion	Transparent (Pearson 1938); smooth and transparent.
Perivitelline space	Wide, ca. 65–85% of egg diameter (Mansueti 1958, 1964).
Egg mass	Broadcast singly into water.
Adhesiveness	Nonadhesive (Pearson 1938).
Buoyancy	Slightly heavier than freshwater (Raney 1952); suspended near bottom (less than 2 m) (Woodhull 1947); live eggs near bottom and dead eggs close to surface.

LARVAE (Figure 24-5, 24-6, 24-7)

Length at hatching	2.5 mm TL (Pearson 1938); 2.0–3.7 mm TL (Mansueti 1958); 1.7–3.0 mm TL (Lippson and Moran 1974); 2.9–5.0 mm TL (Wang and Kernehan 1979); ca. 3.0–4.0 mm TL in field collections.
Snout to anus length	74% of TL of larvae at 2.5–3.0 mm TL; 55% of TL of larvae at 5.6–6.0 mm TL (Mansueti 1958); ca. 51–59% of TL of both prolarvae and postlarvae.
Yolk sac	Protudes forward past head or at least anterior to eye (Pearson 1938); large, oblong, with cylindrical head recess.
Gut	Intestine distinctly folded (Hardy 1978b); initially straight, and then becoming S-shaped because of the expansion of the air bladder.

Air bladder	Shallow, located near pectoral fin in prolarvae; shifting to midway between pectorals and anus in postlarvae.
Teeth	Sharp, conical, apparent in prolarvae (Mansueti 1958).
Size at completion of yolk-sac stage	5.0–6.5 mm TL (Manueti 1958); mostly 6.0–7.0 mm TL; some variation of individuals.
Total myomeres	17–25, with an average of 22 (Mansueti 1958); 22–25, usually 24.
Preanal myomeres	8–13 (Mansueti 1958); 11–13, with mean of 12 (Hardy 1978b); 11–13 and mostly 12 for postlarvae in the Sacramento-San Joaquin Estuary.
Postanal myomeres	9–13 (Mansueti 1958); 11–13 and mostly 12 for postlarvae in the Sacramento-San Joaquin Estuary.
Last fin(s) to complete development	Pelvic.
Pigmentation	In prolarvae, scattered melanophores on entire body, more along yolk sac and in postanal region; in postlarvae, large stellate melanophores found in lower jaw, isthmus, thoracic, dorsal portion of gut, and postanal regions.
Distribution	Both shallow and open waters of the lower reaches of the Sacramento and San Joaquin Rivers, the Delta, Suisun Bay, Montezuma Slough, and Carquinez Strait.

JUVENILES (Figure 24-8)

Dorsal fin	West Coast population: IX, I–II, 12 (Miller and Lea 1972); VIII–X, I, 10–13 (Hardy 1978b). In Chesapeake Bay, Atlantic coast: IX, 10–14 (Hardy 1978b); IX–X, I, 11–12 (Hildebrand and Schroeder 1928).
Anal fin	West Coast population: III, 9–11 (Miller and Lea 1972); III, 7–13 (Hart 1973). In Chesapeake Bay, Atlantic Coast: III, 9–12 (Hardy 1978b); III, 10–11 (Hildebrand and Schroeder 1928).
Pectoral fin	West Coast population: 16–17 (Miller and Lea 1972); 15–17 (Hart 1973). In southeast U.S., including Chesapeake Bay: 13–19 (Raney and Woolcott 1955).
Mouth	Large, oblique, lower jaw projecting, maxillary extending to the middle of eye (Hildebrand and

	Schroeder 1928); terminal for small juveniles, lower jaw gradually projecting in later stages.
Vertebrae	24–25 (Truitt 1936, Merriman 1940); 25 (Mansueti 1958, Miller and Lea 1972, Fritzsche and Johnson 1980); 24 (Scott and Crossman 1973).
Distribution	The Sacramento-San Joaquin Estuary, O'Neill Forebay, San Luis Reservoir, some irrigation ditches in Delta and Central Valley. Juvenile striped bass have been stocked in Millerton Lake and large reservoirs elsewhere by the CDFG (Moyle 1976).

LIFE HISTORY

The striped bass, an anadromous fish, inhabits marine and estuarine waters from the St. Lawrence River to the St. Johns River, Florida, and along the Gulf Coast to Louisiana (Raney 1952). They were introduced to California in 1879 and 1882 (Scofield 1931, Skinner 1962, Moyle 1976). On the West Coast, the striped bass has been recorded from slightly south of the California-Mexico border to Barkley Sound, British Columbia (Miller and Lea 1972). In this study, this species was taken from the Sacramento and San Joaquin Rivers to San Francisco Bay, including the Delta. They were also found in O'Neill Forebay, San Luis Reservoir, and Millerton Lake. Along the coast, striped bass were collected at Moss Landing Harbor-Elkhorn Slough and in Tomales Bay.

Spawning occurs from April through June (Chadwick 1958). In this study, in 1978 and 1979 eggs and prolarvae were collected in July, so apparently the spawning season can extend into midsummer. Chadwick (1958) found the spawning peak of striped bass to be in early May in the San Joaquin River and Delta, but in late May or early June in the Sacramento River. A similar situation was observed in this study. Warmer water temperatures in the Delta and lower San Joaquin River (as much as 5°C higher in the lower San Joaquin River) probably promotes the early spawn. Turner (1972) and Turner and Chadwick (1972) commented that the time and location of spawning is closely correlated with the temperature, flow, and salinity of the two rivers. The flows from both rivers are extremely variable and are partially controlled by an extensive series of dams and reservoirs throughout the watershed. Higher riverflows increase spawning habitat and generally yield a stronger year class (Stevens 1977). Farley (1966) indicated that spawning of striped bass is not significant where the total dissolved solids exceeds 180 ppm.

A reproductive landlocked striped bass population is believed to exist in Millerton Lake (Moyle 1976). However, no striped bass eggs have been found there (Lambert 1979). In this study, ripe male striped bass were collected in Millerton Lake by gill-netting between 1979 and 1981. A few small, unfertilized striped bass eggs were collected in the lake in August 1980. No ripe females were collected during the study period. Therefore, the existence of a self-producting population is still in question. Currently, the Central Valley Fish Hatchery of the CDFG plants new stocks of striped bass juveniles in Millerton Lake yearly (M. Cochran 1981, personal communication). Edwards (1974) reported a landlocked striped bass population in the Colorado River between Davis and Parker Dams.

Striped bass eggs are slightly heavier than freshwater (Raney 1952) and have a tendency to sink. Striped bass spawn in areas with good flow and/or tidal action which provides increased agitation and aeration to the eggs and helps keep them in suspension. The large perivitelline space in striped bass eggs enables them to absorb the shock of bouncing. Eggs generally hatch within 2 days at 17–18°C (Pearson 1938, Raney 1954, Mansueti 1958, Doroshov 1970).

Newly hatched larvae, with unpigmented eyes, mostly lie on the bottom (Rinaldo 1971), but may ascend into the water column (Mansueti 1958). In the plankton samples collected in this study, evidence was found that opossum shrimp, *Neomysis mercedis*, devoured striped bass prolarvae, which indicates that striped prolarvae are not good swimmers and may lie on or near the bottom. After spawning, developing larvae are carried downstream to the Delta and upper bays (Calhoun and Woodhull 1948, Erkkila *et al.* 1950), where they are abundant (Chadwick 1958, Farley 1966). Apparently the oligohaline and tidal freshwater of the estuary serve as a very important nursery ground for striped bass larvae. They have been collected as far downstream as Carquinez Strait and San Pablo Bay. These specimens probably originated from the Delta and Suisun Bay.

A spawning survey of striped bass in the lower reaches of the Napa River was conducted in 1979. No eggs or larvae were collected, although the Napa River has been described as a potential spawning area for striped bass (Chadwick 1958). Historically, various life stages of striped bass larvae have been found in the Federal and State water projects because of the water diversion from the Delta. Many of the larvae perish, though some of them survive in the canals and reservoirs such as O'Neill Forebay and San Luis Reservoir. These areas have become popular fishing spots for striped bass.

Scofield and Bryant (1926) reported that young striped bass occur in the shallow water of San Francisco Bay and the upper bays. Results of the beach seining and bottom trawling of this study showed that young striped bass are near the bottom in both the deeper and the inshore waters of Suisun Bay and Montezuma Slough. Sasaki (1966b) observed young striped bass in the lower San Joaquin River. Ganssle (1966) reported young striped bass concentrated in the Pittsburg-Crockett-Pinole section of the estuary in summer and fall, and less frequently in San Pablo Bay during the same period. In this study, large concentrations of young striped bass were found in the vicinity of the Contra Costa and Pittsburg Powerplants in fall and early winter in 1978 and 1979. The distributional range and migratory patterns of the striped bass, of juveniles in particular, have been studied for many years by the CDFG (Scofield and Bryant 1926; Scofield 1931; Calhoun and Woodhull 1948; Skinner 1962; Ganssle 1966; Sasaki 1966b; Chadwick 1964, 1967; Turner and Chadwick 1972). However, the complex migratory pattern of young striped bass is not completely understood (Ganssle 1966). Radovich (1963) stated that Pacific Coast striped bass do not appear to make extensive migration, unlike members of the same species on the Atlantic Coast. The cold-water barrier of the

California Current as it passes in front of the Golden Gate retards the seaward run. The lack of large estuaries on the West Coast could be an important factor contributing to this difference in their migratory behavior (this study). Calhoun (1949) and Radtke (1966a) reported the distribution of 2–3 year old bass throughout the Sacramento-San Joaquin River system. In this study, different year classes of striped bass were collected by beach seining, trawling, electrofishing, and gill-netting year-round, between 1978 and 1979. It is possible that some of the striped bass population may remain in the estuary for a substantial part of their life span, if not its entirety. (H.K. Chadwick 1981, personal communication).

Juvenile striped bass feed on invertebrates, such as opossum shrimp, amphipods, copepods, and occasionally on shad (Heubach *et al.* 1963, Thomas 1967, Moyle 1976).

Male striped bass may reach maturity in their first year (Raney 1952), but mostly in their second (Raney 1954) and some in their third year (Moyle 1976). Females mature at 3–4 years (Merriman 1940, Raney 1952) and may take up to 6 years (Moyle 1976). After maturing, the striped bass does not necessarily spawn every year (Raney 1952).

Striped bass are one of the most valuable game species in California and are an important recreational resource. Unfortunately, the striped bass population has been declining since the early 1960s (Turner 1972). This trend accelerated in the mid-1970s and many theories have evolved to account for the decline. Such factors as controlled flow, freshwater diversion, industrial pollution, post-spawn mortality, entrainment and impingement, limited system carrying capacity, and long-term inbreeding have been proposed as causes of the decline.

References

Albrecht 1964; Calhoun 1949; Calhoun *et al.* 1950; Calhoun and Woodhull 1948; Chadwick 1958, 1964, 1967; Doroshov 1970; Edwards 1974; Erkkila *et al.* 1950; Farley 1966; Fritzsche and Johnson 1980; Ganssle 1966; Hardy 1978b; Hart 1973; Hatton 1940; Henback *et al.* 1963; Hildebrand and Schroeder 1928; Hollis 1967; Lambert 1979; Lippson and Moran 1974; Mansueti 1958, 1964; Merriman 1940; Miller and Lea 1972; Moyle 1976; Murawski 1969; Pearson 1938; Radovich 1963; Radtke 1966a; Raney 1952, 1954; Raney and Woolcott 1955; Rinaldo 1971; Sasaki 1966b; Scofield 1931; Scofield and Bryant 1926; Scott and Crossman 1973; Skinner 1962; Stevens 1977; Thomas 1967; Truitt 1936; Turner 1972; Turner and Chadwick 1972; Von Geldern 1966; Wang and Kernehan 1979; Woodhull 1947.

Figure 24.—Percichthyidae: *Morone saxatilis*, striped bass.

FIGURE 24-1.—Egg, morula, 3.0 mm diameter.

FIGURE 24-2.—Egg, early embryo, 4.0 mm diameter.

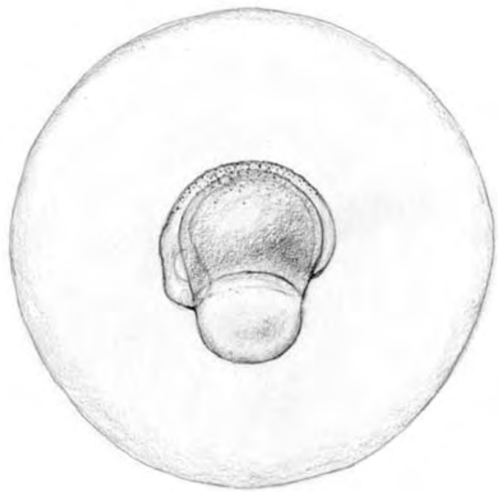


FIGURE 24-3.—Egg, early embryo, 4.0 mm diameter.

FIGURE 24-4.—Egg, late embryo, 4.0 mm diameter.

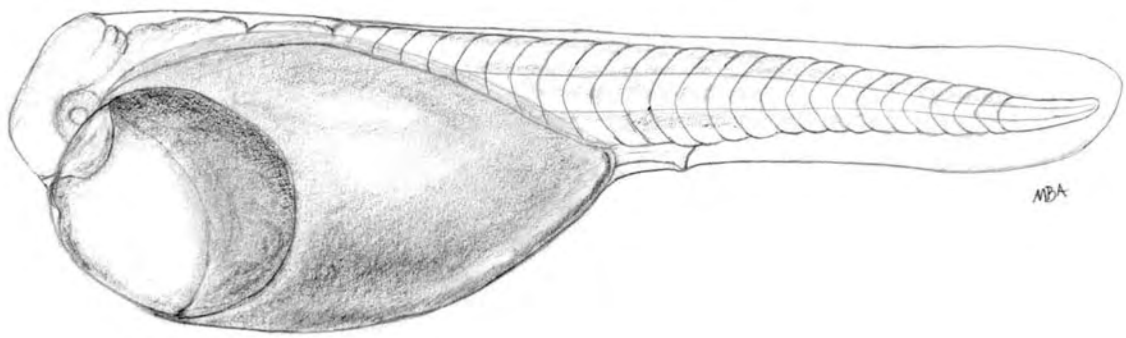


FIGURE 24-5.—Prolarva 3.6 mm TL.

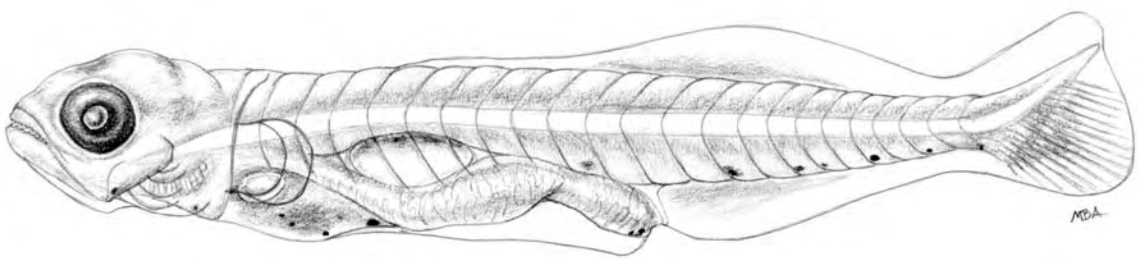


FIGURE 24-6.—Postlarva, 9.5 mm TL.

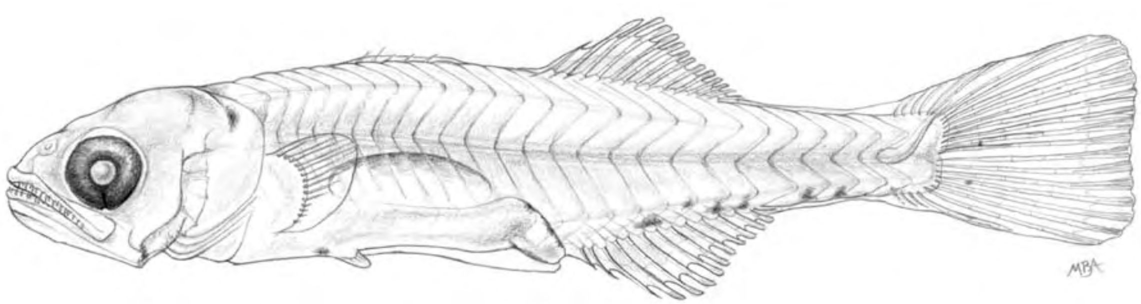


FIGURE 24-7.—Postlarva 15.2 mm TL.

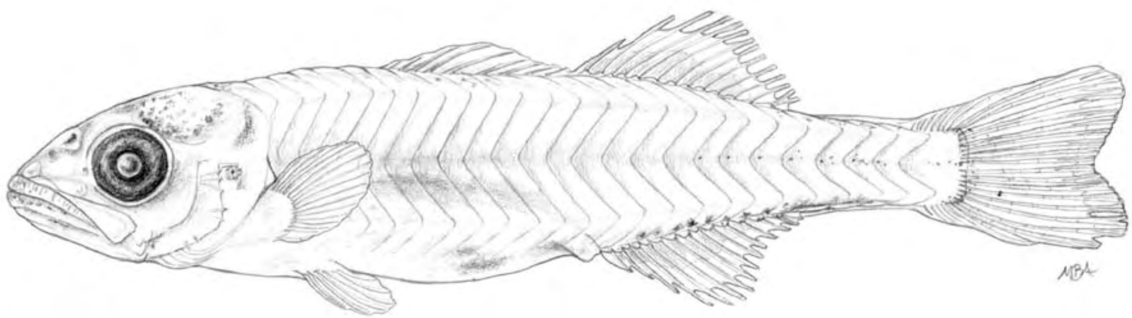


FIGURE 24-8.—Juvenile, 18 mm TL.

25. Centrarchidae – Sunfishes

Moyle (1976) and Shapovalov *et al.* (1981) reported 12 species of centrarchids in California. In this study 11 of the 12 species were found in the Sacramento-San Joaquin River system.

	Distribution	
Species	**River**	**Estuary**
Sacramento perch, *Archoplites interruptus*	x	x
Green sunfish, *Lepomis cyanellus*	x	x
Pumpkinseed, *Lepomis gibbosus*	x	
Warmouth, *Lepomis gulosus*	x	x
Bluegill, *Lepomis macrochirus*	x	x
Redear sunfish, *Lepomis microlophus*	x	
Smallmouth bass, *Micropterus punctulatus*	x	
Spotted bass, *Micropterus punctulatus*	x	
Largemouth bass, *Micropterus salmoides*	x	x
White crappie, *Pomoxis annularis*	x	x
Black crappie, *Pomoxis nigromaculatus*	x	x

The Sacramento perch, *Archoplites interruptus*, is the only sunfish originally found west of the Rocky Mountains; the others were introduced from the eastern states. The reproductive behavior of the centrarchids is generally characterized by nest-building followed by parental care, although the Sacramento perch may behave differently. Eggs of sunfishes are demersal, and so are the newly hatched larvae. Postlarvae and juveniles use aquatic vegetation as their nursery area or shelter. Centrarchids are generally considered to be an excellent pan fish by anglers, particularly the largemouth bass and bluegill.

References

Moyle 1976, Shapovalov *et al.* 1981.

SACRAMENTO PERCH, *Archoplites interruptus* (Girard)

SPAWNING

Location	In weedy ponds and lakes such as Lake Anza, Jewel Lake, and an unnamed private pond near Sonoma Mountain Road, Sonoma County. Juvenile Sacramento perch were taken in the vicinity of Contra Costa Powerplant. Spawning may also occur in Delta sloughs.

Season	April through August (Murphy 1948a; Johnson 1958; Mathews 1962, 1965); peaking in May and June (Mathews 1962, Aceituno and Vanicek 1976, Moyle 1976); April through June.
Temperature	21.7–23.9°C (Mathews 1962); 21–29°C (McCarraher and Gregory 1970); 20–24°C when the eggs were collected.
Salinity	Freshwater (Murphy 1948a, Mathews 1962, this study); in mesohaline up to 17,000 ppm or alkalinities 800 ppm (McCarraher and Gregory 1970).
Substrates	Filamentous algae, algae-covered rocks, rooted plants (Murphy 1948a, Mathews 1962).
Fecundity	8,400–16,000 for 120–157 mm TL specimens from Lake Anza; 9,700–125,000 for 196–337 mm TL specimens from Pyramid Lake (Mathews 1962).

CHARACTERISTICS

EGGS (Figure 25-1)

Shape	Spherical.
Diameter	0.9–1.1 mm.
Yolk	Yellowish, granular.
Oil globule	Single, large, ca. 0.3–0.4 mm in diameter.
Chorion	Transparent, elastic.
Perivitelline space	Narrow in all stages.
Egg mass	Deposited singly or small clusters.
Adhesiveness	Adhesive (Mathews 1962); adhesive to slightly adhesive.
Buoyancy	Demersal (Murphy 1948a, Mathews 1962).

LARVAE (Figure 25-2, 25-3, 25-4, 25-5)

Length at hatching	Less than 4.0 mm TL.
Snout to anus length	36–44% of TL, from prolarvae at 4.0 mm TL to postlarvae at 9.8 mm TL.
Yolk sac	Oval, large, yellowish, extends from jugular to abdominal region.
Oil globule	Single, large, ca. 0.3 mm in diameter, anterior or posterior.
Air bladder	Small, oval, midway between pectorals and anus in prolarvae; large in postlarvae.

Teeth	Small, pointed, apparent in postlarvae.
Size at completion of yolk-sac stage	Ca. 4.7–4.9 mm TL.
Total myomeres	31–34, mostly 32.
Preanal myomeres	10–12.
Postanal myomeres	21–22.
Last fin(s) to complete development	Pelvic.
Pigmentation	In prolarvae, large stellate melanophores scattered on head, trunk, and tip of caudal region on dorsum; large stellate melanohores are also found on midventral and dorsal surfaces of gut and postanal regions; dashed melanophores along lateral line. In postlarvae, pigmentation patterns are similar to those of prolarvae, but heavier on snout, head, and postanal region.
Distribution	Planktonic (Mathews 1962, 1965); swim in shallow inshore water among or near vegetation.

JUVENILES (Figure 25-6, 25-7)

Dorsal fin	XII–XIII; I, 10–11 (Moyle 1976).
Anal fin	VI–VII, 10 (Moyle 1976).
Pectoral fin	14–16.
Mouth	Large, oblique (Moyle 1976); terminal to slightly superior.
Vertebrae	31–34.
Distribution	Ponds and reservoirs (Murphy 1948a, Mathews 1962, Aceituno and Nicola 1976); among aquatic plants or congregating in shallow waters (Moyle 1976); in schools among or near inshore vegetation.

LIFE HISTORY

The Sacramento perch is the only centrarchid native to waters west of the Rocky Mountains. Prior to the introduction of other sunfishes into California, Sacramento perch were abundant in the Sacramento-San Joaquin River system, Pajaro and Salinas Rivers, and Clear Lake (Moyle 1976). In recent years, however, they have been depleted in their native range, and now are restricted to a few locations, principally ponds and reservoirs where they are stocked (McCarraher and Gregory 1970, Aceituno and Nicola 1976, Moyle 1976). In this study, most of the specimens were taken from Sterling Ranch Pond near Sonoma Mountain Road, Sonoma County, Lake Anza, and Jewel Lake of

C.T. Tilden Regional Park. A few were collected at the intake screens of the Contra Costa Powerplant. These latter fish probably came from Delta sloughs.

Spawning has been reported to extend from April (Murphy 1948a, Mathews 1962) through August (Johnson 1958), depending on location and water temperature. In Lake Anza, spawning occurs from April through July (Mathews 1962), mostly in April and May. Spawning activities were described by Murphy (1948a) and Mathews (1962, 1965). Murphy (1948a) reported that Sacramento perch show no nest-building behavior, only deposition sites, and no parental care. However, Mathews (1962, 1965) observed nest-like sites with male fish guarding the site until few days after hatching. He also recorded eggs adhering to spawning substrates such as filamentous algae and rooted vegetation. In this study, eggs were collected from a clear spot (ca. 1 m in depth) in a weedy pond near Sonoma Mountain Road in Early May 1980. The water temperature ranged from 20–24°C and the collected eggs were spherical (0.9–1.1 mm in diameter), with a single large oil globule. Eggs were adhesive to slightly adhesive.

Newly hatched larvae are estimated to be less that 4.0 mm TL. They have light pigmentation and swim near the surface. In the pond near the Sonoma Mountain Road, Sacramento perch larvae were found in the plant beds with Sacramento blackfish larvae; in Lake Anza, Sacramento perch larvae were found with green sunfish, largemouth bass, and golden shiner larvae in the plant beds.

Small juveniles venture into deeper water in schools of their own species, seeming to prefer shade created by overhanging trees. As juveniles grow, the school is gradually diffused, with individuals inhabiting local areas within the plant beds. The diet of juvenile perch includes amphipods, cladocerans, ostracods, copepods, and chironomids (Moyle *et al.* 1974b, Aceituno and Vanicek 1976). In the laboratory, small juveniles took amphipods, chopped mysid shrimp, and brine shrimp. Large juveniles consumed live mosquitofish (this study).

Sacramento perch reach maturity at 2–3 years of age, and some may live up to 9 years (Mathews 1962). In this study, a pair of Sacramento perch juveniles (10–15 mm TL) were collected from Lake Anza on May 17, 1980, and kept alive in the laboratory. One of the females released eggs on May 7, 1982, when she was 3 years old and 24 cm TL.

Sacramento perch were used as food fish by Indians (Skinner 1962, Moyle 1976). Today, this species is hardly found in its native waters, although they have been successfully introduced into several saline or alkaline lakes in the western states (McCarraher and Gregory 1970, Imler *et al.* 1975). Moyle (1976) offered some hypotheses regarding the cause of their depletion. The future ecological status of this species in California is very uncertain. Miller (1972) classified the Sacramento perch as depleted in its native range.

References

Aceituno and Nicola 1976; Aceituno and Vanicek 1976; Imler *et al.* 1975; Johnson 1958; McCarraher and Gregory 1970; Mathews 1962, 1965; Miller 1972; Moyle 1976; Moyle *et al.* 1974b; Murphy 1948a; Skinner 1962.

GREEN SUNFISH, *Lepomis cyanellus* (Rafinesque)

SPAWNING

Location	Near shore (Hubbs 1919); shallow water near overhanging bushes or other cover (Moyle 1976); sunlit waters in creeks, ponds, ditches, sloughs and reservoirs, such as lower portion of Walnut Creek; Napa River near spillway of Lake Anza, inshore of Marsh Creek Reservoir; coves of Millerton Lake and Union Valley Reservoir.
Season	May through August (Moyle 1976, this study); early June to mid-August in Colorado (Beckman 1952).
Temperature	20–28°C (Scott and Crossman 1973); in excess of 19°C (Moyle 1976); eggs collected at 19–24°C.
Salinity	Freshwater.
Substrates	Gravel (Beckman 1952); clumps of vegetation or rock (Scott and Crossman 1973); among the branches of fallen trees, gravel, and sand.
Fecundity	2,000–10,000 (Beckman 1952).

CHARACTERISTICS

EGGS (Figures 25-8, 25-9, 25-10)

Shape	Spherical (Meyer 1970).
Diameter	1.0–1.4 mm (Meyer 1970); 1.1–1.3 mm.
Yolk	Yellowish (Scott and Crossman 1973); granular.
Oil globule	Single oil globule 0.3–0.5 mm in diameter, sometimes with one or more small oil globules.
Chorion	Transparent, elastic not smooth because of adhering substrates.
Perivitelline space	Narrow to wide; 6–25% of egg diameter.
Egg mass	Deposited singly or in small clusters in the nest.
Adhesiveness	Very adhesive.
Buoyancy	Demersal.

LARVAE (Figures 25-11, 25-12, 25-13)

Length at hatching	3.6–3.7 mm TL (Taubert 1977); 3.2–3.9 mm TL.
Snout to anus length	39–49% of TL of prolarvae at 3.3 mm TL to postlarvae at 11.1 mm TL.
Yolk sac	Spherical to oval, large, extends from jugular to abdominal region.
Oil globule	Single, mostly in posterior of yolk sac.
Gut	Short, straight, and bent ventrally in anal region in prolarvae; twisted in postlarvae.
Air bladder	Shallow, large, near pectorals.
Teeth	Small, pointed, develop in postlarvae.
Size at completion of yolk-sac stage	Ca. 4.5–5.0 mm TL.
Total myomeres	27–28 (Taubert 1977); 12–14.
Preanal myomeres	11 (Taubert 1977); 12–14.
Postanal myomeres	16–17 (Taubert 1977); 14–16.
Last fin(s) to complete development	Pelvic.
Pigmentation	In prolarvae, large stellate melanophores on cephalic, middorsal, midventral, dorsal surface of gut and postanal regions; in postlarvae, dashed melanophores along lateral line; cephalic melanophores become heavier, more melanophores scatter in thoracic region.
Distribution	Prolarvae, near bottom of nesting area; postlarvae in shallow water near or among vegetation.

JUVENILES (Figure 25-14)

Dorsal fin	IX–XI, 10–12 (Scott and Crossman 1973); IX–X, 10–12 (Moyle 1976).
Anal fin	III, 9–10 (Scott and Crossman 1973); III, 8–9 (Moyle 1976).
Pectoral fin	12–13 (Scott and Crossman 1973); 13–15 (Moyle 1976); 12–14.
Mouth	Large (Moyle 1976); terminal, oblique, maxillary reaching anterior edge of eye (Scott and Crossman 1973, this study).
Vertebrae	28 or 29 (Scott and Crossman 1973); 28–30.

Distribution	Mostly in the shallow, still or low-velocity waters of the Sacramento-San Joaquin river system (this study).

LIFE HISTORY

The green sunfish is a freshwater fish native to eastern and central North America (Scott and Crossman 1973). They have also been introduced into several western states such as Utah, Nevada, and California (Scott and Crossman 1973, Moyle 1976). In this study, green sunfish were found to be among the most abundant centrarchids in the study area, ranging from coastal freshwater lagoons (such as Rodeo Lagoon), to inland mid-elevation Sierra water bodies such as Union Valley Reservoir on the upper American River.

Spawning takes place from May through August (Moyle 1976, this study). Males build nests near protected coves, or at the lower end of the pool where the water is less than 0.5 m in depth. Several nests are constructed in close proximity, although occasionally a single nest is found. During the spawning season, males mate with numerous females in the same or different nests (Hunter 1963). Hunter included a detailed description of the mating behavior and sexual dimorphism of this species. In this study, eggs were excavated from the natural nest and were taken to the laboratory for observation. Eggs adhered to the gravel singly or in small clumps. Scott and Crossman (1973) reported a 3–5 day incubation period at unspecified temperature. In this study, the eggs took 3–4 days to hatch at 19–23°C. Males continue to guard the nest for a short period after hatching (Scott and Crossman 1973).

In the laboratory the newly hatched larvae were unpigmented. They swam among the crevices of the gravel for about 1–2 days and then rose to the water column and swam freely 3–4 days after hatching. Postlarvae swam in schools in the laboratory aquarium; they probably disperse into beds of vegetation in the wild.

Juveniles are abundant in various habitats such as small ponds with dense vegetation, ditches with filamentous algae, and inshore areas of large reservoirs. Juvenile green sunfish feed on crustaceans, aquatic insects, larvae, and terrestrial insects (Applegate and Mullan 1967, Moyle 1976).

The minimum age at maturity is: less than 6 months (White 1971); usually 3 years (Scott and Crossman 1973); in California, mostly 1–2 years or at 5–7 cm SL (Moyle 1976). The life expectancy is 7–9 years (Scott and Crossman 1973). Green sunfish have little sport value, since they have a slow growth rate and stunted populations (Moyle 1976).

After introduction, green sunfish expanded their territory successfully in the Sacramento-San Joaquin River system. They are probably responsible for the depletion of California roach in some streams (Moyle 1976). The green sunfish shows a great adaptability to various environments (McCarraher 1972). This adaptability includes aggressive territorial behavior and fierce feeding competition, as described by Moyle (1976). In this study, the nests of green sunfish were found in polluted and channelized rivers and creeks which run through cities, such as the Petaluma River at Petaluma, the Napa River below

Napa, Walnut Creek at Walnut Creek, and Grayson Creek at Concord. In Grayson Creek, filamentous algae surrounded the nesting area, and dissolved oxygen was less than 4.0 mg/L during the evening hours. In spite of the apparent adverse environmental conditions, the green sunfish eggs hatched out with no evidence of stress.

References

Applegate and Mullan 1967, Beckman 1952, Hubbs 1919, Hunter 1963, McCarraher 1972, Meyer 1970, Moyle 1976, Scott and Crossman 1973, Taubert 1977, White 1971.

PUMPKINSEED, *Lepomis gibbosus* (Linnaeus)

SPAWNING

Location	Lakes, reservoirs, ponds, and creeks (Breder 1936); in Walnut Creek near Las Lomas High School.
Season	May through August in mid-Atlantic region (Smith 1971, Wang and Kernehan 1979); estimated in June and July in Walnut Creek.
Temperature	Ca. 20°C (Scott and Crossman 1973); optimum temperature 21–24°C (Anjard 1974); 17.5–20°C in Delaware (Wang and Kernehan 1979).
Salinity	Freshwater.
Substrates	Sand, gravel (Carbine 1939); debris such as broken glass (Wang and Kernehan 1979).
Fecundity	600–2,900 for females at ages 2–5 (Scott and Crossman 1973); fecundity increase with age and size of females (Hubbell 1966).

CHARACTERISTICS

EGGS

Shape	Spherical.
Diameter	0.8–1.2 mm (Tracy 1910); ca. 1.0 mm (Scott and Crossman 1973).
Yolk	Pale amber (Scott and Crossman 1973); granular.
Oil globule	Single, large, with several extremely small ones (Hardy 1978b); single, ca. 0.3 mm in diameter, occasionally with small oil globules on the periphery of the large one, amber color (Wang and Kernehan 1979).
Chorion	Transparent, thick (Hardy 1978b, this study).
Perivitelline space	Narrow, 0.5 mm in width (Balon 1959); fairly wide

	in early developmental stages, ca. 8–22% of egg diameter.
Egg mass	Deposited in clusters, or singly but very densely per unit area.
Adhesiveness	Adhesive, attached to substrates (Balon 1903, Fish 1932, Scott and Crossman 1973, this study).
Buoyancy	Demersal.

LARVAE (Figure 25-15, 25-16)

Length at hatching	2.6–3.1 mm TL (Balon 1959); 2.4–2.9 mm TL (Wang and Kernehan 1979).
Snout to anus length	Ca. 45–50% of TL for prolarvae; 40–45% of TL for postlarvae.
Yolk sac	Large, spherical to oval, extending from head or jugular to abdominal region.
Oil globule	Single, 0.2–0.3 mm in diameter in the newly hatched larvae; located mostly posterior to midpoint of yolk sac (Hardy 1978b).
Gut	Short and straight in prolarvae; coiled in postlarvae (Anjard 1974).
Air bladder	Small, oval, behind pectoral fins.
Teeth	Small, pointed apparent in postlarval stage.
Size at completion of yolk-sac stage	Ca. 4.0–5.0 mm TL.
Total myomeres	27 (Taubert 1977); up to 35 (Hardy 1978b); 33 (Anjard 1974); 28–34.
Preanal myomeres	10–13 (Hardy 1978b; Fish 1932).
Postanal myomeres	17–21 (Hardy 1978b).
Last fin(s) to complete development	Pelvic.
Pigmentation	Newly hatched larvae have no pigmentation; then stellate melanophores appear on cephalic, dorsal surface of gut and sometimes in postanal regions; otherwise no, or very little, pigmentation.
Distribution	Shallow weedy waters of creeks, ponds, and reservoirs.

JUVENILES (Figure 25-17)

Dorsal fin	X, 10–12 (Moyle 1976); X–XI, 10–12 (Scott and Crossman 1973).

Anal fin	III, 10–11 (Moyle 1976); III, 8–11 (Scott and Crossman 1973; Hardy 1978b).
Pectoral fin	12 (Moyle 1976); 12–14 (Carbine 1939; Scott and Crossman 1973).
Mouth	Terminal, small, oblique (Scott and Crossman 1973).
Vertebrae	28–29 (Scott and Crossman 1973).

LIFE HISTORY

The pumpkinseed is a native freshwater fish in eastern and central North America, and has been introduced into California (Curtis 1949, Scott and Crossman 1973). The exact date of their introduction is unknown (Moyle 1976). Currently, the populations are well established in the Klamath and Lahontan systems and in southern California (Moyle 1976; Williams *et al.* 1955). The occurrence of this species in the Sacramento-San Joaquin River system is uncommon. It was observed in Walnut Creek in this study. Fishermen have reported that pumpkinseed are also found in Lafayette Reservoir.

Judging by the brilliant green to orange-red spawning coloration of the male fish, spawning occurs in June and July in the study area. Males construct nests in close proximity; larger nests are built in deeper water and small ones on the periphery (Breder 1936, this study). Details of courtship behavior of the pumpkinseed have been summarized by Breder and Rosen (1966). Eggs are deposited in the center of the nests, which contain gravel, sand, or hard clay as substrates. Males guard the nests, and sometimes a single male may guard two nests by moving back and forth. During spawning, both males and females may mate with more than one partner in the same or different nests. Eggs hatch in 3 days at 28°C (Scott and Crossman 1973).

Newly hatched larvae are transparent. The eyes are unpigmented in the first 48 hours after hatching, and the larvae remain at the bottom of the nest for a short period. The male continues to guard the larvae against predators until they are free-swimming. However, some larvae are eaten by hydras, which are commonly attached to the gravel in the nest. When the larvae leave the nest, they inhabit dense vegetation in shallow waters and also venture out into open waters (Faber 1967).

Juveniles can be solitary or form small schools near or among aquatic vegetation; some move into deeper pools, but rarely remain in rapidly running water. Larvae and early juveniles feed on zooplankton (Faber 1967), with aquatic insects and snails becoming the important food items for the large juveniles (Reid 1930, Seaburg and Moyle 1964).

Pumpkinseed mature in about 2 years (Scott and Crossman 1973); 2 or 3 years (Moyle 1976). Some pumpkinseed live up to 12 years (Hubbell 1966). Their sport value is insignificant, because of their rarity in the study area.

References

Anjard 1974, Balon 1959, Breder 1936, Breder and Rosen 1966, Carbine 1939, Curtis 1949, Faber 1967, Fish 1932, Hardy 1978b, Hubbell 1966, Moyle 1966, Reid 1930, Scott and Crossman 1973, Seaburg and Moyle 1964, Smith 1971, Taubert 1977, Tracy 1910, Wang and Kernehan 1979, Williams *et al.* 1955.

WARMOUTH, *Lepomis gulosus* (Cuvier)

SPAWNING

Location	Ponds (Larimore 1957); Bass Lake, Madera County and Central Valley of the Sacramento-San Joaquin System (Moyle 1976); sloughs of the Delta.
Season	May to August in Illinois (Larimore 1957, Carr 1939); April to October in Texas (Larimore 1957); generally spring and summer.
Temperature	Minimum 21.1°C (Larimore 1957).
Salinity	Freshwater.
Substrates	Mud, silt, sand, rubble, detritus, leaves, sticks (Larimore 1957, Richardson 1913).
Fecundity	4,500–63,000 (Larimore 1957).

CHARACTERISTICS

EGGS

Shape	Spherical (Larimore 1957).
Diameter	Mature eggs, unfertilized, ca. 1.1 mm or larger (Larimore 1957); fertilized eggs, 1.0–1.1 mm (Carr 1939).
Yolk	Light amber (Larimore 1957).
Oil globule	Single (Larimore 1957); ca. 0.35 mm in diameter (Carr 1939).
Chorion	Clear (Carr 1939).
Perivitelline space	Thin (Larimore 1957).
Egg mass	Small clusters (Carr 1939).
Adhesiveness	Adhesive (Carr 1939).
Buoyancy	Demersal (Carr 1939).

LARVAE

Length at hatching	2.30–2.85 mm TL (Larimore 1957).
Snout to anus length	Ca. 50% of prolarvae at 3.4 mm TL; 42–45% of TL of postlarvae at 5.3–12.0 mm TL (Larimore 1957).
Yolk sac	Oval, large, extends from jugular to abdominal region (Larimore 1957).
Oil globule	Single, ca. 0.3 mm in diameter (Larimore 1957).
Total myomeres	29–30 (Larimore 1957); 25–30 (Taubert 1977).
Preanal myomeres	8–11 (Larimore 1957).

Postanal myomeres	17–19 (Larimore 1957).
Pigmentation	Newly hatched larvae have no pigmentation; in postlarvae 5.3–7.6 mm TL, stellate melanophores on cephalic, thoracic, base of pectoral and postanal regions; dashed melanophores along lateral line region (Larimore 1957).
Distribution	Sloughs of Delta, such as Taylor Slough, Franks Slough, and lower reach of the San Joaquin River.

JUVENILES (Figure 25-18)

Dorsal fin	X–XI, 9–11 (Moyle 1976); X for spiny dorsal (Beckman 1952); II, 9–11 for soft dorsal (Trautman 1957).
Small fin	III, 9–10 (Moyle 1976); III, 8–9 (Beckman 1952).
Pectoral fin	12–13.
Mouth	Large (Moyle 1976); terminal, large, oblique.
Vertebrae	29 (Bean 1903).
Distribution	Sloughs of the Delta to the vicinity of Oleum Powerplant, San Pablo Bay.

LIFE HISTORY

The warmouth is a freshwater fish native to the eastern United States from the Great Lakes region southward to the Mississippi River drainage and throughout the Atlantic states (Eddy 1957, Hubbs and Lagler 1958). This species was introduced into southern California in 1921 (Evermann and Clark 1931); currently they are widely distributed in the Sacramento-San Joaquin River system (Turner 1966b, Moyle 1976). In this study, the warmouth was observed from the Delta (such as Tracy Pumping Station) to the San Joaquin River, Suisun Bay, and as far as San Pablo Bay.

Spawning takes place in spring and summer in shallow waters with aquatic vegetation or tree roots (Larimore 1957). Male warmouth construct solitary nests (Childers 1965) or in colonies (Larimore 1957). Details of reproductive biology have been described by Larimore (1957); many aspects of parental care are very similar to those of the green sunfish (Moyle 1976). Eggs hatch within 35 hours at 25.0–26.4°C (Larimore 1957).

The newly hatched larvae remain in the nest and are guarded by the male until they swim freely, in about 10 days (Carr 1939). Larvae use submerged plant beds as shelters, and they school together (Larimore 1957).

Juveniles become more solitary and prefer protected shallow waters (Carr 1939, Larimore 1957). In this study, juvenile warmouth were found in various sections of the Delta and the estuary (as far as San Pablo Bay). This species is apparently able to tolerate higher-salinity water (Renfro 1960). Juveniles feed mainly on mysid shrimps, amphipods, and aquatic insects (Turner 1966b).

Warmouth breed for the first time at 1–2 years of age (Larimore 1957). Their sport fishing value in the Delta is probably little, because of their limited abundance.

References

Bean 1903, Beckman 1952, Carr 1939, Childers 1965, Eddy 1957, Evermann and Clark 1931, Hubbs and Lagler 1958, Larimore 1957, Moyle 1976, Renfro 1960, Richardson 1913, Taubert 1977, Trautman 1957, Turner 1966b.

BLUEGILL, *Lepomis macrochirus* (Rafinesque)

SPAWNING

Location	Near shore in areas shaded by overhanging trees (Breder 1936); sluggish shallow waters of sloughs, ponds, and reservoirs. Nesting areas in the Delta are usually those with little or no tidal influence.
Season	May through August in Delaware (Smith 1971); throughout the summer in California (Moyle 1976). Judging from the breeding color of male fish, spawning is estimated from May through August; larvae were abundant in June and July.
Temperature	17–27°C (Morgan 1951); beginning at 18–21°C (Moyle 1976); mostly over 20°C.
Salinity	Freshwater.
Substrates	Nests are constructed of gravel, sand, or mud interspersed with debris, twigs, or dead leaves (Moyle 1976); sand or hard clay, eggs deposited on sticks or dead leaves.
Fecundity	2,000 –18,000 per nest (Emig 1966); 2,500–50,000 (Moyle 1976); 2,500–64,000 (Morgan 1951, Snow 1960); fecundity increases with size and age of female fish (Carbine 1939).

CHARACTERISTICS

EGGS

Shape	Spherical.
Diameter	Average 1.04 mm (Toetz 1965); 1.37 mm ± 0.020 (Nakamura *et al.* 1971); 1.1–1.3 mm (Wang and Kernehan 1979).

Yolk	Pale yellow (Toetz 1965); amber (Scott and Crossman 1973); granular (Hardy 1978b).
Oil globule	Single (Morgan 1951, Toetz 1965); oil globule ca. 0.38 mm in diameter (Nakamura *et al.* 1971); ca. 0.3–0.6 mm in diameter.
Chorion	Noticeably thick (Carver 1976); transparent, thick.
Perivitelline space	Narrow to slightly wide, ca. 10–20% of egg diameter.
Egg mass	Deposited in small clusters or singly; can be dense per unit area.
Adhesiveness	Adhesive (Adams and Hankinson 1928, Morgan 1951, Moyle 1976).
Buoyancy	Demersal.

LARVAE (Figure 25-19, 25-20)

Length at hatching	2.2–3.2 mm TL (Morgan 1951, Nakamura *et al.* 1971); 2–3 mm TL (Scott and Crossman 1973); 5–6 mm TL (Moyle 1976).
Snout to anus length	In prolarvae ca. 42–46% of TL; in postlarvae, ca. 40% of TL.
Yolk sac	Large, spherical to oval, extending from head to abdominal region.
Oil globule	Single, located in the posterior portion of yolk sac (Carver 1976, Wang and Kernehan 1979).
Gut	Straight in prolarvae and coiled in single loop in postlarvae (Anjard 1974).
Air bladder	In prolarvae, oval, small, midway between pectorals and anus; in postlarvae air bladder becomes large.
Teeth	Small, pointed, apparent in postlarval stage.
Size at completion of yolk-sac stage	4.92–5.84 mm TL (Toetz 1966); 4.8–5.0 mm TL (Wang and Kernehan 1979).
Total myomeres	31 (Taber 1969); 27–31.
Preanal myomeres	10 (Taber 1969); 9–11.
Postanal myomeres	21 (Taber 1969); 17–20.
Last fin(s) to complete development	Pelvic.
Pigmentation	No pigmentation on newly hatched larvae (Hardy 1978b, Wang and Kernehan 1979); in postlarvae a row of chromatophores along posterior margin of head at ca. 7 mm TL (Meyer 1970); stellate melanophores on cephalic, thoracic, dorsal surface of

	gut, and postanal regions, 3 rows of large melanophores in mosaic arrangement in postanal and above postanal regions in late postlarvae.
Distribution	Newly hatched larvae remain in the nesting area (Hardy 1978b, this study); free-swimming larvae inhabit shallow water with vegetation (Taber 1969). Larvae were found in shallow water as well as the open estuary, such as lower reaches of the Delta and Suisun Bay.

JUVENILES (Figure 25-21, 25-22)

Dorsal fin	X, 10–12 (Moyle 1976); X–XI, 10–12 (Scott and Crossman 1973).
Anal fin	III, 10–12 (Moyle 1976); III, 8–11 (Scott and Crossman 1973).
Pectoral fin	Usually 13 (Moyle 1976); 13–14 (Scott and Crossman 1973).
Mouth	Terminal, small, oblique (Scott and Crossman 1973).
Vertebrae	28 or 29 (Scott and Crossman 1973); 28–30 (Stokely 1952).
Distribution	Limnetic to littoral zone (Werner 1967); mostly in the sluggish backwaters of Delta sloughs also observed in San Pablo Bay during high river flow, but mostly in ponds, reservoirs, and pools of creeks.

LIFE HISTORY

The native range of the bluegill is in freshwaters of central and eastern North America, and it has been introduced in many places east and west of this area (Scott and Crossman 1973). This species was introduced into California in 1908, and its population is now established throughout the state, including the tidal waters of the Sacramento-San Joaquin Estuary (Turner 1966b, Moyle and Nichols 1973, Moyle 1976). In this study, bluegill were observed throughout the Delta, tributaries, and westward to San Pablo Bay. However, they were absent in coastal streams, such as Lobitos and Tunita Creeks. The overall distribution and abundance of this species in the study area is very similar to that of the green sunfish.

Spawning takes place in shallow waters with vegetation, tree roots, and tree shade from May through August, peaking I June and July. Males, which become darker on the dorsum and rusty orange in the belly, excavate depressions on sandy, gravel, or hard clay bottoms, and then add sticks and dead leaves (including pine needles) to be used as spawning substrate. Each male builds and defends its own nest, and usually several males have their nests in close proximity (Moyle 1976); nesting areas can be very crowded (Scott and Crossman 1973). Eggs hatch in about 32 hours at 22.2–23.2°C

(Morgan 1951). Often, it takes 2–3 days at 20°C or so in the field (Wang and Kernehan 1979). Although most nests are empty by August, male fish may continue guarding and cleaning them.

Newly hatched larvae remain in the nest (Morgan 1951, Hardy 1978b) until eyes become pigmented and the yolk is completely absorbed (Scott and Crossman 1978, this study). Clady and Ulrichson (1968) reported that fry were free-swimming 6 days after hatching. Taber (1969) found larvae at all depths, but mostly towards the bottom; Werner (1966) found larvae mostly in the epilimnion; others disperse into plant beds from the nesting area (Moyle 1976). In this study bluegill larvae were collected in open water as well as shallow water in the lower Delta and Suisun Bay. Apparently the species is widely distributed.

Juveniles swim in small schools near or among plant beds (Morgan 1951), but this study indicated that some move into open water of the upper Sacramento-San Joaquin Estuary, since juveniles were observed as far west as the Oleum Powerplant, San Pablo Bay, during high freshwater flows. Juveniles feed on copepods and cladocerans (Siefert 1972), planktonic crustaceans, and aquatic and flying insects (Moyle 1976).

The spawning age of the bluegill ranges from 1–3 years (Morgan 1954, Moyle 1976). Their maximum lifespan is 8–10 years (Scott and Crossman 1973), and the maximum length is 300 mm (Trautman 1975). Bluegill are one of the most abundant freshwater gamefish in California (Moyle 1976). The flesh is white, flaky, and sweet.

References

Adams and Hankinson 1928; Anjard 1974; Breder 1936; Carbine 1939; Carver 1976; Clady and Ulrichson 1968; Emig 1966; Hardy 1978b; Meyer 1970; Morgan 1951, 1954; Moyle 1976; Moyle and Nichols 1973; Nakamura *et al.* 1971; Scott and Crossman 1973; Siefert 1972; Smith 1971; Snow 1960; Stokely 1952; Taber 1969; Toetz 1965, 1966; Trautman 1957; Turner 1966b; Wang and Kernehan 1979; Werner 1966, 1967.

REDEAR SUNFISH, *Lepomis microlophus* (Guenther)

SPAWNING

Location	Shallow waters of ponds and reservoirs, such as Rancho Seco Park Pond and Lake Berryessa.
Season	May through September in Tennessee (Schoffman 1939); spring to fall in Alabama (Swingle 1946); throughout the summer (Emig 1966); estimated from April to August in the study area.
Temperature	Approaching 21.1°C (Clugston 1966); 22–24°C (Emig 1966); larvae were collected at 22.5°C.
Salinity	Freshwater.

Substrates	Gravel, sand, hard clay.
Fecundity	120–4,000 by stripping (Smitherman and Hester 1962).

CHARACTERISTICS

EGGS

Shape	Ripe eggs, spherical.
Diameter	1.3–1.6 mm (Meyer 1970).
Adhesiveness	Adhesive.
Buoyancy	Demersal.

LARVAE (Figure 25-23)

Length at hatching	Maximum 5.0 mm TL (Hardy 1978b).
Snout to anus length	Ca. 40–41% of TL of larvae at 6.1–6.5 mm TL.
Yolk	Spherical to oval, extending from jugular to abdominal region in late prolarvae.
Oil globule	Single, bright yellow.
Gut	Straight in prolarvae, forming a single loop in postlarvae.
Air bladder	Oval, shallow, midway between pectorals and anus, air bladder covered with pigmentation at 5.0 mm TL (May and Gassaway 1967).
Teeth	Very small, pointed, apparent in postlarvae.
Size at completion of yolk-sac stage	Ca. 6.5–7.0 mm TL.
Total myomeres	30–32.
Preanal myomeres	10–13.
Postanal myomeres	17–20.
Pigmentation	In prolarvae, small melanophores on head, thoracic and dorsal surface of gut near anal region; a series of melanophores along postanal region extending to dorsal portion of caudal area; a series of melanophores appears on the lateral line in postlarvae (Meyer 1970, this study). In postlarvae, pigmentation is more dense; at 10.0–15.0 mm TL, a conspicuous line of melanophores on breast and belly and a double line of pigment in postanal region (Werner 1966).

Distribution	In shallow water near vegetation, such as in Rancho Seco Park pond and Lake Berryessa.

JUVENILES (Figures 25-24, 25-25)

Dorsal fin	X, 11–12 (Moyle 1976); X, 10–12 (Carr and Goin 1955).
Anal fin	III, 10–11 (Moyle 1976); II, 9–11 (Carr and Goin 1955).
Pectoral fin	13.
Mouth	Terminal, small, oblique.
Vertebrae	32–33.
Distribution	Shallow coves of ponds and reservoirs, near or among vegetation.

LIFE HISTORY

The redear sunfish is a freshwater centrarchid native to the Mississippi River drainage and eastward to Florida (Eddy 1957, Wilbur 1969). This species was introduced into the lower Colorado River during the 1950s (Beland 1953) and probably in the same period into southern California (Shapovalov *et al.* 1959, Moyle 1976). In this study, redear sunfish were observed in Rancho Seco Park Pond, Lake Berryessa, and Millerton Lake.

Spawning occurs mostly in depths of over 1.8 m (Swingle and Smith 1950) to 3 m (Emig 1966). In this study, redear sunfish nests were found close to shore in quiet water deeper than 1 m. The nests are constructed by males in close proximity; male fish guard and fan the nest during incubation. The details of reproductive biology of this species have been described by Emig (1966). In general, the mating behavior is similar to that of pumpkinseed (Wilber 1969). Incubation lasts about 50 hours at 23.6°C (Childers 1967).

Newly hatched larvae remain in the nesting area for a short period until they disperse freely into weedy areas. The larvae school with hitch and bluegill of similar age.

Juveniles swim in schools or alone in vegetated shallow waters (Hellier 1967, this study). Some juveniles venture into deeper open water but remain close to vegetation. Juvenile redear feed primarily on insect larvae and small crustaceans. Large juveniles take small snails (Wilbur 1969); they are also known as "shell-crackers."

Redear sunfish mature during their second summer (Schoffman 1939, Pflieger 1975). In California, maturity of this species may be delayed until they are 3–4 years old (Moyle 1976). Lake Berryessa has a fast growing population of this species (Skillman 1969). The redear sunfish is a desirable pan fish.

References

Beland 1953, Carr and Goin 1955, Childers 1967, Clugston 1966, Eddy 1957, Emig 1966, Hardy 1978b, Hellier 1967, May and Gassaway 1967, Meyer 1970, Moyle 1976, Pflieger 1975, Schoffman 1939, Shapovalov *et al.* 1959, Skillman 1969, Smitherman and Hester 1962, Swingle and Smith 1950, Werner 1966, Wilbur 1969.

SMALLMOUTH BASS, *Micropterus dolomieui* (Lacepède)

SPAWNING

Location	From stream (Trautman 1957) to lake (Webster 1954); areas with little current (Emig 1966); Capell Creek of Lake Berryessa, upper San Joaquin River at Millerton Lake, and Folsom Lake.
Season	Late spring (Moyle 1976); May–July (Fish 1932); estimated in April and May.
Temperature	13–16°C (Moyle 1976); 16.1–18.3°C (Scott and Crossman 1973).
Salinity	Freshwater.
Substrate	Gravel and rock rubble (Emig 1966, Scott and Crossman 1973); rocky river and creek bed.
Fecundity	2,000–21,000 (Moyle 1976); 20,825 (Fajen 1975).

CHARACTERISTICS

EGGS

Shape	Spherical.
Diameter	Unfertilized eggs, mostly 1.2–2.25 mm (Fish 1932); fertilized eggs average 2.0 mm (Meyer 1970); 1.2–2.5 mm (Scott and Crossman 1973).
Yolk	Light amber (Fish 1932, Coble 1975); pale yellow (Hardy 1978b).
Oil globule	Single large oil globule (Fish 1932).
Chorion	Transparent.
Perivitelline space	Narrow (Reighard 1906).
Egg mass	Small cluster, becoming loose (Coble 1975).
Adhesiveness	Adhesive initially after fertilization (Coble 1975).
Buoyancy	Demersal (Scott and Crossman 1973).

LARVAE

Length at hatching	4.6 mm TL (Reighard 1906).
Snout to anus length	(Derived from illustrations.) Ca. 48–53% of TL of larvae at 6.75 to 11.1 mm TL (Reighard 1906); ca. 46% of TL of larvae at 8.8 mm TL (Fish 1932);

	ca. 46% of TL of larvae at 10.2 mm TL (Meyer 1970).
Yolk sac	Spherical to oval, large, extending from head to abdominal region (Reighard 1906).
Oil globule	Single, bright golden (Reighard 1906).
Gut	Gut massively coiled at 8.0 mm TL (Anjard 1974); intestine becomes coiled at 9.5 mm TL (Fish 1932).
Air bladder	Near pectoral (Anjard 1974).
Size at completion of yolk-sac stage	Ca. 8.0–9.0 mm TL (Reighard 1906).
Total myomeres	29–33 (Fish 1932).
Preanal myomeres	10–11 (Fish 1932).
Postanal myomeres	19–22 (Fish 1932).
Last fin(s) to complete development	Pelvic (Hardy 1978b).
Pigmentation	No pigmentation at hatching. Later, pigmentation appears on head, trunk, and thoracic regions. At 7.5 mm TL, dense pigmentation covers entire body (Hardy 1978b); the entire larva is densely spotted at 8.8 mm TL (Fish 1932).
Distribution	Initially in the nesting area and then dispersing to shallow water along the shore (Reighard 1906); in side pools and pools of Capell Creek of Lake Berryessa and in the upper San Joaquin River at Millerton Lake.

JUVENILES (Figure 25-26)

Dorsal fin	IX–X, 13–15 (Moyle 1976); X, 14 (Fish 1932); X, 12–15 (Scott and Crossman 1973).
Anal fin	III, 10–12 (Moyle 1976; Scott and Crossman 1973); III, 12 (Fish 1932).
Pectoral fin	16–18 (Moyle 1976); 13–15 (Scott and Crossman 1973).
Mouth	Terminal, large, slightly oblique, maxillary reaching to middle of the eye (Scott and Crossman 1973).
Vertebrae	31–32 (Scott and Crossman 1973).
Distribution	Sandy shoals (Webster 1942), rocky areas (Coble 1975); shallow stream pools with sandy and rock bottoms.

LIFE HISTORY

The smallmouth bass is native to the freshwaters of eastern and central North America, and has been introduced to almost the entire United States and many other parts of the world (Scott and Crossman 1973). The smallmouth bass was introduced into California in 1874 (Curtis 1949). In this study area, smallmouth bass were observed in the San Joaquin River at Millerton Lake (Lambert 1978, Lambert and Handley 1980, this study); Lake Berryessa (Moyle 1976); Capell Creek of Lake Berryessa; and Folsom Lake (Moyle 1976, this study).

Many juveniles were collected in Capell Creek in summer months, and spawning was estimated to have occurred in April and May. Spawning in the San Joaquin River at Millerton Lake may be variable, because of the colder water from the upper basin draining through Kerckhoff Dam. The optimum temperature for egg deposition of this species is 16.1–18.3°C (Scott and Crossman 1973). Courtship behavior of the California smallmouth bass population has been described by Emig (1966) and Moyle (1976). Male fish construct a nest 30–60 cm in diameter in shallow water with a sandy to rocky bottom. Some nesting sites are close to spotted bass nests (D. Mitchell 1982, personal communication). Eggs are demersal and adhesive, and attach to rocky surfaces in the nest. The male guards the nest during incubation and after hatching until juvenile fish reach about 25 mm TL (Emig 1966). Eggs hatch in 10 days at 12.8°C and in 2.5 days at 25.6°C (Emig 1966).

Newly hatched larvae remain in the nest for several days (Reighard 1906, Emig 1966), and then swim in dense schools (Coble 1975). They are continuously guarded by the male parent for 1–3 weeks (Moyle 1976) or 2–3 cm TL (Emig 1966). Finally, the larvae and juveniles disperse into shallow waters.

Juveniles are solitary in sandy pools, such as in Capell Creek of Lake Berryessa and Temperance flat of Millerton Lake in summer months. Smallmouth bass juveniles initially feed on crustaceans and aquatic insects and then prey on small fish as they grow larger (Moyle 1976).

Maturity is reached during their third or fourth year (Moyle 1976); others have reported that the fish mature mostly at age 2 (Emig 1966, Webster 1954). Moyle (1976) comments that smallmouth bass are of minor importance to the sport fishermen because of the sparse population, although the flesh is as tasty as that of largemouth bass.

References

Anjard 1974; Coble 1975; Curtis 1949; Emig 1966; Fajen 1975; Fish 1932; Hardy 1978b; Lambert 1978; Lambert and Handley 1980; Meyer 1970; Mitchel 1982, personal communication; Moyle 1976; Reighard 1906; Scott and Crossman 1973; Trautman 1957; Webster 1942, 1954.

SPOTTED BASS, *Micropterus punctulatus* (Rafinesque)

SPAWNING

Location	In the flats of Millerton Lake, from shallow water up to 6 m (D. Mitchell 1982, personal communication).
Season	Estimated from April to June; late March to June, peaking in late April and early May (D. Mitchell 1982, personal communication).
Temperature	18°C (Howland 1931); started at 12.0–12.5°C (D. Mitchell 1982, personal communication).
Salinity	Freshwater.
Substrates	Mud to gravel (Moyle 1976); mud, sand (D. Mitchell 1982, personal communication).
Fecundity	2,000–2,500 each nest (Howland 1931).

CHARACTERISTICS

EGGS

Shape	Spherical.
Diameter	Less than one third of that of smallmouth bass eggs (Pflieger 1975).
Buoyancy	Demersal.

LARVAE

Distribution	Newly hatched larvae remain in the nesting area (Pflieger 1975); swim in schools in the shallow flats of Millerton Lake (D. Mitchell 1982, personal communication).

JUVENILES (Figure 25-27)

Dorsal fin	IX–XI, 9–11 (Moyle 1976); X, 12 (Cross 1967).
Anal fin	III, 9–11 (Moyle 1976); III, 10 (Cross 1967); spiny anal fin, II–V (Pflieger 1975).
Pectoral fin	14–17 (Moyle 1976); 15–16 (Cross 1967).
Mouth	Large (Pflieger 1975); maxillary extending past the middle of the eye to hind margin of the eye (Moyle 1976).
Vertebrae	Usually 32 (Cross 1967).
Distribution	Millerton Lake; Millerton Lake and Upper San Joaquin River below PG&E powerhouse; introduced

to Lake Berryessa in 1981 and 1982 (D. Mitchell 1982, personal communication).

LIFE HISTORY

The original distribution of the spotted bass is from southern Illinois, Missouri, and Ohio, southward to eastern Texas and the Gulf, covering major drainages of the Mississippi River (Eddy 1957, Pflieger 1975). The spotted bass populations in California were introduced from Ohio in 1933 (McKechnie 1966). They are found in the Cosumnes River and in Lake Oroville of the Feather River (Moyle 1976). The spotted bass population in Millerton Lake had two origins: the Elk Grove Fish Hatchery and Lake Perris, Riverside County. They were introduced in 1974 and 1975 respectively (D. Mitchell 1982, personal communication).

Spawning is most intense from mid-April to early July in Missouri (Pflieger 1975). Judging from the small juvenile spotted bass taken in this study, spawning was estimated to have occurred from April to June. The spawn started as early as late March and peaked in late May and early June in Millerton Lake (D. Mitchell 1982, personal communication). Nesting areas include most of the peripheral regions of Millerton Lake, with concentrations in the shallow flats near the Madera Boat Ramp; depth ranged from 1–6 m. Males construct nests in colonies (D. Mitchell 1982, personal communication). Eggs are quite small, about one-third or less of smallmouth bass eggs (Pflieger 1975). Moyle (1976) reported that spotted bass nests are constructed in low current areas.

Larvae are pale green or translucent (Pflieger 1975), or almost transparent (D. Mitchell 1982, personal communication). They were not collected by Lambert and Handley (1980), nor in this study. Pflieger (1975) reported that spotted bass larvae disperse from the nest 8–9 days after hatching, and the male parents do not guard the larvae as long as the smallmouth bass do. D. Mitchell (1982, personal communication) observed spotted bass larvae and smallmouth bass larvae in a mixed school which was guarded by a smallmouth bass male.

Juveniles are often observed near all boat ramps of Millerton Lake in the summer months. Juveniles feed on crustaceans and aquatic insects (Smith and Page 1969). Small threadfin shad were found in the stomachs of larger juvenile spotted bass (this study, D. Mitchell 1982, personal communication).

Maturity is reached at the age of 2 or 3 (Howland 1931), and the maximum total length is about 51 cm (McKechnie 1966). A single fish weighing more than 3 kg was landed at Millerton Lake (D. Mitchell 1982, personal communication). The life expectancy is about 6 years, shorter than that of a largemouth bass (Pflieger 1975). The spotted bass is gaining popularity as a sport fish at Millerton Lake.

The spotted bass seems to adapt very well in fluctuating reservoirs, since nesting areas can be in deeper water. Spotted bass larvae disperse faster than those of either smallmouth or largemouth bass. The early life history of this species is still sketchy, and more studies are needed.

References

Cross 1967; Eddy 1957; Howland 1931; Lambert and Handley 1980; McKechnie 1966; Mitchell 1982, personal communication; Moyle 1976; Pflieger 1975; Smith and Page 1969.

LARGEMOUTH BASS, *Micropterus salmoides* (Lacepède)

SPAWNING

Location	Shallow inshore waters of ponds, lakes, reservoirs, sloughs of the Delta, creeks, and some irrigation ditches.
Season	April (Emig 1966) to June (Moyle 1976); mid-April to late May (von Geldern 1971); April through June, peaking in early May.
Temperature	Started at 14–16°C (Emig 1966, Miller and Kramer 1971); up to 24°C (Moyle 1976); eggs were collected at 14.0–18.2°C.
Salinity	Freshwater.
Substrates	Mostly over gravel (Emig 1966, Miller and Kramer 1971); mud (Webster 1942); sand to mud below boulders.
Fecundity	2,000–94,000 or more (Moyle 1976); 2,000–110,000 (Scott and Crossman 1973); fecundity increases with age, weight and length of female fish (Latta 1975).

CHARACTERISTICS

EGGS

Shape	Spherical.
Diameter	1.5–1.7 mm (Kelley 1962); 1.4 mm (Meyer 1970); maximum 1.95 mm (Merriner 1971); 1.63–1.71 mm (Wang and Kernehan 1979).
Yolk	Yellowish, light yellow, clear (Saika 1973); granular (Wang and Kernehan 1979).
Oil globule	Single, dark amber color, ca. 0.7 mm in diameter (Carr 1942); single, 0.52–0.55 mm in diameter (Wang and Kernehan 1979).
Chorion	Transparent, thin (Hardy 1978b); transparent to translucent, elastic.

Perivitelline space	Narrow, ca. 0.16–0.24 mm in width (Wang and Kernehan 1979).
Egg mass	Deposited in center of the nest (Hardy 1978b); eggs deposited in small clusters or loosely all over the nest.
Adhesiveness	Adhesive, attached to stones (Fish 1932); sticky when first deposited; lose their adhesiveness after water hardening (Carr 1942).
Buoyancy	Demersal.

LARVAE (Figures 25-28, 25-29, 25-30)

Length at hatching	As small as 2.3 mm TL (Perche 1964); recently hatched fish collected in field, 3.6–4.1 mm TL (Wang and Kernehan).
Snout to anus length	Ca. 47–50% of TL of prolarvae and postlarvae.
Yolk sac	Large, spherical to oval, extending from head to abdominal region; head slightly recessed into yolk sac.
Gut	Short and straight in prolarvae; massively coiled in postlarvae (Anjard 1974).
Air bladder	Large, above and behind the base of pectoral; air bladder becomes first evident at ca. 5.0 mm TL (Carr 1942).
Teeth	Sharp, pointed, developing in postlarval stage.
Size at completion of yolk-sac stage	Ca. 6.5–8.5 mm TL.
Total myomeres	30 (Carr 1942); 28–34, mostly 32.
Preanal myomeres	11 (Carr 1942); 11–13.
Postanal myomeres	19 (Carr 1942); 17–21.
Last fin(s) to complete development	Pelvic.
Pigmentation	Newly hatched larvae have no pigmentation; then pigments appear on head and yolk sac regions, and small melanophores on middorsum, operculum, and postanal region. In postlarvae, small melanophores extend to entire posterior half of the body, with a dark horizontal band in the lateral line region.
Distribution	Newly hatched larvae remain in the nest (Carr 1942); postlarvae venture to the surface in small schools and eventually disperse into shallow weedy waters, such

	as Lake Hennessey, Lake Anza, Folsom Lake, and Millerton Lake.

JUVENILES (Figure 25-31)

Dorsal fin	IX, 12–13 (Moyle 1976); X, 12–14 (Scott and Crossman 1973).
Anal fin	III, 10–12 (Moyle 1976); III, 10–12, usually 11 (Scott and Crossman 1973); spiny anal fin, II–III (Beckman 1952).
Pectoral fin	13–17, usually 14 or 15 (Moyle 1976); 13–15 (Hardy 1978b).
Mouth	Terminal, large, oblique, maxillary reaching to posterior margin of the eye (Scott and Crossman 1973); mouth slightly superior, maxillary reaching to the middle of the eye in juvenile.
Vertebrae	30–32 (Scott and Crossman 1973); 33 (Bean 1903); mostly 32 (Ramsey 1975).
Distribution	Juveniles associated with vegetation (Carbine 1939, Carlander 1975) school near edge of pond or near vegetation with golden shiner larvae (Kramer and Smith 1962); throughout sloughs and tributaries of the Delta, also found in ponds and reservoirs of the Sacramento-San Joaquin river system and adjacent waters.

LIFE HISTORY

The native range of the largemouth bass is from the lower Great Lakes to the Mississippi River drainages, the Gulf coast, Florida and part of the Rio Grande, and along the Atlantic slope as far north as Virginia (Scott and Crossman 1973). Because of the tremendous sport demand for this species, largemouth bass has been stocked through public agencies and individuals throughout North America and some other warm regions of the world (Robbins and MacCrimmon 1974). Largemouth bass were introduced into California in 1874 (Skinner 1962). Most of this population is believed to be the northern subspecies, *Micropterus salmoides salmoides*, also known as the Illinois largemouth bass. A fast growing subspecies, the Florida black bass, *Micropterus salmoides floridus*, was also introduced into California in recent years (Moyle 1976, Shapovalov *et al.* 1981).

In this study, largemouth bass have been observed throughout the freshwater areas except in some coastal streams, such as Tunitas Creek and Tennessee Valley Creek, and some midelevation lakes, such as Ice House Reservoir and Loon Lake. They seldom move into the oligohaline portion of the Sacramento-San Joaquin Estuary, a characteristic quite different from East Coast populations (Smith 1971, Christmas and Waller 1973).

Spawning of the largemouth bass in California occurs as early as April when water temperatures approach 14°C (Emig 1966, Miller and Kramer 1971); this is generally 2–4 weeks prior to the spawning of *Lepomis* spp. The males construct a nest, usually a depression near the shore, in substrate of submerged vegetation, sand, gravel or mud (Emig 1966), depending upon what is available. Eggs are deposited in the center of the nest, and some eggs may become covered by the substrate as a result of spawning activity. Pflieger (1975) stated that largemouth bass have never built nests in areas with current or wave action. However, some nests were observed in the sloughs of the Delta and the inshore areas of large reservoirs (such as Millerton Lake) where there are currents and/or waves. During the spawning period, a female may mate with several males in different nests, and thus several batches of eggs are deposited into the nests at short intervals (Reighard 1906, Breder and Rosen 1966). The male guards the nest and the subsequent brood. Golden shiner eggs are often found in largemouth bass nests (Scott and Crossman 1973, this study). A possible explanation for this is that the largemouth bass allows the shiners to deposit eggs into its nest, eggs which will hatch and become forage fish for the bass. Eggs hatch in 5 days at 18.9°C and in 2 days at 22.2°C (Emig 1966).

Newly hatched larvae are unpigmented and remain in the nest for several more days before rising to the surface and forming a school near the spawning ground (Carr 1942). The male largemouth bass is a very attentive parent, and he closely follows and guards the bass larvae (Pflieger 1975) and the golden shiner larvae as well, although the shiner are much darker than largemouth bass. As larvae grow larger and become more active, they eventually disperse into shallow waters or weedy areas.

Small juveniles still stay in tight schools (Carr 1942; Kramer and Smith 1960, 1962; this study). At this stage, they swim with their own species or mix with golden shiner juveniles at the edges of the ponds, reservoirs, or sloughs, within a close distance to plant beds. Any disturbance will cause the juveniles to dive quickly into the deeper water or plant beds. In aquarium observation, small juveniles hatched from the same batch may develop into different sizes after a short period. Cannibalism occurs as juveniles grow larger. Large juveniles become more solitary, although they sometimes keep a close distance. Major food items for the small juveniles are cladocerans, chironomid larvae, amphipods, copepods, and small invertebrates (Kramer and Smith 1960). Larger juveniles take mainly aquatic insects or small fish such as golden shiner and threadfin shad (Goodson 1965), bluegill (McCammon *et al.* 1964), and largemouth bass larvae (Keast 1966). Juvenile largemouth bass are aggressive predators whose feeding strategy includes ambushing and chasing of the prey at high speeds.

The age of maturity of this species ranges from 1 year in southern states to 2–4 years in northern states (Emig 1966). In California, largemouth bass mature during their second or third spring (Moyle 1976). Maximum lifespan is about 13–15 years (Scott and Crossman 1973). The largemouth bass are the most sought after warm-water gamefish in California (Moyle 1976), and the Florida black bass has become a popular strain since its introduction (D. Mitchell 1981, personal communication).

References

Anjard 1974; Bean 1903; Beckman 1952; Breder and Rosen 1966; Carbine 1939; Carlander 1975; Carr 1942; Christmas and Waller 1973; Emig 1966; Fish 1932; Goodson 1965; Hardy 1978b; Keast 1966; Kelley 1962; Kramer and Smith 1960, 1962; Latta 1975; McCammon *et al.* 1964; Merriner 1971; Meyer 1970; Miller and Kramer 1971; Mitchell 1981, personal communication; Moyle 1976; Perche 1964; Pflieger 1975; Ramsey 1975; Reighard 1906; Robbins and MacCrimmon 1974; Saika 1973; Scott and Crossman 1973; Shapovalov *et al.* 1981; Skinner 1962; Smith 1971; Von Geldern 1971; Wang and Kernehan 1979; Webster 1942.

WHITE CRAPPIE, *Pomoxis annularis* (Rafinesque)

SPAWNING

Location	In ponds, lakes (Hansen 1943, 1965; Whiteside 1964); nest in depths of less than 1 m (Hansen 1951) to 3 m (Pflieger 1975), and as deep as 6–7 m (Moyle 1976); in ponds, reservoirs, sloughs, and ditches of the Sacramento-San Joaquin River systems, such as Lindsey Slough, Cache Slough, and Montezuma Slough.
Season	April or May in California (Moyle 1976); May–June in Illinois (Hansen 1965); April–June in Missouri (Pflieger 1975); judging by the small juveniles taken, spawning was estimated from April through June.
Temperature	17–20°C (Moyle 1976); 16–20°C (Siefert 1968).
Salinity	Freshwater.
Substrates	Gravel, sand, clay, or mud (Hansen 1943, 1965; Whiteside 1964); algae, dead leaves (Hansen 1965); aquatic vegetation (Siefert 1968).
Fecundity	970 (Whiteside 1964); 213,000 (Moyle 1976); 325,677 (Morgan 1954).

CHARACTERISTICS

EGGS

Shape	Spherical.
Diameter	0.82–0.92 mm with an average of 0.89 mm (Hansen 1943, Whiteside 1964).
Yolk	Colorless (Scott and Crossman 1973); granular (Morgan 1954).
Oil globule	Single, large (Morgan 1954).
Chorion	Transparent; newly fertilized eggs elastic (Morgan 1954).

Perivitelline space	Ca. one-seventh of yolk diameter (Morgan 1954).
Egg mass	Single to small clumps (Siefert 1968).
Adhesiveness	Adhesive (Hansen 1943, Morgan 1954).
Buoyancy	Demersal (Morgan 1954).

LARVAE

Length at hatching	1.22–1.98 mm TL (Morgan 1954).
Snout to anus length (derived from illustrations)	Ca. 41–48% of TL of larvae at 1.75 to 6.0 mm TL (Morgan 1954); ca. 38–40% of TL of larvae at 4.3 to 11.2 mm TL (Taber 1969).
Yolk sac	Spherical to oval, large, extending from head or jugular to abdominal region (Morgan 1954).
Oil globule	Single, located in various sections of the yolk sac (Morgan 1954)
Gut	Straight in prolarvae, becoming folded at 3.9 mm TL (Morgan 1954); very short, gut coiled in postlarval stage (Anjard 1974).
Air bladder	Oval, large, near anal region (Anjard 1974).
Size at completion of yolk-sac stage	Ca. 3.7–4.0 mm TL (Morgan 1954).
Total myomeres	28–31 (Siefert 1969a).
Preanal myomeres	10–13 (Siefert 1969a).
Postanal myomeres	17–20 (Siefert 1969a).
Last fin(s) to complete development	Pelvic (Taber 1969).
Pigmentation	Newly hatched larvae are unpigmented, then melanophores become evident along postanal region at 3.9 mm TL (Morgan 1954); postanal melanophores disappeared at 13.5 mm TL, and there are a few melanophores in the cephalic region (Taber 1969).
Distribution	In shallow water near the spawning area (Taber 1969); shallow water of Lindsey Slough and adjacent ditches.

JUVENILES (FIGURE 25-32)

Dorsal fin	V–VI, 13–15 (Moyle 1976); VI–VII, 13–15 (Scott and Crossman 1973); spiny dorsal fin, IV to VIII (Trautman 1957).

Anal fin	V–VI, 17–18 (Moyle 1976); VI–VIII, 16–18 (Scott and Crossman 1973); spiny anal fin as low as V and soft anal fin as high as 19 (Beckman 1952).
Pectoral fin	14–15 (Moyle 1976); 13 (Scott and Crossman 1973).
Mouth	Lower jaw projects, mouth large, oblique (Moyle 1976); lower jaw longer than upper jaw (Scott and Crossman 1973); mouth slightly superior.
Vertebrae	30–32 (Scott and Crossman 1973).
Distribution	Delta sloughs, irrigation ditches, some reservoirs, and ponds.

LIFE HISTORY

The native range of the white crappie extends from the Mississippi River drainage to the Gulf coast and along the eastern seaboard to North Carolina, and northward to most of the Great Lake Basin (Scott and Crossman 1973). However, Pflieger (1975) says that the eastern range of this species is restricted to the west slope of the Appalachians. Like the largemouth bass, the white crappie has been planted in many western states for sport fishing. Goodson (1965) reported the initial introduction of the white crappie to southern California in 1917 and to northern California in 1951. In this study, white crappie were found to be rare in the tidal estuary and patchy in some Delta sloughs and irrigation ditches, and none were found in coastal streams or foothill creeks and reservoirs.

Spawning was estimated to be from April to June or July in the study area. Nests are constructed by males in shallow water, usually less than 1 m in depth (Hansen 1951), but sometimes up to 3 m (Pflieger 1975) or even deeper (6–7 m) (Moyle 1976). Nests are constructed on hard bottoms using gravel, clay, and plant materials; sometimes the nests lack depressions (Hansen 1965; Pflieger 1975). Females release only a few eggs at each interval and mate with different males (Scott and Crossman 1973). Males guard the nest. Incubation lasts from 43–51 hours at 18.3–1.4°C and 93 hours at 14.4°C (Siefert 1968).

Newly hatched larvae are transparent and remain in the guarded nest until they can swim freely and diffuse into adjacent plant beds (Siefert 1969b). Small white crappie larvae concentrate at the surface of the water column at night and are evenly distributed in daytime. Larger larvae (5–10 mm TL) are mostly abundant at the bottom during daytime.

Juveniles school in ponds and reservoirs near weedy shores. They were common in Lindsey and Cache sloughs and their adjacent irrigation ditches. Sometimes this species is associated with the black crappie. Apparently white crappie stray occasionally into open waters of Suisun Bay, since they were collected on the intake screens of the Contra Coast and Pittsburg Powerplants. The major dietary component of small juvenile white crappie is planktonic crustaceans (Goodson 1965, Nelson *et al.* 1967, Siefert 1968); larger juveniles feed on insects and small fishes such as threadfin shad and inland silverside (Moyle 1976).

Sexual maturity is reached at 2–3 years (Morgan 1954, Goodson 1966, Pflieger 1965). The maximum life expectancy of this species has been reported as 8–10 years (Scott and Crossman 1973), but few of them live more than 3–4 years (Pflieger 1975). The sport value of the white crappie in the study area is probably restricted by their patchy distribution.

References

Anjard 1974; Beckman 1952; Goodson 1965; Hansen 1943, 1951, 1965; Morgan 1954; Moyle 1976; Nelson *et al.* 1967; Pflieger 1975; Siefert 1968, 1969a,b; Taber 1969; Trautman 1957; Whiteside 1964.

BLACK CRAPPIE, *Pomoxis nigromaculatus* (Lesueur)

SPAWNING

Location	In backwaters of sloughs and tributaries associated with the Delta, such as Lindsey Slough, Wilson Slough, Montezuma Slough, and Bear Creek; in ponds and reservoirs, such as Folsom Lake and Millerton Lake.
Season	March or April through July (Moyle 1976); April through June or July.
Temperature	Exceeding 14°C (Moyle 1976); 16–21°C (Siefert 1969a); exceeding 15°C (Smith 1971).
Salinity	Freshwater.
Substrates	Clay, sand, and fine gravel (Breder 1936); these and mud (Scott and Crossman 1973); near aquatic vegetation (Evermann and Clark 1920).
Fecundity	10,000–20,000 (Moyle 1976); 26,700–65,520, average 37,796 (Scott and Crossman 1973).

CHARACTERISTICS

EGGS

Shape	Spherical.
Diameter	0.93 mm (Merriner 1971).
Yolk	Whitish (Scott and Crossman 1973).
Oil globule	Single (Hardy 1978b).
Chorion	Unfertilized eggs; transparent, elastic and smooth.
Egg mass	Presumably single or small clumps.
Adhesiveness	Adhesive (Scott and Crossman 1973).
Buoyancy	Demersal.

LARVAE (Figure 25-33)

Length at hatching	2.32 mm TL (Siefert 1969a).
Snout to anus length	Ca. 38–40% of TL of larvae at 10.8–11.4 mm TL.
Oil globule	Single (Faber 1963).
Gut	Coiled at 6–9 mm TL (Anjard 1974).
Air bladder	Large and near anal region (Anjard 1974).
Teeth	Small, pointed, becoming evident in postlarval stage.
Total myomeres	29–32 (Siefert 1969a); 31–34, mean 32 (Faber 1963); 31–32.
Preanal myomeres	10–14 (Siefert 1969a); 9–10 (Faber 1963); 13–14.
Postanal myomeres	18–21 (Siefert 1969a); 21–24 (Faber 1963); 18–19.
Last fin(s) to complete development	Pelvic.
Pigmentation	Transparent (Adams and Hankinson 1928); small melanophores on head, isthmus, and postanal region in postlarvae.
Distribution	Mostly in shallow weedy sloughs, such as Lindsey and Wilson Sloughs; lakes and reservoirs, such as Folsom Lake and Millerton Lake.

JUVENILES (Figure 25-34, 25-35)

Dorsal fin	VII–VIII, 15–16 (Moyle 1976); soft dorsal fin, 14–16 (Scott and Crossman 1973).
Anal fin	VI, 16–18 (Moyle 1976); spiny anal fin, VI–VII (Scott and Crossman 1973).
Pectoral fin	14–15 (Moyle 1976); 13–15 (Hardy 1978b).
Mouth	Large, oblique, lower jaw slightly protruding (Scott and Crossman 1973).
Vertebrae	31–33 (Scott and Crossman 1973).
Distribution	Wide distribution in Delta sloughs (Turner 1966b); in tidal water as far as San Pablo Bay.

LIFE HISTORY

The native range of the black crappie is in eastern and central North America, including the Great Lakes; from Florida west to the Gulf coast and Alabama, and north along the Atlantic coast to Virginia (Scott and Crossman 1973). It has been widely planted in many states beyond its natural distribution. The black crappie was introduced into California in 1908 (Goodson 1965). Now the black crappie can be found in almost any warm, quiet waters in the state (Moyle 1976). In this study, black crappie were commonly found in the Delta, Suisun Bay, Montezuma Slough, and even in oligohaline San Pablo Bay during high riverflows. However, at the present time, this species was not observed in the coastal creeks such as Walker Creek and Estero Americano, or in mid-elevation reservoirs such as Ice House Reservoir and Loon Lake.

Moyle (1976) reported black crappie spawning from March or April through July. Judging from the larvae collected in this study, the breeding period was from April to June or July. Turner (1966b) reported that black crappie are one of the most abundant centrarchids in the Delta, and it is possible that spawning may take place in the tidal and nontidal sloughs of the Delta. Nests are excavated by the male fish in bottoms of sand, gravel, or mud, near shores with vegetation (Breder 1936, Scott and Crossman 1973). Male fish guard the nest. Eggs hatch in 2–3 days at 18.3°C (Merriner 1971). In general, the spawning behavior of the black crappie is similar to that of the white crappie (Scott and Crossman 1973, Pflieger 1975). However, the early development of the black crappie is poorly described in the literature.

Newly hatched larvae are unpigmented, and remain in the nest. Males continue to guard the larvae for several days and then desert the nest (Scott and Crossman 1973). In this study, the larvae were observed in Lindsey and Cache Sloughs and surrounding turbid irrigation ditches.

Juveniles prefer quiet shallow water with patchy vegetation. Many of them were taken by beach seine in the vicinity of Wilson and Montezuma sloughs in summer months; they were also observed on the intake screens of the Oleum Powerplant. Apparently, the black crappie can tolerate water of moderately high salinity (Lebida 1969, Smith 1971). Small young (less than 10 cm FL) feed on zooplankton (Faber 1967) and larger ones take mostly amphipods, mysid shrimp, and other planktonic crustaceans in the estuary (Moyle 1976).

Black crappie become mature in 2–4 years; the maximum life expectancy has been reported as 8–10 years (Scott and Crossman 1973). The black crappie is an important game fish in California. Its flesh has a good quality, and farm-raised crops have been sold in Bay area fish markets on occasion.

References

Adams and Hankinson 1928; Anjard 1974; Breder 1936; Evermann and Clark 1920; Faber 1963, 1967; Goodson 1965; Hardy 1978b; Lebida 1969; Merriner 1971; Moyle 1976; Pflieger 1975; Scott and Crossman 1973; Siefert 1969a,b; Smith 1971; Turner 1966b.

Characteristic Comparison: Sunfishes

Characteristic	Sacramento Perch	Green Sunfish
Eggs		
Diameter (mm)	0.9–1.1	1.0–1.4
Larvae		
Length at hatch (mm)	Less than 4.0	3.2–3.9
Snout-anus length	36–44	39–49
Gut in postlarvae	Twisted or coiled	Coiled
Air bladder (between pectoral and anus)	Near pectoral or midway	Near pectoral
Total myomeres	31–34	27–30
Preanal myomeres	10–12	11–14
Postanal myomeres	21–22	14–17
Pigmentation	Prolarvae and postlarvae: large stellate melanophores on head, extending to tail; melanophores in mid-ventral, dorsal surface of gut, and postanal regions; dashed melanophores along lateral line	Prolarvae: large stellate melanophores on head, middorsal and midventral, dorsal surface of gut and postanal regions; postlarvae: pigmentation heavier, dashed melanophores along lateral line
Juveniles		
Dorsal fin	XII–XIII; I, 10–11	IX–XI, 10–12
Anal fin	VI-VII, 10	III, 8-10
Mouth	S1. Superior, large, oblique, maxillary to posterior margin of eye	Terminal, large, oblique, maxillary to anterior edge of eye
Pigmentation	7 or more vertical bands on side of body (mismatched in lateral line region)	7-12 vertical bands on side of body
Distinguishing characters	Spiny dorsal fin base very elongate	Mouth very large; dark blotch at end of soft dorsal fin

Characteristic Comparison: Sunfishes

Characteristic	**Pumpkinseed**	**Warmouth**
Eggs		
Diameter (mm)	0.8–1.2	1.0–1.1
Larvae		
Length at hatch (mm)	2.4–3.1	2.30–2.85
Snout-anus length	Prolarvae: 45–50 Postlarvae: 40–45	Prolarvae: 50 Postlarvae: 42–45
Gut in postlarvae	Coiled	—
Air bladder (between pectoral and anus)	Near pectoral	—
Total myomeres	27–35	29–30
Preanal myomeres	10–13	8–11
Postanal myomeres	17–21	17–10
Pigmentation	Prolarvae and postlarvae: stellate melanophores on cephalic, dorsal surface of gut, and (sometimes) postanal regions	Prolarvae: stellate melanophores on cephalic, thoracic, base of pectoral, and postanal regions; dashed melanophores on lateral line
Juveniles		
Dorsal fin	X–XI; 10–12	X–XI, 9–11
Anal fin	III, 8–11	III, 8–10
Mouth	Terminal, small, oblique	Terminal, large, oblique, maxillary near or reaching mid-eye
Pigmentation	Mosaic pattern; no vertical bands on side of body	9 or more short, stubby bands above lateral line; irregular blotches below it
Distinguishing characters	Gill rakers short, stubby; rear margin of opercular lobe stiff	Teeth on tongue; ca. 4 radial stripes behind eye

Characteristic Comparison: Sunfishes

Characteristic	Bluegill	Redear Sunfish
Eggs		
Diameter (mm)	1.04–1.37	1.3–1.6
Larvae		
Length at hatch (mm)	2.0–3.2	Maximum 5.0
Snouth-anus length	Prolarvae: ca. 42–45 Postlarvae: ca. 40	Postlarvae: 40–41
Gut in postlarvae	Coiled in single loop	Coiled in single loop
Air bladder (between pectoral and anus)	Oval to large, midway	Oval, midway
Total myomeres	27–31	30–32
Preanal myomeres	9–11	10–13
Postanal myomeres	17–21	17–20
Pigmentation	Postlarvae: a row of chromatophores along posterior margin of head; stellate melanophores on cephalic, thoracic, dorsal surface of gut, and postanal regions; ca 3 rows of large malanophores in and above postanal region in late postlarvae	Prolarvae: small melanophores on head, thoracic, and dorsal surface of gut near anus; a series of melanophores along postanal region, extending to dorsal portion of caudal region; postlarvae: pigmentation heavier, melanophores on lateral line
Juveniles		
Dorsal fin	X–XI; 10–12	X, 10–12
Anal fin	III, 8–12	III, 9-11
Mouth	Terminal, small, oblique	Terminal, small oblique
Pigmentation	9–11 elongate vertical bands on side of body	9 elongate vertical bands on side of body; bands disappear in large juveniles
Distinguishing characters	Gill rakers elongate; a dark blotch at posterior end of soft dorsal fin	Gill rakers short, stubby; rear margin of opercular lobe flexible

Characteristic Comparison: Sunfishes

Characteristic	Smallmouth Bass	Spotted Bass	Largemouth Bass
Eggs			
Diameter (mm)	1.2–2.5	1/3 or less of smallmouth bass eggs	1.4–1.95
Larvae			
Length at hatch (mm)	4.6	—	2.3–3.6
Snout-anus length	Ca. 46–53	—	47–50
Gut in postlarvae	Massively coiled	—	Massively coiled
Air bladder (between pectoral and anus)	Near pectoral	—	Near pectoral
Total myomeres	29–33	—	28–34
Preanal myomeres	10–11	—	11–13
Postanal myomeres	19–22	—	17–21
Pigmentation	Postlarvae: melanophores on head, trunk, and thoracic regions; covering entire larva at 7.5–8.8 mm TL	—	Prolarvae: melanophores on head, yolk sac, mid-dorsum, operculum, and postanal region; post-larvae: small melanophores extending to entire posterior half of body, with dark band of lateral line
Juveniles			
Dorsal fin	IX–X; 12–15	IX–XI, 9–12	IX–X, 12–14
Anal fin	III, 10–12	II–V, 9–11	II–III, 10–12
Mouth	Terminal, large, slightly oblique, maxillary to middle of eye	Terminal, large, maxillary past middle of eye	Terminal, large, oblique, maxillary to posterior margin of eye
Pigmentation	Ca. 10–12 short, stubby vertical bands on side of body	One broad horizontal band from snout to caudal region	One broad horizontal band from snout to caudal region
Distinguishing characters	No horizontal strip in lateral line region	Body almost cylindrical, very elongate	Tail or caudal fin two-colored

Characteristic Comparison: Sunfishes

Characteristic	**White Crappie**	**Black Crappie**
Eggs		
Diameter (mm)	0.82–0.92	0.93
Larvae		
Length at hatch (mm)	1.22–1.98	2.32
Snouth-anus length	Prolarvae, early postlarvae: 35–40 Late postlarvae: 35–40	Late postlarvae: 38–40
Gut in postlarvae	Very short, coiled	Very short, coiled
Air bladder (between pectoral and anus)	Oval, large, near anus	Large, above anus
Total myomeres	28–31	29–34
Preanal myomeres	10–13	9–14
Postanal myomeres	17–20	18–24
Pigmentation	Postlarvae: melanophores along postanal region at 3.9 mm TL; postanal melanophores disappear at 13.5. mm TL; sparse melanophores in cephalic region	Late postlarvae: small melanophores on head, isthmus, and postanal regions
Juveniles		
Dorsal fin	IV–VIII; 13–15	VII–VIII, 14–16
Anal fin	V–VII, 16–19	VI–VII, 16–18
Mouth	Large, oblique, lower jaw larger than upper, maxillary post middle of eye	Large, oblique, lower jaw slightly protruding, maxillary past middle of eye
Pigmentation	Ca. 10 vertical bands on side of body; body pigmentation light	Ca. 10 vertical bands on side of body; body pigmentation heavier
Distinguishing characters	Spiny dorsal fin usually VI	Spiny dorsalfin usually VII

Figure 25.—Centrarchidae: *Archoplites interruptus*, Sacramento perch.

FIGURE 25-1.—Newly fertilized egg, 1.1 mm diameter.

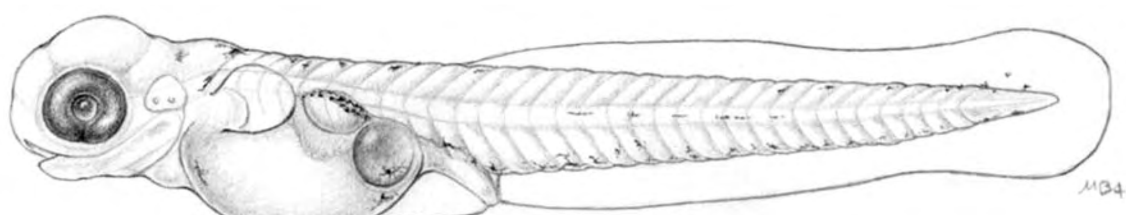


FIGURE 25-2.—Prolarva, 4 mm TL.

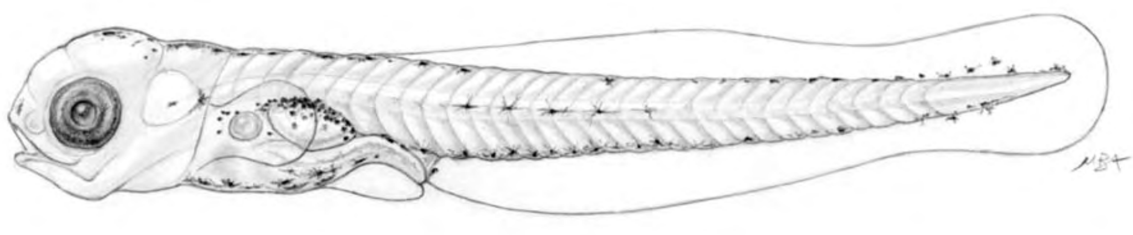


FIGURE 25-3.—Postlarva, 4.7 mm TL.

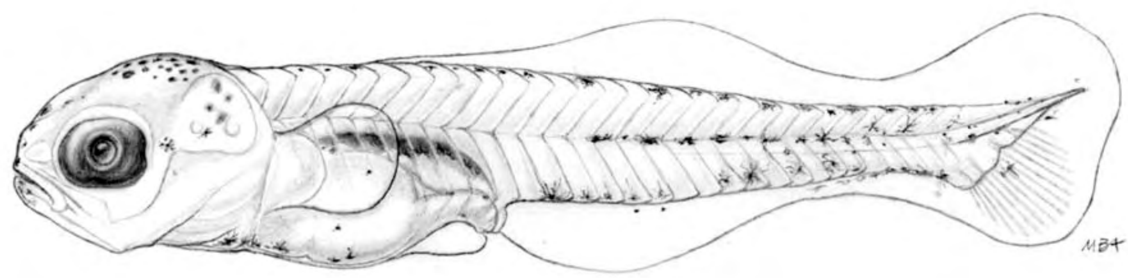


FIGURE 25-4.—Postlarva, 5 mm TL.

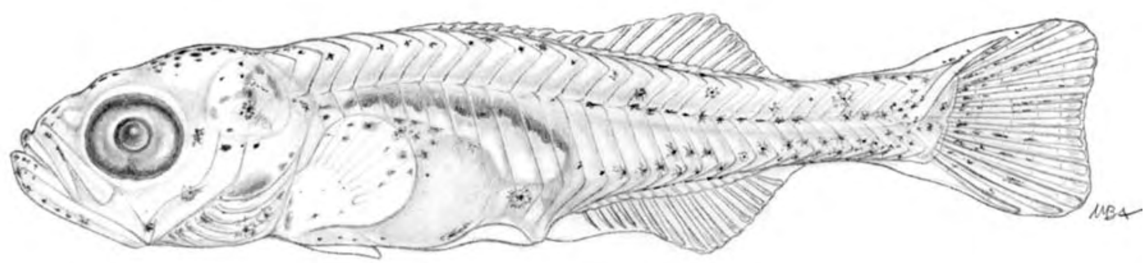


FIGURE 25-5.—Postlarva, 12 mm TL.

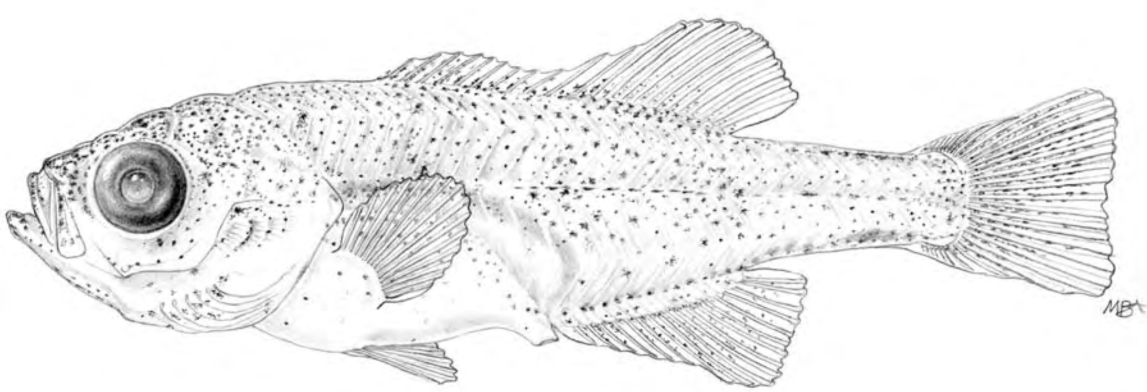


FIGURE 25-6.—Juvenile, 18.2 mm TL.

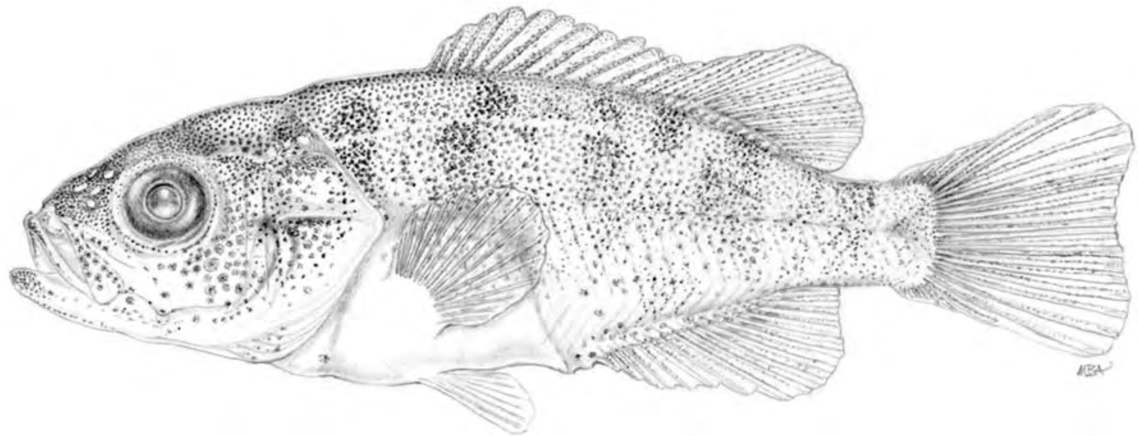


FIGURE 25-7.—Juvenile, 26.5 mm TL.

Centrarchidae: *Lepomis cyanellus*, green sunfish.

FIGURE 25-8.—Egg. morula, 1.1 mm diameter.

FIGURE 25-9.—Egg, gastrula, 1.3 mm diameter.

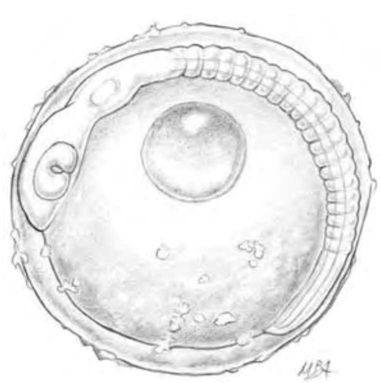


FIGURE 25-10.—Egg, late embryo, 1.3 mm diameter.

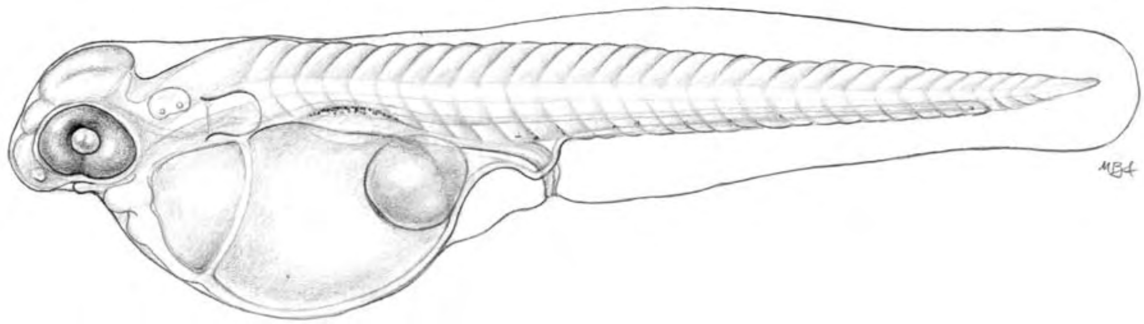


FIGURE 25-11.—Prolarva, 4.5 mm TL.

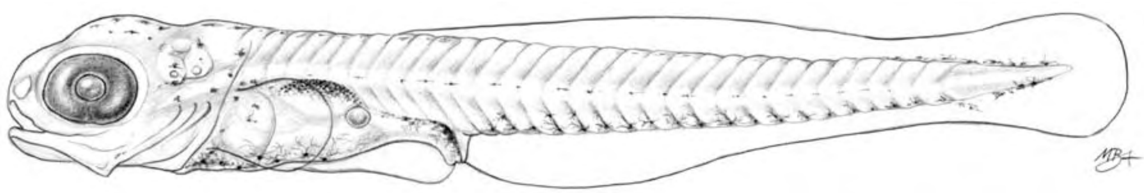


FIGURE 25-12.—Postlarva, 5 mm TL.

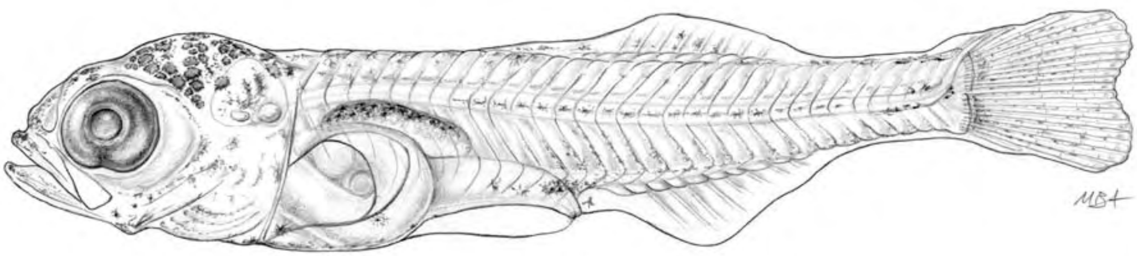


FIGURE 25-13.—Postlarva 9 mm TL.

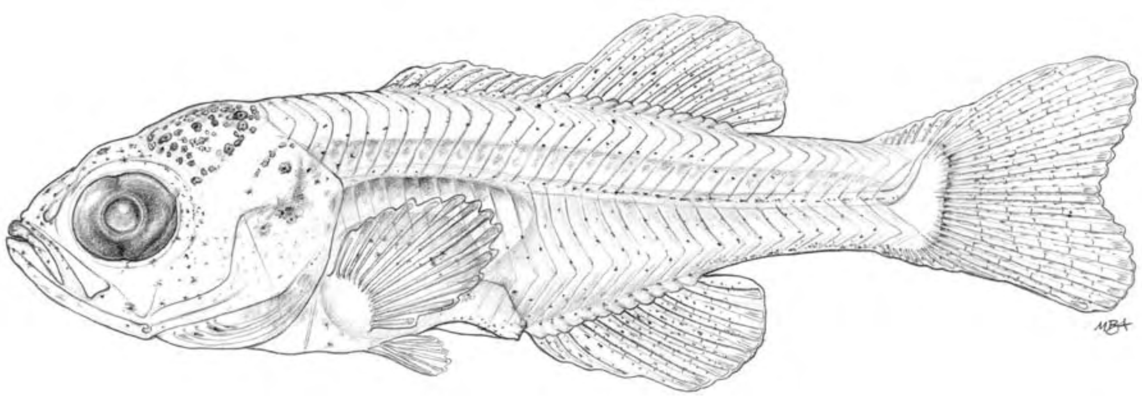


FIGURE 25-14.—Juvenile, 11.6 mm TL.

Centrarchidae: *Lepomis gibbosus*, pumpkinseed.

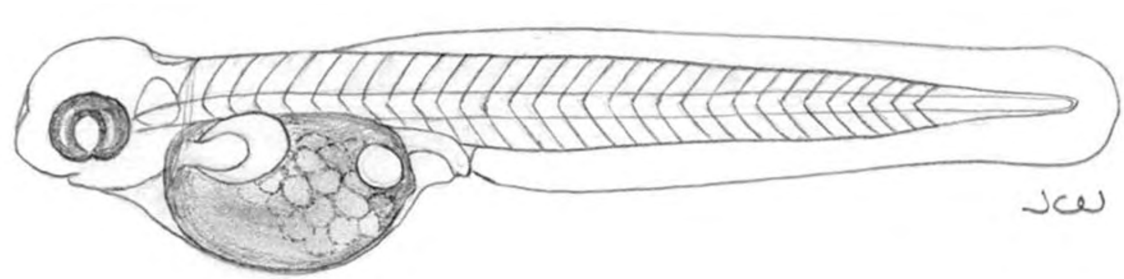


FIGURE 25-15.—Prolarva 4.2 mm TL.

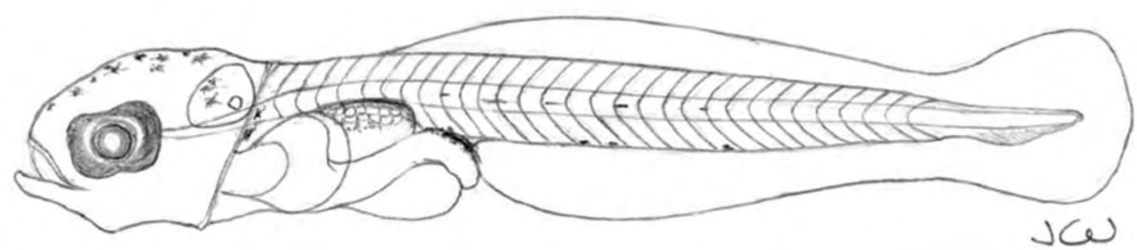


FIGURE 25-16.—Postlarva, 5.5 mm TL.

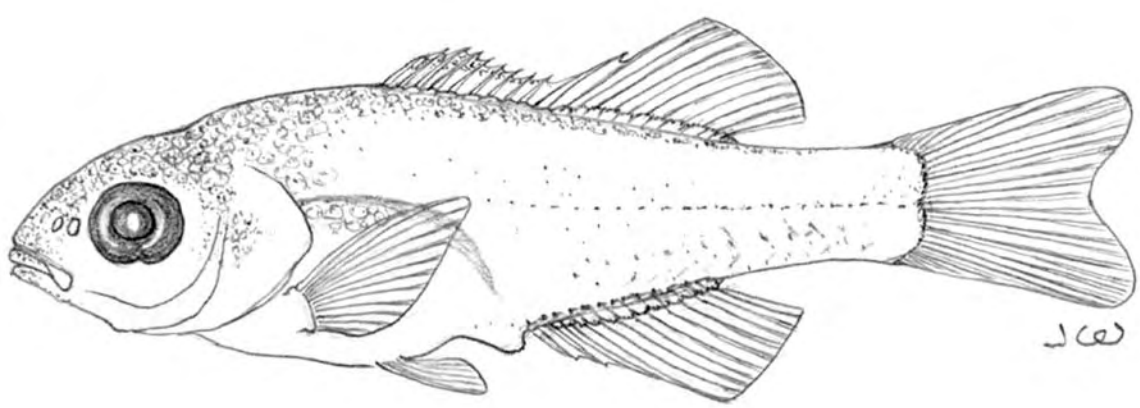


FIGURE 25-17.—Juvenile, 15.1 mm TL.

Centrarchidae: Sunfishes.

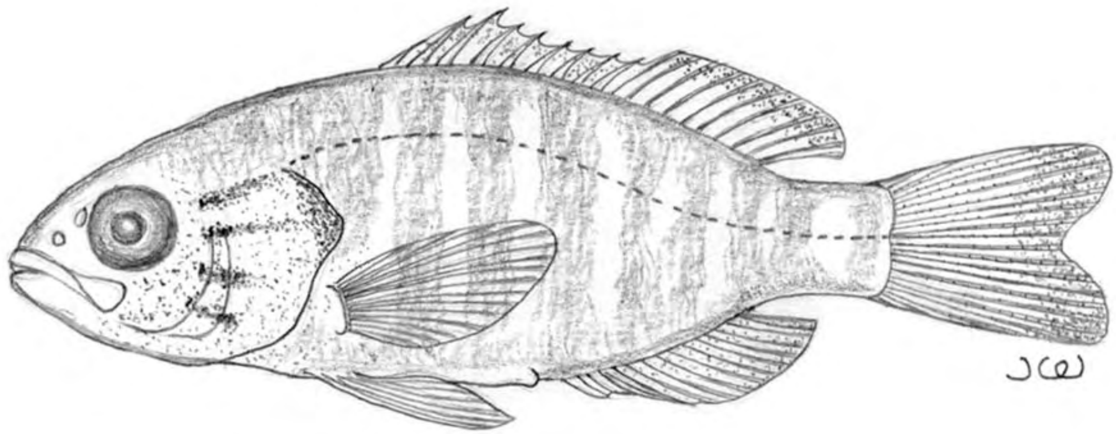


FIGURE 25-18.—*Lepomis gulosus*, warmouth juvenile, 38 mm TL.

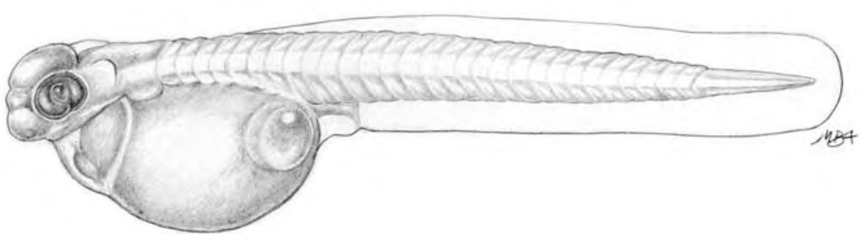


FIGURE 25-19.—*Lepomis macrochirus*, bluegill prolarva, 3.8 mm TL.

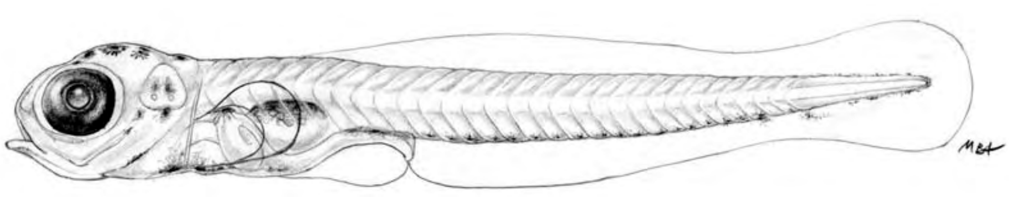


FIGURE 25-20.—*Lepomis macrochirus*, bluegill postlarva, 5.2 mm TL.

Centrarchidae: *Lepomis macrochirus*, bluegill.

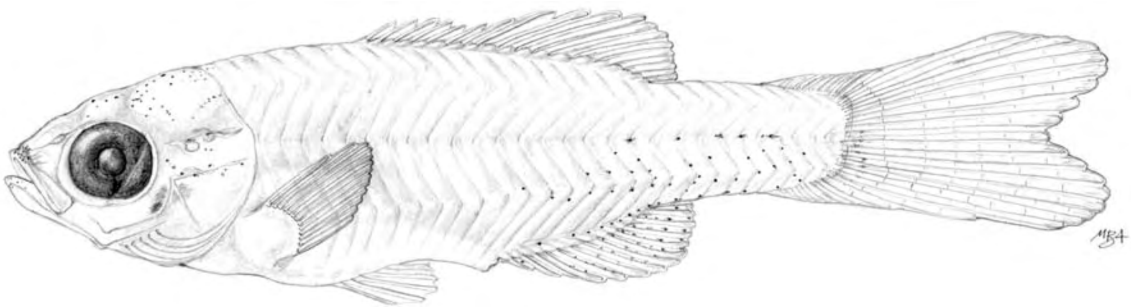


FIGURE 25-21.—Juvenile, 14 mm TL.

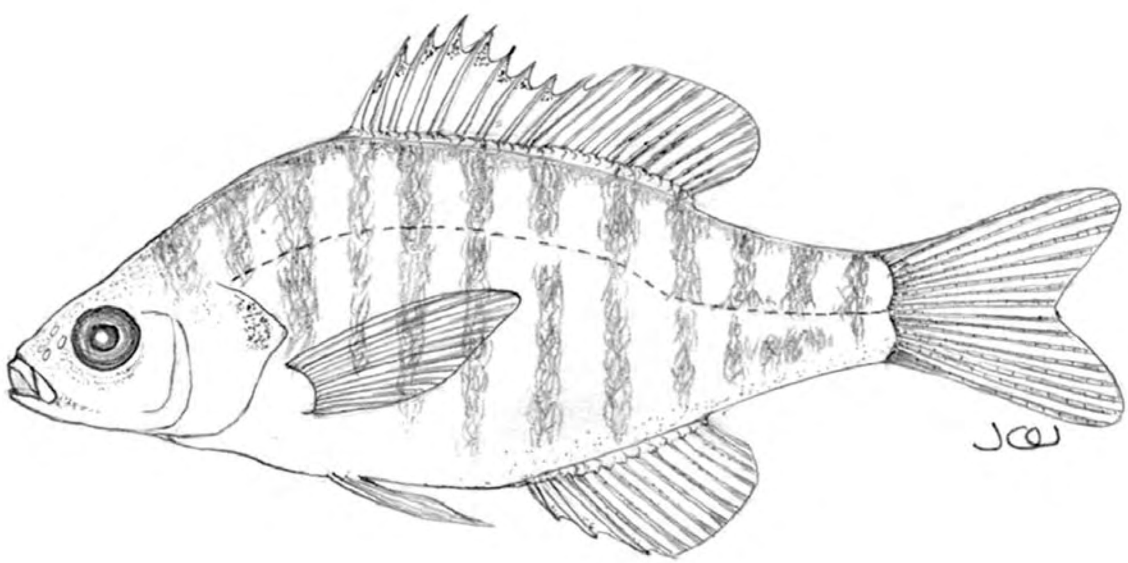


FIGURE 25-22.—Juvenile, 42 mm TL.

Centrarchidae: *Lepomis microlophus*, redear sunfish.

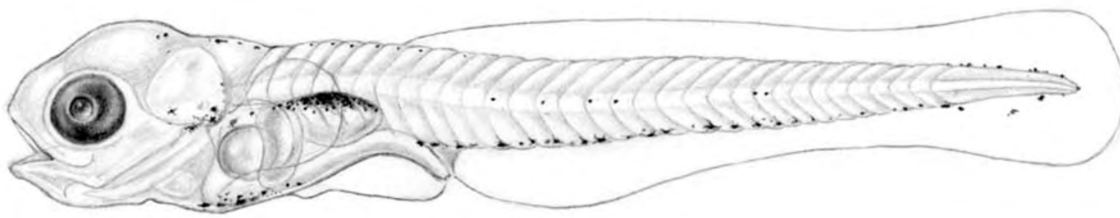


FIGURE 25-23.—Prolarva, 6.5 mm TL.

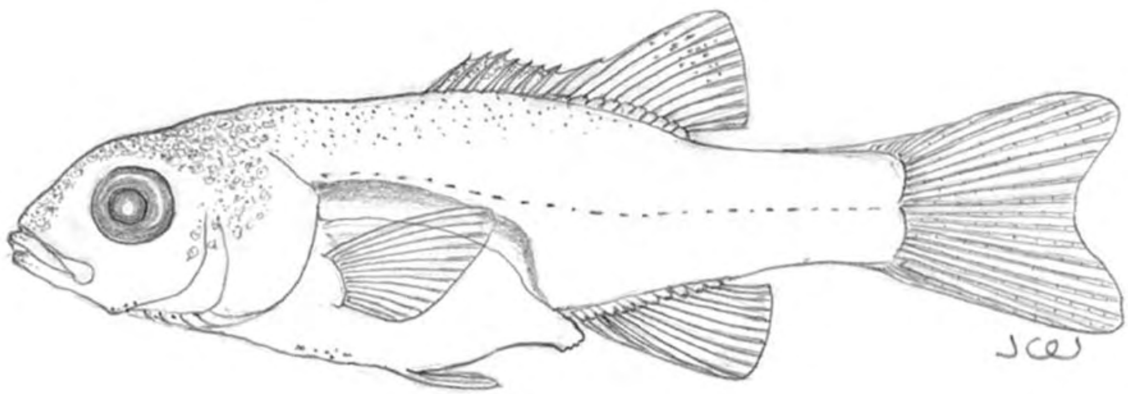


FIGURE 25-24.—Juvenile, 13 mm TL.

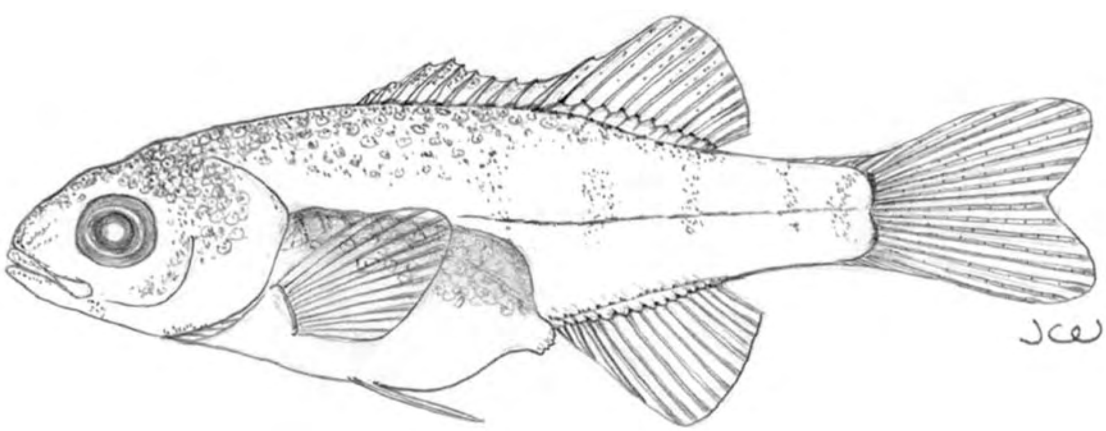


FIGURE 25-25.—Juvenile, 14.3 mm TL.

Centrarchidae: Sunfishes.

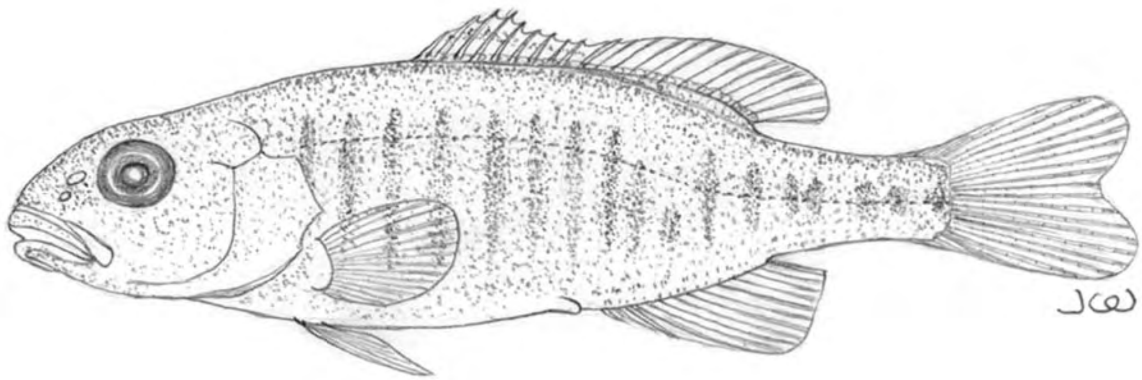


FIGURE 25-26.—*Micropterus dolomieui*, smallmouth bass juvenile 32mm TL.

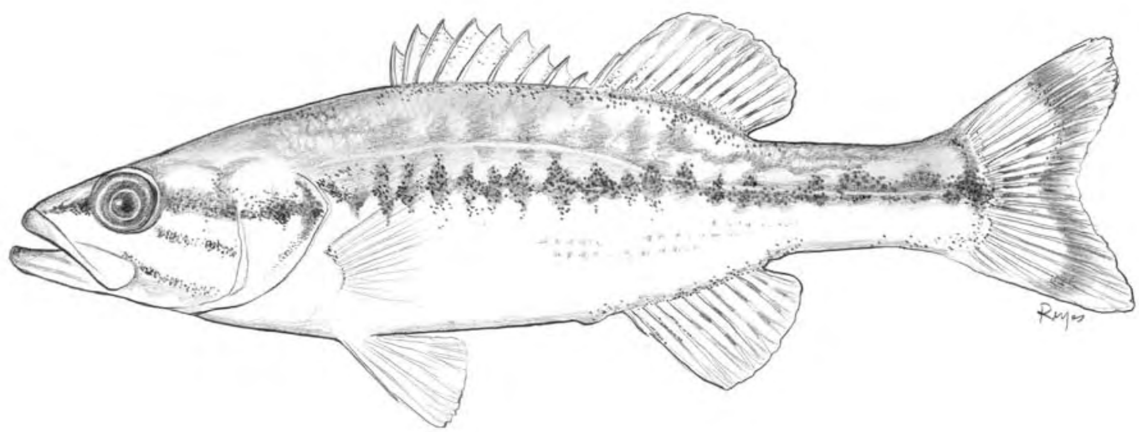


FIGURE 25-27.—*Micropterus punctulatus*, spotted bass juvenile, 56 mm TL.

Centrarchidae: *Micropterus salmoides*, largemouth bass.

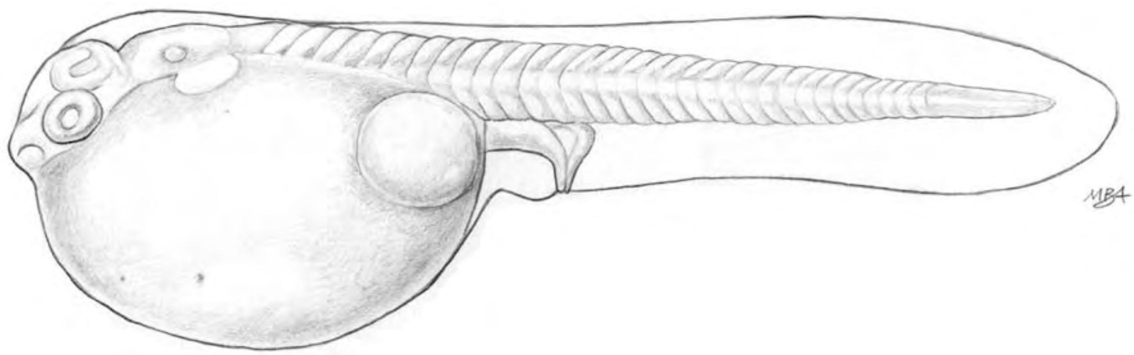


FIGURE 25-28.—Prolarva, 4 mm TL.

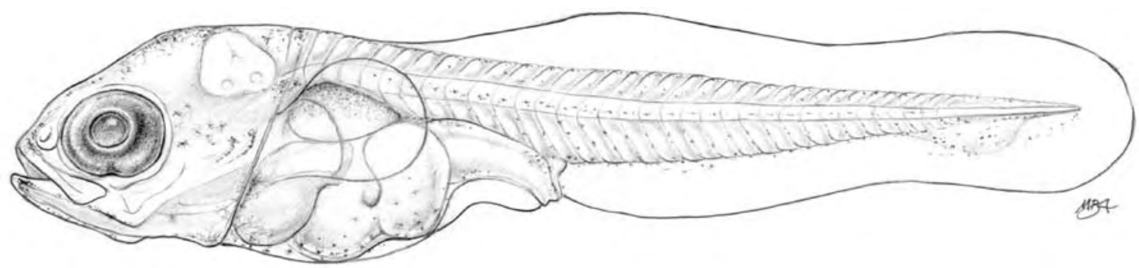


FIGURE 25-29.—Postlarva, 7 mm TL.

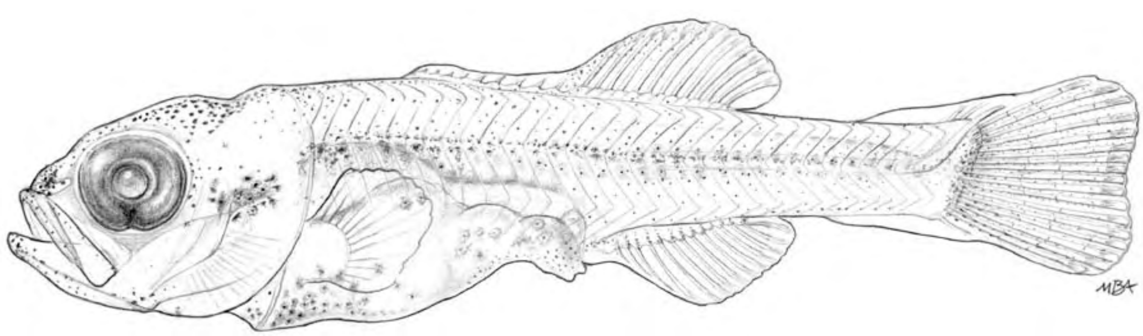


FIGURE 25-30.—Postlarva, 9.6 mm TL.

Centrarchidae: Sunfishes.

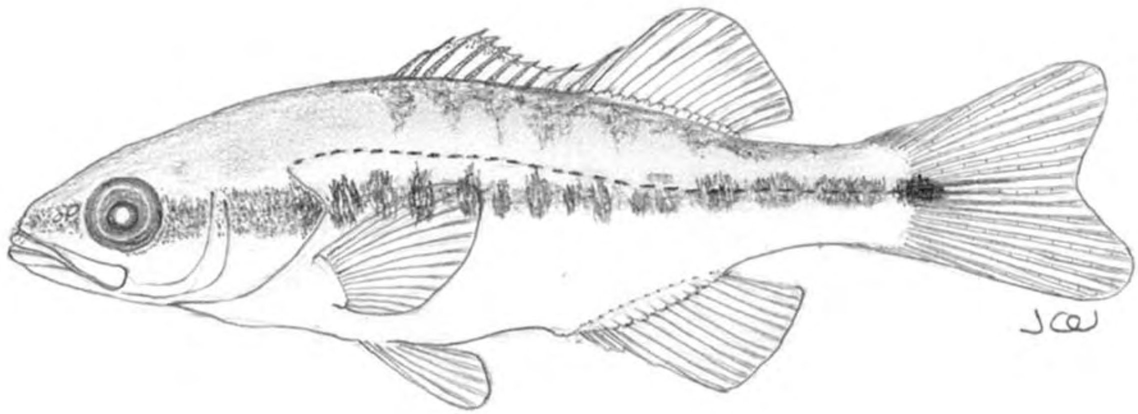


FIGURE 25-31.—*Micropterus salmoides*, largemouth bass juvenile, 36 mm TL.

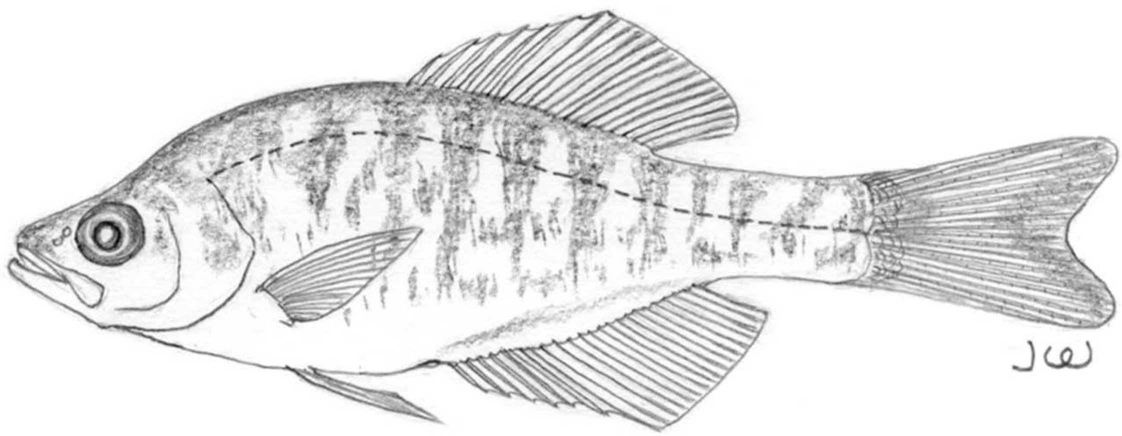


FIGURE 25-32.—*Pomoxis annularis*, white crappie juvenile, 93 mm TL.

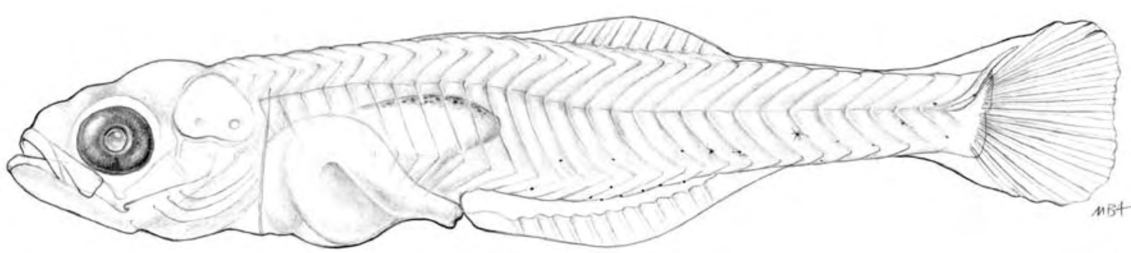


FIGURE 25-33.—*Pomoxis nigromaculatus*, black crappie postlarva, 11.6 mm TL.

Centrarchidae: *Pomoxis nigromaculatus*, black crappie.

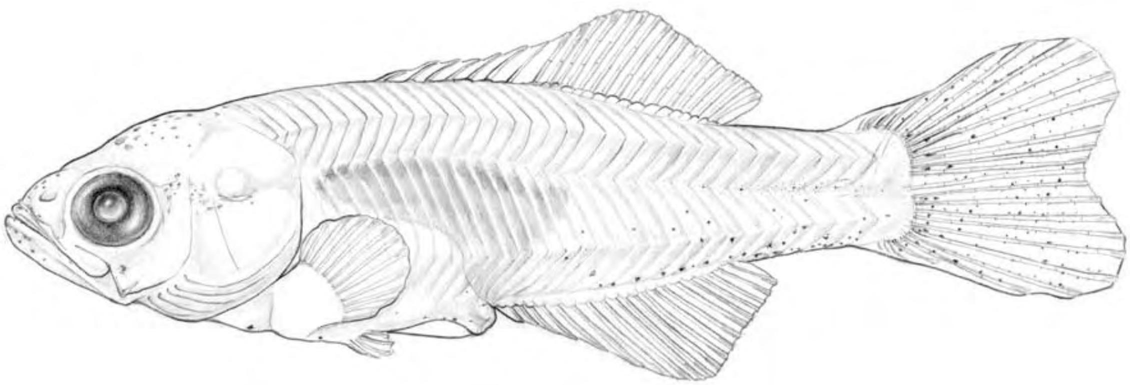


FIGURE 25-34.—Juvenile, 16 mm TL.

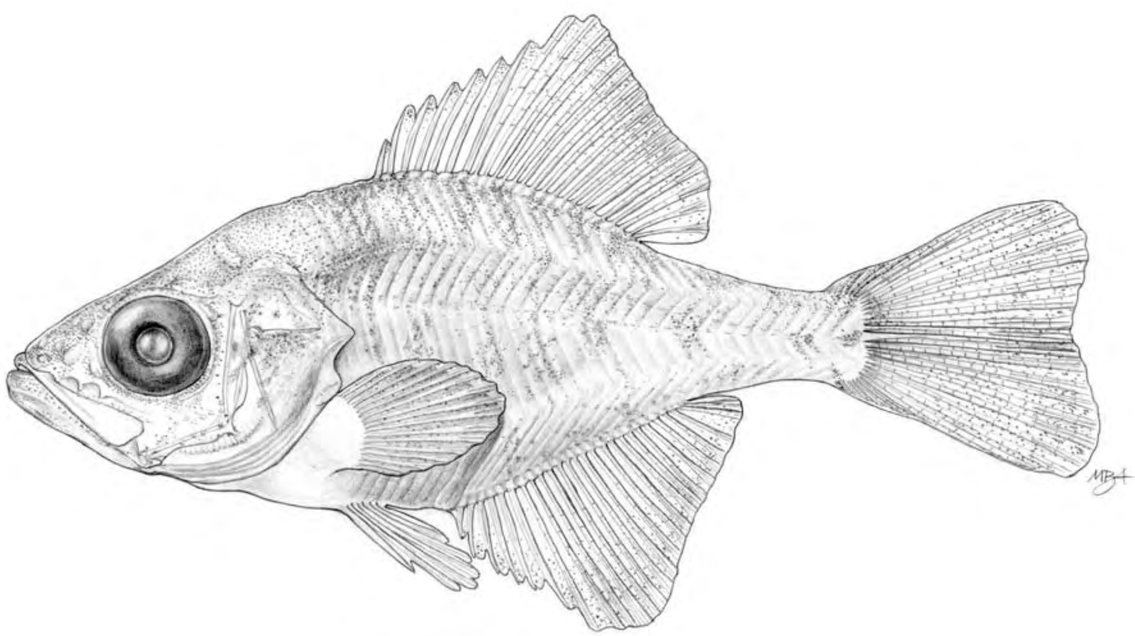


FIGURE 25-35.—Juvenile, 43 mm TL.

26. Percidae – Perches

There are no native perches in California. According to the description of Moyle (1976), three species of this family have been introduced into California from the east of the Rocky Mountains. They are (1) yellow perch, *Perca flavescens*, (2) *bigscale logperch*, *Percina macrolepida*, and walleye, *Stizostedion vitreum*. Both yellow perch and biscale logperch are known to the Sacramento-San Joaquin River systems, but in this study only the biscale logperch was observed.

Reference

Moyle 1976.

BIGSCALE LOGPERCH, *Percina macrolepida* Stevenson

SPAWNING

Location	Freshwater sloughs and irrigation ditches of the Sacramento-San Joaquin River system. Particular locations where spawning was observed including Lindsey Slough and its adjacent irrigations ditches(near Liberty Road); eggs were collected from Cache Slough, Middle River, Stone Slough and its adjacent irrigation ditches (near Liberty Road), and Clifton Court Forebay.
Season	March–June, with a peak in May.
Temperature	Ca. 12°C and greater, peak at 17–20°C.
Salinity	Freshwater.
Substrates	Aquatic plants (Moyle 1976).
Fecundity	10–20 eggs per batch, and female fish will spawn many times during the breeding season (Moyle 1976); 186–365 for female fish at 72 and 83 mm TL (Hubbs 1967).

CHARACTERISTICS

EGGS (FIGURE 26-1)

Shape	Spherical, or can be slightly flat and irregular at the adhering surface.
Diameter	Average 1.32–1.4 mm (Hubbs 1967); 1.1–1.3mm.
Yolk	Yellowish, clear and smooth.
Oil globule	Single, very large, ca. 0.3–0.4mm in diameter.

Chorion	Transparent, clear smooth.
Perivitelline space	Narrow in the late incubation.
Egg mass	Deposited singly on the stems or leaves of aquatic plants (Moyle 1976, this study).
Adhesiveness	Adhesive (Moyle 1976, this study).
Buoyancy	Demersal (this study).

LARVAE (Figures 26-2, 26-3)

Length at hatching	Ca. 4.3–5.0 mm TL.
Snout to anus length	54–59% of TL for both prolarvae and poslarvae.
Yolk sac	Large, elongate and cylindrical, extends from thoracic to abdominal region.
Gut	Straight.
Air bladder	None.
Teeth	Sharp, pointed, apparent in postlarval stage.
Size at completion of yolk sac	Ca. 5.5 mm TL.
Total myomeres	39–43.
Preanal myomeres	23–27.
Postanan myomeres	4–18.
Last fin(s) to complete development	Spiny dorsal fin.
Pigmentation	Light melanophores along midventral and postananl regions. A few melanophores also can be found near anus.
Distributiuon	Planktonic, in freshwater sloughs and irrigation ditches of the Delta.

JUVENILES (Figure 26-4)

Dorsal fin	XIII–XV, 12–15 (Stevenson 1971).
Anal Fin	II, 7–10 (Stevenson 1971, Moyle 1976).
Pectoral fin	12–14 (Stevenson 1971); 13–15.
Mouth	Subterminal to infrerior, small.
Vertebrae	Modal number 40 (Stevenson 1971); 40–43.
Distribution	Epibenthic or on the bottoms of sloughs and irrigation ditches of the Delta.

LIFE HISTORY

Bigscale logperch, originally from the Trinity River in Texas, were accidentally introduced into Yuba County, California, by the U.S. Fish and Wildlife Service in 1953 (McKechnie 1966). At that time they were identified as the logperch, *Percina caprodes*.

In 1971, Stevenson described a new species of logperch, Percina macrolepida, living in sympatric and allopatric association with *P. Caprodes* in Texas and Oklahoma, although Miller and Robison (1973) expressed reservations about this separation. The California population was then recognized as *P. macrolopida* by J. Sturgess, and this was confirmed by M. Stevenson (Moyle1976).

In recent years, the bigscale logperch population has expanded from the tributaries of the Yuba River into the lower Sacramento River and the Delta (Moyle1976). They have also been recorded as far south as Mendota in the San Joaquin River system (Farley 1972, Moyle *et al*.1974a). During this study, bigscale logperch were observed in Lindsey Slough, Suisun Bay near Pittsburg and Antioch, and Clifton Court Forebay. No specimens were collected from the drainage of San Pablo Bay.

In this study area, bigscale logperch spawn from March through June. Eggs with plant fragments adhering to them were found in ichthyoplankton samples collected in the Delta. Moyle (1976) reported that bigscale logperch deposit their eggs on aquatic plants, and commented that this behavior is different from that other Percina. However, this behavior could be part of their adaptation to the environment, like that of a related percid, the swamp darter, *Etheostoma fusiforme*, which, in mid-Atlantic coastal plain streams and swamps, also used aquatic vegetation for its spawning substrate (Wang and Kernhan 1979). The female bigscale logperch will spawn many times with different males during the breeding season (Moyle 1976).

Early juveniles (ca. 15 mm TL) are still free-swimming in the water column. The larger juveniles gradually descend to the bottom sand practice jerky movement. Many of them were captured in the same seine haul. It is presumed that this species may congregate in small groups, since they show no territorial behavior (Moyle 1976, this study). Juveniles feed on insect larvae, small crustaceans, particularly copepods, and mysid shrimp (Moyle 1976).

Bigscale logperch become mature in their second year (Moyle 1976). This species has no commercial or sport value, because of their small size. Mullan *et al.* (1968) have stated that this species has a low value as a forage fish to others. Bigscale logperch take shelter under rocks or in dense vegetation and are seldom seen.

References

Farley 1972, Hubbs 1967, McKechnie 1966, Miller and Robison 1973, Moyle 1976, Moyle *et al.* 1974a, Mullan *et al.* 1968, Stevenson 1971, Wang and Kernhean 1979.

Figure 26.—Percidae: *Percina macrolepida*, bigscale logperch.

Figure 26-1.—Egg, 1.3 mm diameter.

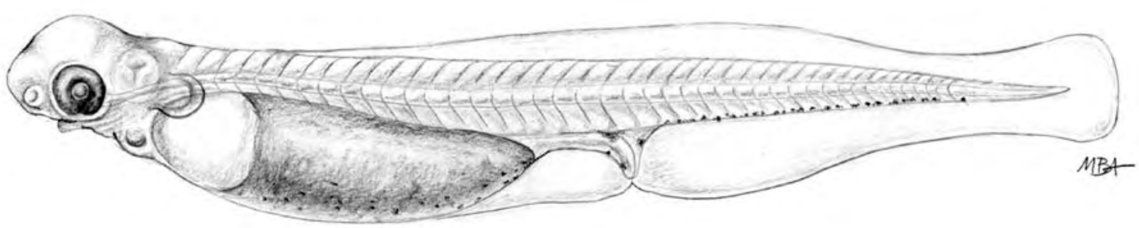


Figure 26-2.—Prolarva, 5 mm TL.

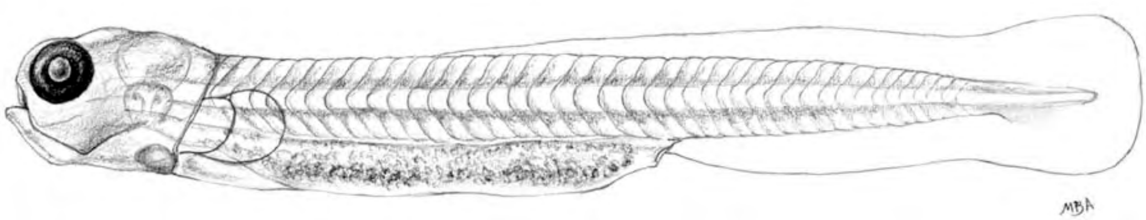


Figure 26-3— Postlarva, 8.2 mm TL.

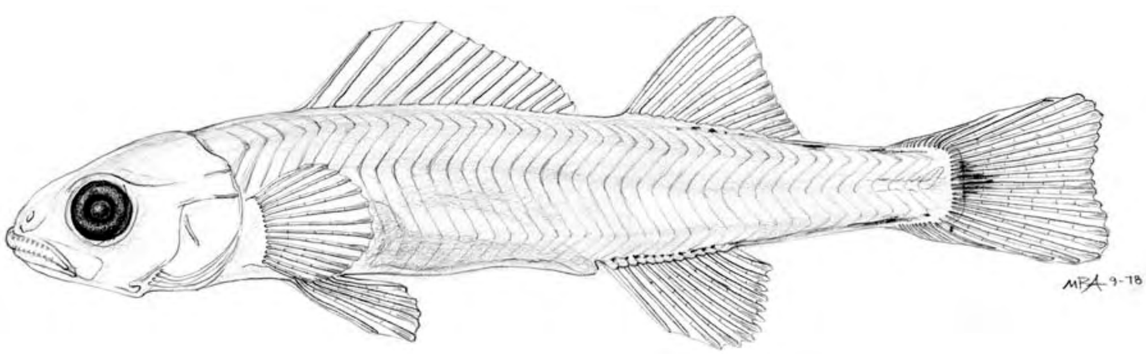


Figure 26-4.—Juvenile, 22.5 mm TL.

27. Scianidae – Drums And Croakers

Three members of the family Sciaenidae are known to the coastal waters adjacent to San Francisco Bay: the white seabass, *Cynoscion (Atractoscion) nobilis*, white croaker, *Genyonemus lineatus*, and the queenfish, *Seriphus politus*. Only the white croaker was collected in San Francisco Bay.

WHITE CROAKER, *Genyonemus lineatus* (Ayres)

SPAWNING

Location	Shallow water near shore (Skogsberg 1939); in San Francisco Bay, Tomales Bay, Moss Landing Harbor, and coastal waters.
Season	November–May (Skogsberg 1939, Hart 1973); January–March (Bane and Bane 1971); October–March (Eldridge 1977); October–April (Goldberg 1976); September–May.
Temperature	Ca. 8–19°C.
Salinity	Seawater-mesohaline.
Substrates	Most eggs are found over sand-gravel bottoms.

CHARACTERISTICS

EGGS (Figure 27-1, 27-2)

Shape	Spherical.
Diameter	0.5–0.9 mm.
Yolk	Whitish to yellowish, clear, smooth.
Oil globule	Single, ca. 0.1–0.2 mm in diameter.
Chorion	Transparent, smooth.
Perivitelline space	Very narrow.
Adhesiveness	None.
Buoyancy	Pelagic.

LARVAE (Figure 27-3, 27-4)

Length at hatching	Ca. 2.2–2.8 mm TL or less.
Snout to anus length	Ca. 33–35% of TL of prolarvae at 2.2–2.8 mm TL; ca. 36–39% of TL of postlarvae at 3.8–8.9 mm TL.

Yolk sac	Spherical to oval, very large, extending from jugular to abdominal region, head recessive in newly hatched larvae.
Oil globule	Single, mostly bright yellow, located in central or anterior portion of the yolk sac.
Gut	Short, coiled, bends ventrally in a sharp angle at anal region.
Air bladder	Spherical to oval, near base of pectoral fins, becoming enlarged in postlarvae.
Teeth	Conical, sharp, apparent in postlarval stage.
Size at completion of yolk-sac stage	Ca. 3.0 mm TL.
Total myomeres	24–26.
Preanal myomeres	7–11.
Postanal myomeres	14–17.
Last fin(s) to complete development	Pectoral.
Pigmentation	Prolarvae: a series of melanophores along postanal region and forming a bar. Several melanophores on thorax, scapular, and anus. Single melanophore on nape and suborbital region. Postlarvae: a number of melanphores along postanal region. Scattered melanophores are found in suborbital, thoracic, and anus areas.
Distribution	In open water and shallows inshore of embayments, estuaries, and coastal waters.

JUVENILES (Figure 27-5)

Dorsal fin	XII–XV, I, 21–24 (Skogsberg 1939); XII–XV, I, 18–25 (Miller and Lea 1972).
Anal fin	II, 11–12 (Skogsberg 1939, Hart 1973); II, 10–12 (Miller and Lea 1972).
Pectoral fin	I, 17 (Miller and Lea 1972); 15 (Bane and Bane 1971); 16–19 (Hart 1973).
Mouth	Snout round, lower jaw included, maxillary usually extends to middle or posterior edge of pupil (Skogsberg 1939, Hart 1973); mouth moderate (Bane and Bane 1971); terminal to subterminal, large.
Vertebrae	25 (Hart 1973); 26 (Miller and Lea 1972).

Distribution	Mostly near bottom. Early juveniles remain in the bay and estuary; most large juveniles gradually move to the ocean.

LIFE HISTORY

The white croaker ranges from Todos Santos Bay, Baja California, northward to Barkley Sound, Vancouver Island, British Columbia (Skogsberg 1939, Miller and Lea 1972, Hart 1973). This species inhabits both inshore and offshore waters up to 100 m in depth (Skogsberg 1939, Frey 1971). In this study, all life stages of white croaker were observed in the Sacramento-San Joaquin Estuary, Tomales Bay, and Moss Landing Harbor-Elkhorn Slough.

Spawning takes place from November through May (Skogsberg 1939) and possibly from October to April in southern California (Goldberg 1976). In the study area, judging by the eggs and small larvae collected, spawning apparently occurs from September through May in the study area.

Gravid female croaker were collected from the intake screens of the Potrero and Hunters Point Powerplants in San Francisco Bay and Moss Landing Powerplant in Moss Landing Harbor. Eggs were found from Horseshoe Cove, just below the Golden Gate Bridge, up to Paradise Beach County Park in the Bay and to Hunters Point, and in Moss Landing Harbor. Apparently spawning occurs in both open and shallow waters of bays. White croaker eggs ranged in size from 0.5–0.9 mm in diameter, with a single oil globule ca. 0.1–0.2 mm and a very narrow perivitelline space. The characteristics of white croaker eggs are very similar to another sciaenid, bairdiella *Bairdiella icistia*, as reported by May (1975).

Newly hatched larvae are pelagic, with a large yolk sac and a high fnfold. As the larvae develop they descend to sand and gravel bottom substrates (this study). Bays and estuaries are used as spawning and nursery grounds by this species. The newly hatched larvae are thought to drift into the bay and estuary on the incoming tide. In this study, larval croaker were not only observed in the higher salinity waters of San Francisco Bay, but also in the less saline waters of Suisun Bay and the south end of Tomales Bay.

It is assumed that the white croaker exhibits migratory behavior similar to that of some of the East Coast sciaenids, that is, early in their life they leave the estuary (Smith 1971, Thomas 1971).

Catch data from the impingement studies at Potrero, Hunters Point, and Moss Landing Powerplants showed that juvenile croaker move into the ocean during the summer and fall, although some juvenile croaker were reported in San Pablo Bay and Suisun Bay (Ganssle 1966, Messersmith 1966).

Major food items of juvenile croaker include small invertebrates, crabs, shrimps, mollusks, and unidentified detritus (Bane and Bane 1971, Baxter 1974, this study).

White croaker mature in 2–3 years. Some may live as long as 15 years (Frey 1971). This species is used as baitfish and there is a small commercial fishery. White croaker is not prime market fish because the texture of the flesh is soft and it commonly has parasites (Baxter 1962, Bane and Bane 1971, Hart 1973).

References

Bane and Bane 1971, Baxter 1962, 1974, Eldridge 1977, Frey 1971, Ganssle 1966, Goldberg 1976, Hart 1973, May 1977, Messersmith 1966, Miller and Lea 1972, Skogsberg 1939, Smith 1971; Thomas 1971.

Figure 27.—Scianidae: *Genyonemus lineatus*, white croaker.

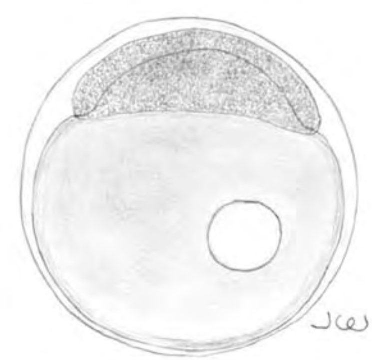


FIGURE 27-1.—Egg, gastrula, 0.7 mm diameter.

FIGURE 27-2.—Egg, late embryo, 0.8 mm diameter.

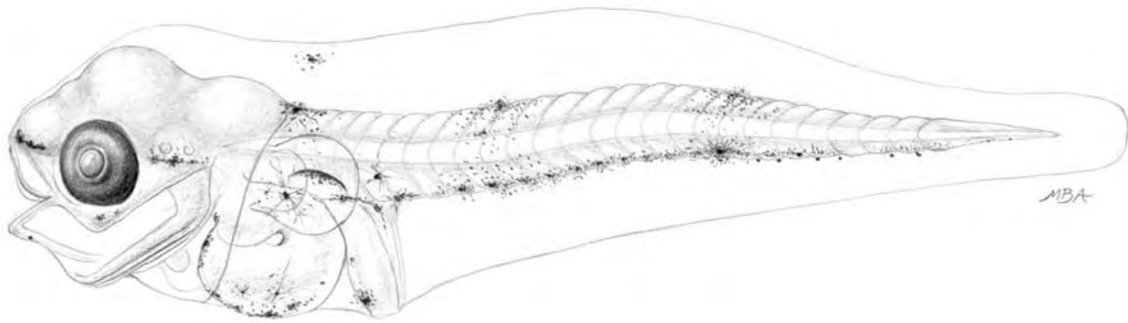


FIGURE 27-3.—Prolarva, 3.3 mm TL.

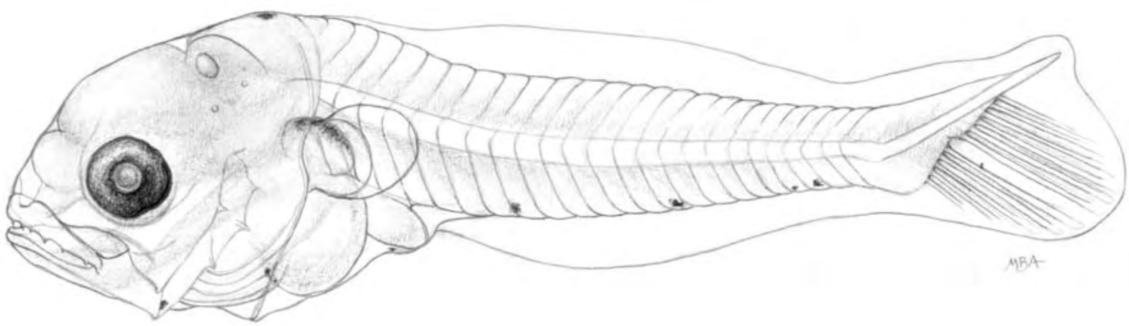


FIGURE 27-4.—Postlarva, 6.5 mm TL.

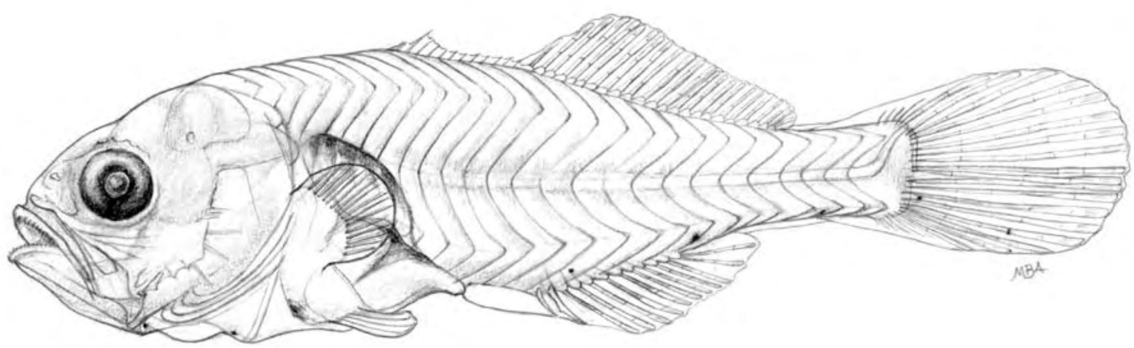


FIGURE 27-5.—Juvenile, 13 mm TL.

28. Embiotocidae – Surfperches

Seventeen species of surfperches have been reported in the study area. Of these 17 species, only 1 inhabits freshwater. All others are found in the estuarine and coastal marine environments:

Species	Habitat
Freshwater	
Tule perch, *Hysterocarpus traski*	Tules and other vegetation
Estuarine and Coastal Marine	
Barred surfperch, *Amphistichus argenteus*	Sandy surf and rocky areas
Calico surfperch, *Amphistichus koelzi*	Rocky, pier, and sandy surf areas
Redtail surfperch, *Amphistichus rhodoterus*	Sandy surf area
Kelp perch, *Brachyistius frenatus*	Kelp beds, rocky areas
Shiner perch, *Cymatogaster aggregata*	Variety of habitats, mostly in bay and estuary
Black perch, *Embiotoca jacksoni*	Kelp beds, shallow rocky areas
Striped seaperch, *Embiotoca lateralis*	Kelp beds, shallow rocky areas
Spotfin surfperch, *Hyperprosopon anale*	Sandy surf areas
Walleye surfperch, *Hyperprosopon argenteum*	Variety of habitats
Silver surfperch, *Hyperprosopon ellipticum*	Sandy surf areas
Rainbow seaperch, *Hypsurus caryi*	Kelp beds, shallow rocky areas
Dwarf perch, *Micrometrus minimus*	Kelp beds, shallow rocky areas
White seaperch, *Phanerodon furcatus*	Variety of habitats
Rubberlip seaperch, *Rhacochilus toxotes*	Variety of habitats
Pile perch, *Rhacochilus vacca*	Rocky shores, old piers
Pink seaperch, *Zalembius rosaceus*	Deeper coastal waters

Surfperches are ovoviviparous fishers (Hart 1973), although some ichthyologists have described them as viviparous (Eigenmann 1892, Wiebe 1968). This reproductive strategy has contributed to the highly successful status of all species of this family except the tule perch, whose population is declining due to the loss of native habitat (Moyle 1976).

During the mating season, the tissue surrounding the anal spine of the male swells, and a bulbous intromittent organ develops in front of the anal spines to facilitate internal fertilization (Carlisle *et al.* 1960; D. Behrens 1981, personal communication). Sperm are stored in the ovarian cavity for several months until the ova are mature, at which time fertilization takes place. Females have a double-lobed ovary (which looks single-lobed in late development). Oocytes develop in the ovarian follicle. When an ovum matures it falls into the ovarian cavity; fertilization occurs either when the egg is still embedded in the ovarian follicle (Eigenmann 1892, Wiebe 1968) or possibly after it is freed (Triplett 1960). Mature eggs are relatively small (ca. 0.3–0.7 mm in diameter); some approach holoblastic cleavage because of the small amount of yolk (Eigenmann 1892); others exhibit meroblastic cleavage (Triplett 1960). Larvae (in this chapter, a larva is also called an embryo) hatch prematurely and remain in the ovarian cavity about 5 months or more, depending on the species. During the gestation period there are no tissue connections between the parent female and the embryos. Nutrients and gases are exchanged through the female's highly vascularized ovarian wall and the vascular fin membranes and hind gut regions of the embryos. The embryos develop within the ovarian cavity and are born as juveniles.

Prior to giving birth, females of most of the estuarine and coastal marine surfperch species move into shallow coastal waters, some entering San Francisco Bay, the Sacramento-San Joaquin Estuary, Moss Landing Harbor-Elkhorn Slough, and Tomales Bay. Breeding is generally during the warmer months, but may occur all year in some species. Newly born juveniles of some species may become sexually mature within a year after birth; in other species, juveniles may take 2–3 years to mature; in still other species the males may be born already mature. The fecundity of surfperches is generally lower than most of the egg broadcasting teleosts because of the limited space in the ovarian cavity.

Surfperches constitute a major portion of the sport and commercial fish catches along the Pacific coast and in the bays of California.

The calico surfperch and redtail surfperch were not collected in this study, and only a few pink seaperch were observed. These three species are not discussed in this chapter.

References

Behrens 1981, personal communication; Carlisle *et al.* 1960; Eigenmann 1892; Hart 1973; Moyle 1976; Triplett 1960; Wiebe 1968.

BARRED SURFPERCH, *Amphistichus argenteus* (Agassiz)

SPAWNING

Location	Mostly coastal water with sandy beaches.
Season	Mating: November and December in southern California (Feder *et al.* 1974). Birth: April–June in southern California (Triplett 1960); mid–March through July in southern California (Carlisle *et al.* 1960); young appear in spring and summer (Feder *et al.* 1974).
Temperature	Embryos kept alive in the laboratory at 16–18°C (Triplett 1960).

Salinity	Seawater.
Fecundity (number of embryos)	20–70 (Triplett 1960); 4–113 (Carlisle *et al.* 1960).

CHARACTERISTICS

EGGS

Shape	Spherical (Carlisle *et al.* 1960).
Diameter	0.4 mm (Carlisle *et al.* 1960).

LARVAE (EMBRYO)

Length at hatching (birth)	42.0–53.0 mm SL (Carlisle *et al.* 1960); ca. 40 mm SL (Triplett 1960).
Yolk sac	Small amount of yolk in thoracic region (Triplett 1960).
Gut	Hind gut hypertrophic, thin-walled and highly vilified (Triplett 1960).
Total myomeres	Ca. 31–32.
Pigmentation	Eye became pigmented at ca. 5.5 mm SL (Carlisle *et al.* 1960).

JUVENILES (Figure 28-1)

Dorsal fin	IX–XI, 23–27 (Tarp 1952); IX–XII, 21–27 (Miller and Lea 1972).
Anal fin	III–IV, 25–28 (Tarp 1952); III–IV, 24–29 (Miller and Lea 1972).
Pectoral fin	25–28 (Tarp 1952, Miller and Lea 1972).
Mouth	Terminal, large, oblique, maxillary reaching anterior edge of the pupil of the eye (Tarp 1952).
Vertebrae	29–33 (Miller and Lea 1972).
Distribution	Mostly along coastal areas with sandy beaches; occasionally entering Moss Landing Harbor-Elkhorn Slough (this study).

LIFE HISTORY

The distribution of the barred surfperch is from Playa Maria Bay, Baja California, to Bodega Bay, California (Tarp 1952, Miller and Lea 1972). In the study area, they were reported in San Francisco Bay (Aplin 1967), Tomales Bay (Bane and Bane 1971), Bodega Bay (Standing *et al.* 1975), and Moss Landing Harbor-Elkhorn Slough (Nybakken *et al.* 1977). Barred surfperch were collected at the intake screens of the Moss Landing Powerplant.

Female barred surfperch that are 2 years old carry embryos from January to June; 3-year-old fish carry them from December to May and 4-year-old fish carry them from November to April, giving birth from April to June (Triplett 1960). Female barred surfperch give birth from mid-March through July in southern California (Carlisle *et al.* 1960). Mating has been reported in November and December (Feder *et al.* 1976). The gestation period is about 5 months (Triplett 1960). The number of embryos increases with age and size of the female parent. The number of embryos has been reported as 4–113 (Carlisle *et al.* 1960) and as ca. 20 for 2-year-old fish and 70 for 4-year-old fish (Triplett 1960).

A tagging study done by Carlisle *et al.* (1960) showed that adult barred surfperch do not move a long distance: the longest distance measured was from coastal waters off Long Beach to Santa Monica, a distance of 50 km, in 48 days. It is assumed that behavior of juvenile barred surfperch is similar to that of the adults. Barred surfperch are found schooling along coastal surf zones (Feder *et al.* 1974). Juvenile and adult barred surfperch feed on sand crabs and other crustaceans (Carlisle *et al.* 1960; Bane and Bane 1971) and on echinoderms and fish eggs (Nybakken *et al.* 1977).

Male barred surfperch become sexually mature between birth and their first winter; females are mature when formation of the two annuli on their scales occurs (Triplett 1960). Longevity of this species is reported to be up to 9 years for females (length 326–350 mm SL) and 6 years for males (265 mm SL) (Carlisle *et al.* 1960). Baxter (1966) reported a 9-year-old barred surfperch which was 342 mm in length and weighed 1.8 kg.

The barred surfperch is of minor importance in the commercial perch catch in California; however, it is one of the most frequently caught perch by sport fishermen fishing on piers and along the shore (Bane and Bane 1971, Fitch and Lavenberg 1971). It is an excellent fish for eating (Frey 1971).

References

Aplin 1967, Bane and Bane 1971, Baxter 1966, Carlisle *et al.* 1960, Feder *et al.* 1974, Fitch and Lavenberg 1971, Frey 1971, Miller and Lea 1972, Nybakken *et al.* 1977, Standing *et al.* 1975, Tarp 1952; Triplett 1960; Wiebe 1968.

KELP PERCH, *Brachyistius frenatus* (Gill)

SPAWNING

Location	Mainly in kelp beds in coastal waters (Hubbs and Hubbs 1954).
Season	Mating: September through December (Feder *et al.* 1974); in fall (Hubbs and Hubbs 1954). Birth: June to August (Hubbs and Hubbs 1954); started in April or May (Feder *et al.* 1974).

Salinity	Seawater.
Fecundity (number of embryos)	3–5 from 3 specimens (Hubbs and Hubbs 1954).

CHARACTERISTICS

LARVAE

Length at hatching (birth)	Ca. 32–33 mm SL (Hubbs and Hubbs 1954).
Total myomeres	Ca. 33–34.

JUVENILES (Figure 28-2)

Dorsal fin	VI–IX, 13–15 (Clothier 1950); VII–IX, 13–16 (Tarp 1952); VII–X, 13–16 (Miller and Lea 1972, Hart 1973).
Anal fin	III, IV, 20–25 (Clothier 1950, Miller and Lea 1972) III, 21–24 (Tarp 1952, Hart 1973).
Pectoral fin	17–18 (Tarp 1952, Miller and Lea 1972, Hart 1973).
Mouth	Small (Tarp 1952); superior (Hubbs and Hubbs 1954); terminal, small, directed slightly upward (Hart 1973).
Vertebrae	32–35 (Clothier 1950, Miller and Lea 1972).
Distribution	Moss Landing Harbor.

LIFE HISTORY

The distribution of the kelp surfperch is from Turtle Bay, Baja California, to Vancouver Island, British Columbia (Tarp 1952); also including Guadalupe Island (Miller and Lea 1972). In the study area this species was reported in San Francisco Bay at Marin County (Tarp 1952), Tomales Bay (Bane and Bane 1971), and Bodega Bay (Standing *et al.* 1975). Kelp surfperch were collected in small numbers at the intake screens of the Moss Landing Powerplant.

Hubbs and Hubbs (1954) reported that kelp surfperch mate in fall and give birth from June to August. This species prefers living among the giant kelp (*Macrocystis* spp.) and seldom leaves the kelp beds (Feder *et al.* 1974). Specimens collected in Moss Landing Harbor were taken mostly in winter months and were possibly washed in by storm activity. Juvenile and adult kelp surfperch feed on small crustaceans (Hart 1973) such as amphipods and shrimp larvae and benthic diatoms (Bane and Bane 1971); they are also known to eat the external parasites of other fishes which associate with kelp beds (Feder *et al.* 1974).

Kelp surfperch reach sexual maturity some time between birth and their first year, but are not mature immediately after birth. The female fish may not become mature until her second year (Hubbs and Hubbs 1954). Kelp surfperch are too small to serve as a sport or commercial species (Bane and Bane 1971). The picking off of ectoparasites of other fishes by the kelp perch may be beneficial in the kelp community (Feder *et al.* 1974).

References

Bane and Bane 1971, Clothier 1950, Feder *et al.* 1974, Hart 1973, Hubbs and Hubbs 1954, Miller and Lea 1972, Standing *et al.* 1975, Tarp 1952.

SHINER PERCH, *Cymatogaster aggregata* (Gibbons)

SPAWNING

Location	San Francisco Bay, San Pablo Bay, Tomales Bay, and Moss Landing Harbor-Elkhorn Slough.
Season	Mating: throughout the year (Feder *et al.* 1974); mating in summer (Shaw 1971); mating from April through July in British Columbia (Hart 1973). Birth: females become gravid in December (Eigenmann 1892); young are born from May through August (Hart 1973); young are observed throughout the year (Feder *et al.* 1974); in spring and summer (Shaw 1971).
Salinity	Seawater, polyhaline; may occur in mesohaline.
Fecundity (number of embryos)	5–17 (Gordon 1965); 8–36 (Clemens and Wilby 1961); 8 (Bane and Bane 1971).

CHARACTERISTICS

EGGS

Shape	Spherical.
Diameter	Ca. 0.25 mm.
Oil globule	None.
Chorion	Enclosed in the follicle and covered with thick layer of granulous cells; chorion is thick after it is free from ovarian tissue.

LARVAE (EMBRYOS)

Length at hatching (birth)	Newly developed embryo; Ca. 0.45 mm in sagittal section (Eigenmann 1892). Birth: 34 mm long (Eigenmann 1892).
Snout to anus length	Ca. 43–44% of TL of embryo at 1.6 mm TL.
Yolk sac	Flat to oval, in thoracic region (Eigenmann 1892).
Oil globule	None.

Gut	Twisted, then coiled (Eigenmann 1892); large, thick, particularly the hind gut.
Air bladder	Shallow, elongate.
Teeth	None at this stage.
Total myomeres	33–35.
Last fin(s) to complete development	Pelvic.
Pigmentation	No pigmentation (except the eyes) in embryonic stage, light melanophores cover head and body of juveniles prior to being born.

JUVENILES (Figure 28-3)

Dorsal fin	IX, 20 (Clothier 1950); VIII–XI, 19–22 (Tarp 1952); VIII–XI, 18–23 (Miller and Lea 1972); VIII–XI, 19–22 (Hart 1973).
Anal fin	III, 23 (Clothier 1950); III, 22–25 (Tarp 1952); III, 22–26 (Miller and Lea 1972); III, 22–25 (Hart 1973).
Pectoral fin	19–21 (Tarp 1952, Miller and Lea 1972); 19–20 (Hart 1973).
Mouth	Terminal, small, directed slightly upward (Hart 1973).
Vertebrae	33–37 (Clothier 1950); 34–38 (Miller and Lea 1972).
Distribution	Euryhaline in San Francisco San Pablo bays. Occasionally found in Suisun Bay; also observed in Tomales Bay and Moss Landing Harbor-Elkhorn Slough.

LIFE HISTORY

The shiner perch has one of the broadest distributions of all the embiotocids found along the Pacific coast: it is known from San Quintin Bay, Baja California, to Port Wrangell, Alaska (Roedel 1953, Miller and Lea 1972). In the study area, shiner perch were recorded in San Francisco Bay (Aplin 1967); Richardson Bay (Green 1975, Eldridge 1977); San Pablo Bay (Ganssle 1966); Carquinez Strait (Messersmith 1966); Tomales Bay (Bane and Bane 1971); Bodega Bay (Standing *et al.* 1975); and Moss Landing Harbor-Elkhorn Slough (Nybakken *et al.* 1977). Shiner perch were observed in San Francisco Bay and San Pablo Bay, and in Suisun Bay near the Pittsburg Powerplant. They were also observed in Tomales Bay and Moss Landing Harbor-Elkhorn Slough and were the most abundant embiotocids in the study area.

Prior to giving birth, the females enter coastal bays (Bane and Robinson 1970). The reproductive behavior of the shiner perch has been described by Hubbs (1917), Wiebe (1968), and Shaw (1971). In general, the sperm remain inactive in the ovary of the female fish for about 5–6 months after mating (Eigenmann 1892, Gordon 1965, Wiebe 1968). When ova become mature, in December, the sperm become activated and fertilization takes place while the ova are still in the ovarian tissue (Turner 1938). The total time between mating and giving birth of young is approximately 1 year (Hubbs 1917, 1921).

Newly born juveniles display fin rays; females are slightly larger than males (Wiebe 1968). Bane and Robinson (1970) observed that most of the juveniles and 1-year-old adults remain in the bay in their first year and emigrate to coastal waters when they are 2 years old. Ganssle (1966) and Aplin (1967) found that young shiner perch are common in San Francisco Bay and San Pablo Bay in the summer and fall months. Apparently shiner perch use the estuary as their nursery ground more extensively than other embiotocids. Juveniles are omnivorous, feeding on zooplankton, small crustaceans, algae, and detritus (Gordon 1965, Bane and Robinson 1970, Odenweller 1975a, b) and also on polychaetes, mollusks, and benthic organisms (Boothe 1967, Nybakken *et al.* 1977).

Male shiner perch reach sexual maturity soon after birth. Females can also be inseminated soon after birth and carry the sperm in their ovaries until December, when fertilization occurs (Turner 1938, Shaw 1971). However, in a study by Gordon (1965), no yearling female perch contained embryos in the first year; only the 2-year-old females did. Anderson and Bryan (1970) reported that the male shiner have a lifespan of 3 years and the female 5 years.

The shiner perch is not of great importance commercially, although they are commonly caught by sport fishermen along the ocean shore and in bays (Odenweller 1975a, b). Shiner perch are sometimes used as bait fish (Bane and Bane 1971).

References

Anderson and Bryan 1970; Aplin 1967; Bane and Bane 1971; Bane and Robinson 1970; Boothe 1967; Clemens and Wilby 1961; Clothier 1950; Eigenmann 1892; Eldridge 1977; Feder *et al.* 1974; Ganssle 1966; Gordon; 1965; Green 1975; Hart 1973; Hubbs 1917, 1921; Messersmith 1966; Miller and Lea 1972; Nybakken *et al.* 1977; Odenweller 1975a, b; Roedel 1953; Shaw 1971; Standing *et al.* 1975; Tarp 1952; Turner 1938; Wiebe 1968.

BLACK PERCH, *Embiotoca jacksoni* (Agassiz)

SPAWNING

Location	San Francisco Bay, Tomales Bay, and Moss Landing Harbor-Elkhorn Slough.
Season	Mating: year-round (Carlisle *et al.* 1964); summer and fall (Issacson and Issacson 1966); mid-September to mid-November (Behrens 1977). Birth: spring and summer (Baxter 1962); year-round (Carlisle *et al.* 1964); April to September (Issacson and Issacson 1966); spring to fall (Behrens 1977).
Salinity	Seawater; may occur in polyhaline.
Fecundity (number of embryos)	7–31 (Behrens 1977).

CHARACTERISTICS

LARVAE (embryos)

Length at hatching (birth)	52–55 mm SL (Issacson and Issacson 1966); 54–61 mm SL (Behrens 1977).
Snout to anus length	Ca. 36% of SL of embryo at 25 mm TL.
Yolk sac	Small, spherical, in thoracic region.
Gut	Thick, with large hind gut.
Air bladder	Very shallow, elongate.
Teeth	None at this stage.
Last fin(s) to complete development	Pelvic.
Pigmentation	None, except the eyes.

JUVENILES (Figures 28-4, 28-5)

Dorsal fin	IX–X, 20 (Clothier 1950); IX–X, 19–20 (Tarp 1952); IX–XI, 18–22 (Miller and Lea 1972).
Anal fin	III, 25 (Clothier 1950); III, 24–27 (Tarp 1952, Miller and Lea 1972).
Pectoral fin	20–22 (Tarp 1952, Miller and Lea 1972).
Mouth	Terminal, small, with thick lips (Feder *et al.* 1974); lips fleshy.
Vertebrae	33–35 (Clothier 1950); 32–36 (Miller and Lea 1972).

Distribution	Mostly in San Francisco Bay, occurring as far as San Pablo Bay; also in Tomales Bay and Moss Landing Harbor-Elkhorn Slough.

LIFE HISTORY

The black perch ranges from Abreojos Point, Baja California, to Fort Bragg, California (Roedel 1953, Miller and Lea 1972). This species has been reported to be common in several fish surveys in San Francisco Bay (Miller and Gotshall 1965, Ganssle 1966, Issacson and Issacson 1966, Aplin 1967, Green 1975). They have also been reported in Tomales Bay (Bane and Bane 1971) and Moss Landing Harbor (Nybakken *et al.* 1977). In this study black perch were collected in the vicinity of the Potrero and Hunters Point Powerplants on San Francisco Bay; they were occasionally collected at the intake screens of Oleum Powerplant, San Pablo Bay, and they were common in Tomales Bay and Moss Landing Harbor-Elkhorn Slough.

Carlisle *et al.* (1964) reported that black perch bear young year-round; Issacson and Issacson (1966) found young black perch from April to September. Behrens (1977) observed that black perch give birth from spring to fall and mating occurs from mid-September to mid-November in the Half Moon Bay area. Surgical examination of ovaries revealed that embryos are present mostly in the spring and summer. Judging from the developmental stages of those embryos, they would probably have been born in the summer months. Older adults give birth to a greater number of juveniles than do younger adults. The number of young per female ranges from 5–7 in 1-year-old fish and from 5–26 in 4-year-old fish (Issacson and Issacson 1966). A wider range of fecundity (7–31) was reported by Behrens (1977).

Soon after birth, mating begins. Large numbers of perch swim in tight schools, some splitting off in pairs to perform the courtship (Feder *et al.* 1974). In this study, juvenile black perch dominated the catch, rather than adults. The major food items for juveniles include polychaete worms and small crustaceans such as amphipods, corophium, and decapods (Bane and Bane 1971, Feder *et al.* 1974, Nybakken *et al.* 1977).

Both sexes are mature at age one (Issacson and Issacson 1966; Fitch and Lavenberg 1975); some individuals may live 10 or more years (Fitch and Lavenberg 1975). The black perch has both commercial and sport value. It is frequently caught by inshore anglers and is an excellent food fish.

References

Aplin 1967, Bane and Bane 1971, Baxter 1962, Behrens 1977, Carlisle *et al.* 1964, Clothier 1950, Feder *et al.* 1974, Fitch and Lavenberg 1975, Ganssle 1966, Green 1975, Issacson and Issacson 1966, Miller and Gotshall 1965, Miller and Lea 1972, Nybakken *et al.* 1977, Roedel 1953, Tarp 1952.

STRIPED SEAPERCH, *Embiotoca lateralis* (Agassiz)

SPAWNING

Location	Mostly in coastal kelp beds and rocky areas; may occur in San Francisco Bay, Tomales Bay, and Moss Landing Harbor-Elkhorn Slough.
Season	Mating: October (Edwards 1970); Birth: June and July (Fraser 1923); young have been observed from May through September (Feder *et al.* 1974).
Salinity	Seawater.
Fecundity (number of embryos)	18–92 (Blanco 1938); 21–80 (Eigenmann 1892); 10–26 (Hubbs 1921); 44 (Fraser 1923).

CHARACTERISTICS

EGGS

Shape	Spherical (Blanco 1938).
Diameter	0.3–0.81 mm (Blanco 1938).
Oil globule	Many oil globules (Blanco 1938).

LARVAE (embryos)

Length at hatching (birth)	Newly developed embryo: ca. 3.0 mm TL (Blanco 1938).
Snout to anus length	Ca. 60% of TL of embryo at 3.0 mm TL; ca. 50% of TL of embryo at 7.0–12.0 mm TL; ca. 43–45% of TL of embryo at 16.0 mm TL (data derived from illustration, Blanco 1938).
Yolk sac	Small, in thoracic region (Blanco 1938).
Gut	Large, thick, coiled; hind gut is a tubular structure (Blanco 1938).
Size at completion of yolk-sac stage	Ca. 5.0 mm TL (Blanco 1938).
Total myomeres	33–35.
Last fin(s) to complete development	Pelvic.
Pigmentation	Embryonic stages have no pigments, but pigmentation appears on head and body prior to bearing.

JUVENILES (Figure 28-6)

Dorsal fin	X–XI, 23–25 (Tarp 1952, Hart 1973); X–XII, 23–26 (Miller and Lea 1972).
Anal fin	III, 29–33 (Tarp 1952, Miller and Lea 1972, Hart 1973).
Pectoral fin	21–24 (Tarp 1952, Miller and Lea 1972, Hart 1973).
Mouth	Terminal, small, directed slightly upward (Hart 1973).
Vertebrae	33–35 (Miller and Lea 1972).
Distribution	Along Pacific coast; occasionally found in San Francisco Bay, Tomales Bay, and Moss Landing Harbor-Elkhorn Slough.

LIFE HISTORY

The striped seaperch ranges from Point Cabras, Baja California, to Port Wrangell, Alaska (Tarp 1952, Roedel 1953, Miller and Lea 1972, Hart 1973). In the study area, the distribution of the striped seaperch is patchy. Aplin (1967) reported finding this species in trawl samples from San Francisco Bay, especially in the channel area. Striped seaperch have not been collected in San Pablo Bay (Ganssle 1966), Carquinez Strait (Messersmith 1966), or Richardson Bay (Green 1975). They have been reported in Tomales Bay (Bane and Bane 1971), Bodega Bay (Standing *et al.* 1975), and Moss Landing Harbor-Elkhorn Slough (Nybakken *et al.* 1977). Striped seaperch, mostly juveniles, were collected at the intake screens of Potrero and Hunters Point Powerplants, San Francisco Bay, and the Moss Landing Powerplant, Moss Landing Harbor.

Edwards (1970) observed striped seaperch mating in Monterey Bay in October. Birth of the young has been reported in summer months along the southern California coast (Feder *et al.* 1974, Fraser 1923), and has occurred in the study area, judging from the small juveniles collected. The early embryonic development has been thoroughly documented by Blanco (1938).

Juveniles and adults feed mainly on amphipods, shrimp, and algae (Bane and Bane 1971) and on mussels and herring eggs (Hart 1973).

Striped seaperch show no evidence of being sexually mature at birth (Hubbs 1921), and little is known on their age-growth and longevity. Striped seaperch are common in coastal waters in rocky areas and kelp beds, preferring depths from the surface to 12 m (Bane and Bane 1971, Feder *et al.* 1974). They are of minor commercial importance in northern California (Hart 1973).

References

Aplin 1967; Bane and Bane 1971, Blanco 1938, Edwards 1970, Eigenmann 1892, Feder *et al.* 1974, Fraser 1923, Ganssle 1966, Green 1975, Hart 1973, Hubbs 1921, Messersmith 1966, Miller and Lea 1972, Nybakken *et al.* 1977, Roedel 1953, Tarp 1952; Standing *et al.* 1975.

SPOTFIN SURFPERCH, *Hyperprosopon anale* (Agassiz)

SPAWNING

Location	Outside of Tomales Bay (Bane and Bane 1971); along coastal waters outside of San Francisco Bay and Moss Landing Harbor-Elkhorn Slough.
Season	Summer.
Salinity	Seawater.

CHARACTERISTICS

JUVENILES (Figure 28-7)

Dorsal fin	VII–IX, 22–25 (Tarp 1952); VII–IX, 20–25 (Miller and Lea 1972).
Anal fin	III, 23–26 (Tarp 1952); III, 21–26 (Miller and Lea 1972).
Pectoral fin	23–27 (Tarp 1952, Miller and Lea 1972).
Mouth	Terminal, large, lower jaw extends beyond upper jaw (Miller and Lea 1972).
Vertebrae	32–35 (Miller and Lea 1972).
Distribution	Coastal water with sandy beaches outside of San Francisco Bay and Moss Landing Harbor-Elkhorn Slough.

LIFE HISTORY

The spotfin surfperch is found from Blanca Bay, Baja California, to Seal Rock, Oregon (Miller and Lea 1972). This species is not taken frequently in San Francisco Bay, but it is common in the coastal waters outside San Francisco Bay (this study). Spotfin surfperch were collected at the mouth of Tomales Bay (Bane and Bane 1971) and in coastal waters outside Moss Landing Harbor (Nybakken *et al.* 1977). Small numbers of spotfin surfperch were collected at the intake screens of the Moss Landing Powerplant.

Judging from the numerous small juveniles taken in coastal waters just outside San Francisco Bay in October 1982, the female spotfin surfperch gives birth in the summer months (M. Carlin 1982, personal communication). Details of the biology of this species in the literature are few. Juveniles and adults feed on young squid, jellyfish, polychate worms, amphipods, other crustaceans, and algae (Bane and Bane 1971) and on fish eggs (Nybakken *et al.* 1977). The spotfin surfperch has no sport or commercial importance, because of its small size.

References

Bane and Bane 1971; Carlin 1982, personal communication; Miller and Lea 1972; Nybakken *et al.* 1977; Tarp 1952.

WALLEYE SURFPERCH, *Hyperprosopon argenteum* (Gibbons)

SPAWNING

Location	Shallow coastal waters, San Francisco Bay, Tomales Bay and Moss Landing Harbor-Elkhorn Slough.
Season	Mating: November (Rechnitzer and Limbaugh 1952); October through December in southern California (Feder *et al.* 1974). Birth: young are born in April (Rechnitzer and Limbaugh 1952).
Temperature	11–21°C (Tarp 1952).
Fecundity (number of embryos)	5–12 (Rechnitzer and Limbaugh 1952).

CHARACTERISTICS

EGGS

Shape	Spherical.
Diameter	0.7 mm (Engen 1968).
Perivitelline space	Ca. 0.2 mm in width (Engen 1968).

LARVAE (EMBRYOS)

Length at hatching (birth)	Early developed embryos: 1.5–2.0 mm SL (Engen 1968). Birth: average 40 mm SL (Rechnitzer and Limbaugh 1952); larger than 45 mm SL before birth (Engen 1968).
Air bladder	Large, flat, elongate as two separate projections (Engen 1968).
Size at completion of yolk-sac stage	Ca. 12 mm SL (Engen 1968).
Total myomeres	Ca. 32.

JUVENILES (Figure 28-8)

Dorsal fin	X, 27 (Clothier 1950); VIII–X, 25–28 (Tarp 1952, Hart 1973); VIII–X, 25–29 (Miller and Lea 1972).
Anal fin	III, 32–34 (Clothier 1950); III, 30–35 (Tarp 1952, Miller and Lea 1972).
Pectoral fin	25–28 (Tarp 1952, Miller and Lea 1972, Hart 1973).
Mouth	Terminal, large, maxillary reaching anterior edge of orbit (Tarp 1952); lower jaw projecting beyond upper jaw (Feder *et al.* 1974).
Vertebrae	34–38 (Clothier 1950); 33–38 (Miller and Lea 1972).
Distribution	San Francisco Bay, San Pablo Bay, Tomales Bay, and Moss Landing Harbor-Elkhorn Slough.

LIFE HISTORY

The range of the walleye surfperch extends from Point San Rosalito, Baja California, to Vancouver Island, British Columbia (Miller and Lea 1972). This species was reported in shallow as well as deeper waters of San Francisco Bay (Aplin 1967), Richardson Bay (Green 1975), San Pablo Bay (Ganssle 1966), and Carquinez Strait (Messersmith 1966). Walleye surfperch were collected in Bodega Bay (Standing *et al.* 1975), and are common at Dillon Beach (Bane and Bane 1971). They were also taken in Moss Landing Harbor-Elkhorn Slough (Nybakken *et al.* 1977). This species was common in the vicinity of the Potrero and Hunters Point Powerplants, San Francisco Bay, and Moss Landing Powerplant, Moss Landing Harbor; catches were dominated by the juveniles (this study). Rechnitzer and Limbaugh (1952) observed the courtship of the walleye surfperch. They reported that mating takes place in November, the gestation period is about 5–6 months, and female perch give birth in April, along the southern California coast. During the breeding season, the body of the male becomes darker, particularly the lower half of the pelvic fins (Feder *et al.* 1974).

Small juveniles (ca. 25–40 mm TL) have been collected along the sandy beach as well as rocky jetty areas of San Francisco Bay, Richardson Bay, and San Pablo Bay (Aplin 1967, Green 1975, Ganssle 1966, this study). Gravid females were also observed in the catches; therefore, this species appears to bear its young in the bay and estuary (this study). Major food items for juvenile and adult walleye surfperch include squid eggs and small crustaceans (Bane and Bane 1971) and also polychaetes, ostracods, and gastropods (Nybakken *et al.* 1977).

Juvenile fish reach sexual maturity in the fall after their first year. At that time, these fish are 140–170 mm TL (Rechnitzer and Limbaugh 1952). Adult walleye surfperch produce smaller numbers of young (5–12) than do other embiotocids (Rechnitzer and Limbaugh 1952). A walleye surfperch can live 6 years (Anderson and Bryan 1970, Frey 1971). The walleye surfperch is an important commercial fish along the California coast (Roedel 1953): it ranks second to the white seaperch in the total California perch catch (Bane and Bane 1971) and is an excellent food fish (Feder *et al.* 1974).

References

Anderson and Bryan 1970, Aplin 1967, Bane and Bane 1971, Clothier 1950, Engen 1968, Feder *et al.* 1974, Frey 1971, Ganssle 1966, Green 1975, Hart 1973, Messersmith 1966, Miller and Lea 1972, Nybakken *et al.* 1977, Rechnitzer and Limbaugh 1952, Roedel 1953, Standing *et al.* 1975, Tarp 1952.

SILVER SURFPERCH, *Hyperprosopon ellipticum* (Gibbons)

SPAWNING

Location	Mostly along coastal waters with sandy bottoms, outside of San Francisco Bay and Moss Landing Harbor-Elkhorn Slough.
Season	Mating: September along Oregon coast (Wydoski and Bennett 1973); in October at Point Arguello, southern California (Feder *et al.* 1974). Birth: June to August in Oregon (Wydoski and Bennett 1973); young are born in spring and summer in southern California (Feder *et al.* 1974).
Salinity	Seawater.
Fecundity (number embryos)	4–17 (Wydoski and Bennett 1973).

CHARACTERISTICS

LARVAE (embryos)

Length at hatching (birth)	Early developed embryo: ca. 6.0 mm SL (Wydoski and Bennett 1973) Birth: ca. 40 mm SL or more (Wydoski and Bennett 1973).
Total myomeres	Ca. 33.

JUVENILES (Figure 28-9)

Dorsal fin	VII–X, 25–28 (Tarp 1952, Hart 1973); VIII–X, 25–29 (Miller and Lea 1972).
Anal fin	III, 29–34 (Tarp 1952, Hart 1973); III, 29–35 (Miller and Lea 1972).

Pectoral fin	26–28 (Tarp 1952, Miller and Lea 1972, Hart 1973).
Mouth	Terminal, moderately large, maxillary reaching anterior edge of orbit (Tarp 1952).
Vertebrae	32–35 (Miller and Lea 1972).
Distribution	Along coastal waters with sandy bottoms; outside of San Francisco Bay, Tomales Bay, and Moss Landing Harbor-Elkhorn Slough.

LIFE HISTORY

The distribution of the silver surfperch is from Rio San Vicente, Baja California, to Schooner Cove, Vancouver Island, British Columbia (Miller and Lea 1972). In the study area this species was reported along the coast outside of San Francisco Bay (Ruth 1969) and in Tomales Bay (Bane and Bane 1971), Bodega Bay (Standing *et al.* 1975), and Moss Landing Harbor-Elkhorn Slough (Nybakken *et al.* 1977). Small numbers of the silver surfperch were collected at the intake screens of Moss Landing Powerplant.

Along the Oregon coast, mating of the silver surfperch occurs in September. The birth of the young occurs from June through August of the next year, following a gestation of about 9 months (Wydoski and Bennett 1973). Mating takes place in shallow coastal waters less than 8 m deep. The male approaches the female from below. Copulation lasts a few seconds, they separate and then repeat the process (Feder *et al.* 1976). As in other embiotocids, the sperm are apparently stored in the ovary of the females. The embryos were about 6 mm SL in January and grow to 40 mm L or larger by June and July (Wydoski and Bennett 1973).

Juveniles are found along surf zones with sandy bottoms. They enter the bay and estuary occasionally (this study). Adult silver surfperch, about 52–133 mm long, feed on amphipods, caprellid shrimps, and algae (Bane and Bane 1971).

Some silver surfperch are sexually mature at age 1, but most are not mature until they 2 years old. Size and age have an influence on their maturity (Wydoski and Bennett 1973). Longevity of this species is reported to be 7 years for female fish and 5 for male fish (Wydoski and Bennett 1973). The silver surfperch is an important sport fish that is caught along sandy shorelines from Oregon to Point Arguello (Miller and Gotshall 1965).

References

Bane and Bane 1971, Feder *et al.* 1974, Hart 1973, Miller and Gotshall 1965, Miller and Lea 1972, Nybakken *et al.* 1975, Ruth 1969, Standing *et al.* 1975, Tarp 1952; Wydoski and Bennett 1973.

RAINBOW SEAPERCH, *Hypsurus caryi* (Agassiz)

SPAWNING

Location	Half Moon Bay (Behrens 1977); Tomales Bay (Bane and Bane 1971); may occur in San Francisco Bay.
Season	Mating: in fall (Feder *et al.* 1974). Birth: August through November (Behrens 1977); young are born throughout summer (Feder *et al.* 1974).
Salinity	Seawater.
Fecundity (number of embryos)	9–22 (Behrens 1977); 15 embryos from a single female (Bane and Bane 1971).

CHARACTERISTICS

LARVAE (embryos)

Length at hatching (birth)	55 mm SL (Behrens 1977).

JUVENILES (Figure 28-10)

Dorsal fin	X–XI, 20–23 (Clothier 1950); IX–XI, 21–24 (Tarp 1952); IX–XI, 20–24 (Miller and Lea 1972).
Anal fin	III, 20–24 (Clothier 1950, Miller and Lea 1972); III, 21–23 (Tarp 1952).
Pectoral fin	21–23 (Tarp 1952, Miller and Lea 1972).
Mouth	Terminal, maxillary fairly long (Tarp 1952); upper jaw protruding slightly over low jaw (Feder *et al.* 1974, this study).
Vertebrae	36–38 (Clothier 1950, Miller and Lea 1972).
Distribution	Leaves embayments after spawning, returns to coastal waters with sandy to rocky bottoms of Half Moon Bay area (Behrens 1977); on rocky shores (Bane and Bane 1971); some found in San Francisco Bay and Moss Landing Harbor-Elkhorn Slough.

LIFE HISTORY

The range of the rainbow seaperch is from Rio Santo Tomas, Baja California, to Cape Mendocino, California (Miller and Lea 1972). In the study area, this species was reported in San Francisco Bay (Aplin 1967), Richardson Bay (Green 1975), Tomales Bay (Bane and Bane 1971), Bodega Bay (Standing *et al.* 1975), and Moss Landing Harbor-Elkhorn Slough (Nybakken *et al.* 1977). A few were observed in San Francisco Bay, and some were collected at the intake screens of the Moss Landing Powerplant.

The reproductive biology of the rainbow seaperch in the Half Moon Bay area was investigated by Behrens (1977). Behrens has summarized his results as follows:

> *Female rainbow seaperch were gravid from April through mid-September. The size of these gravid females ranged from 131 to 214 mm SL. Fecundity was found to range from 9–22 embryos per female. The majority of the embryos were facing anteriorly in the ovary, and very few embryos develop abnormally during the 5- to 6-month gestation period. As in other embiotocids, gases and nutrients are exchanged between the female parent and the embryos. When the embryo is ready to be born, it develops into a juvenile about 55 mm SL.*

No specimens were found in October and November at the collecting sites. Behrens (1977) assumed that both female and newly born juvenile rainbow seaperch leave the embayments after spawning. Stomach contents of both juveniles and adults contain mostly amphipods and copepods (Bane and Bane 1971). Little has been written on age and longevity of the rainbow seaperch. This species has minor importance in the overall commercial catch of embiotocids (Bane and Bane 1971).

References

Aplin 1967, Bane and Bane 1971, Behrens 1977, Clothier 1950, Feder *et al.* 1974, Green 1975, Miller and Lea 1972, Nybakken *et al.* 1977, Standing *et al.* 1975, Tarp 1952.

TULE PERCH, *Hysterocarpus traski* (Gibbons)

SPAWNING

Location	Among the tule marshes and other types of vegetation from Napa River, Suisun Bay, Montezuma Slough, Suisun Marsh, most sloughs in the Delta, the Sacramento River up to Red Bluff, in the vicinity of Tracy Pumping Station, and as far as O'Neill Forebay.
Season	Mating: judging from condition of tests, mating begins in July and continues through September (Bundy 1970). Birth: in May (Bundy 1970, Bryant 1977).
Temperature	Females give birth at 18–20°C in the laboratory.
Salinity	Freshwater.
Fecundity (number of embryos)	22–83 (Bundy 1970); 5–93 (Bryant 1977); 26–75.

CHARACTERISTICS

EGGS

Shape	Spherical.
Diameter	0.3–0.5 mm.
Yolk	Yellowish, granular.
Oil globule	None, or occasionally has small oil globules.
Chorion	Clear, smooth.
Perivitelline space	Fairly wide.

LARVAE (embryos)

Length at hatching (birth)	Early developed embryo: 0.25 mm in January (Bryant 1977, this study); 3.0 mm TL in March (Bundy 1970). Birth: 29 mm SL (Bryant 1977); 33–44 mm long (Bundy 1970).
Snout to anus length	Ca. 60% of TL of embryos at 2.5 mm TL; decreasing to ca. 45% of TL of embryo at 14.0 mm TL.
Yolk sac	Small amount of yolk in thoracic region (Bundy 1970, Bryant 1977); yellowish, small, in thoracic region.
Gut	Coiled at 5 mm long; hind gut protrudes from the body (Bundy 1970); large, thick, particularly the portion of hind gut, protruding (this study); hind gut extends beyond the yolk sac (Bryant 1977).
Air bladder	Large, elongate.
Teeth	None at this stage.
Size at completion of yolk-sac stage	Ca. 5.0 mm long (Bundy 1970); 5.8 mm TL (Bryant 1977).
Total myomeres	33–35.
Last fin(s) to complete development	Pelvic.
Pigmentation	No pigments in early development (except for eyes); sparse melanophores cover head and body of the embryo prior to birth.

JUVENILES (Figure 28-11)

Dorsal fin	XII, 11 (Rutter 1908); XV–XVIII, 9–13 (Tarp 1952); XVI–XIX, 10–14 (Hopkirk 1973); XV–XIX, 9–15 (Moyle 1976).

Anal fin	III, 23 (Rutter 1907); III, 19–23 (Tarp 1952); III, 21–26 (Hopkirk 1973); III, 20–26 (Moyle 1976).
Pectoral fin	17–19 (Tarp 1952, Moyle 1976); 15–18 (Hopkirk 1973).
Mouth	Terminal, small (Rutter 1907, Moyle 1976) terminal, small, oblique.
Vertebrae	34–35.
Distribution	In sluggish waters with vegetation of the Sacramento-San Joaquin river systems and the upper estuary, and in some irrigation canals associated with the Sacramento-San Joaquin River system.

LIFE HISTORY

The tule perch is the only freshwater embiotocid found in California (Rutter 1908; Tarp 1952; Hopkirk 1962, 1973). Currently, this species is found in the Sacramento River system, Clear Lake, upper Blue Lake, and the Russian River (Hopkirk 1962, 1973; Moyle 1976). The tule perch is apparently extinct in the Pajaro, Salinas, and San Joaquin rivers (Moyle 1976; Baltz and Moyle 1976). Because of the morphological differences found in the separate drainages, Hopkirk (1962, 1973) recognized three subspecies. The validity of these subspecies has been questioned by Hubbs (1974), but they are fully supported by Baltz and Moyle in their recent study (1981). In the study area, tule perch were reported in Suisun Bay (Ganssle 1966), Carquinez Strait (Messersmith 1966), and the Napa River (Moyle 1976). Populations of tule perch were reported in Alameda and Coyote Creeks by Snyder (1905), but these disappeared in the 1930s (Moyle 1976, Aceituno *et al.* 1976). This species is observed as far as O'Neill Forebay (Moyle 1976, this study). Tule perch were collected from the Napa River, Montezuma Slough, Harris Channel, Wilson Slough, the vicinity of Pittsburg and Contra Costa Powerplants, Lindsey Slough, Cache Slough, the Sacramento River up to Red Bluff, and in Clifton Court Forebay and the vicinity of the Tracy Pumping Station (this study). The specimens used for descriptive information were collected at the Contra Costa and Pittsburg Powerplants, Montezuma Slough, and the Delta.

The mating season is from July through September (Bundy 1970). After mating, sperms are stored in the ovary until the ova become mature. Fertilization takes place in January (Bryant 1977), when the ova are still embedded in the ovarian tissue. Before egg segmentation is completed, they fall into the ovarian cavity (Amoroso 1960, Bryant 1977). Numerous ova were found in the ovarian tissue during November and December. Eggs or early embryos were observed in the ovarian cavity in January. The size range of those ova and eggs or early developed embryos were 0.35–0.5 mm in diameter (this study). Bundy (1970) observed early embryos that were 3.0 mm TL in March, while Bryant (1977) measured embryos from the ovarian cavity as 0.25 mm TL in mid-February. A range of 22–83 embryos per female was recorded by Bundy (1970), 5–93 by Bryant (1977), and 26–75 from 53 specimens examined in this study. Embryos have a small yolk sac in the thoracic region and a much larger tubular hind gut which protrudes from the anal region. The hind gut functions as a nutrient-absorbing organ (Hubbs 1921; Hoar 1955; Turner 1947, 1952). The epithelial cells lining the folded ovarian cavity develop an internal fluid reservoir which provide both nutrients and oxygen to the embryo (Wiebe 1968, Webb and Brett 1972). Nitrogenous wastes are absorbed through the ovarian wall as well (Turner 1952). As fins are developed by the embryo, the highly vascularized ovarian wall can also exchange gases with the vertical fin dermal flaps or spatulate appendages of the embryo (Turner 1938, Bundy 1970, Bryant 1977). After the gill slit is formed, the gut becomes functional (Turner 1958, Amoroso 1969). Embryos grow rapidly in 7–8 ovarian compartments. When the embryos reach 30–40 mm SL, they have developed into juveniles and are ready to be born (Bryant 1977). Most tule perch young are born head first, but they have also been observed tail-first and sideways (Bryant 1977, this study).

Juvenile tule perch swim freely immediately after birth. They are found among vegetation or protected areas such as rock jetties, submerged logs, and old tires (this study). In the laboratory, the juveniles school together but not with the parent fish (this study). Juvenile tule perch feed on zooplankton, aquatic insects, and benthic invertebrates when they are in lakes and rivers (Moyle 1976); they feed mainly on benthic amphipods and mysid shrimp in the Delta and the upper Sacramento-San Joaquin Estuary (Turner 1966b).

Tule perch reach sexual maturity shortly after birth. For males, spermatozoa are found in the juveniles; females can be inseminated prior to August (Bryant 1977). Most tule perch live up to 3 years (Bundy 1970), and the lifespan seldom exceeds 5 years (Moyle 1976). The tule perch has no commercial or sport value because of its small size (less than 16 cm SL, Moyle 1976).

References

Aceituno *et al.* 1976; Amoroso 1960; Bryant 1977; Bundy 1970; Ganssle 1966; Hoar 1955; Hopkirk 1962, 1973; Hubbs 1921, 1974; Messersmith 1966; Moyle 1976; Baltz and Moyle 1981; Rutter 1907; Snyder 1905; Tarp 1952; Turner 1938, 1947, 1952; Webb and Brett 1972; Wiebe 1968.

DWARF PERCH, *Micrometrus minimus* (Gibbons)

SPAWNING

Location	Rocky areas of coastal waters, San Francisco Bay, Tomales Bay, Bodega Bay, and Moss Landing Harbor-Elkhorn Slough (this study).
Season	Mating: in summer months (Hubbs 1921). Birth: June through August (Hubbs 1921); April and May in southern California (Feder *et al.* 1974).
Salinity	Seawater to polyhaline (this study).
Fecundity	Number of embryos 2–25 (Hubbs 1921).

CHARACTERISTICS

EGGS

Shape	Spherical.
Diameter	0.3–0.5 mm for eggs and early embryos observed in the ovarian cavity.
Yolk	Yellowish, granular.
Chorion	Smooth, clear.

LARVAE (embryos)

Length at hatching (birth)	Early developed embryo: 3.0 mm (Hubbs 1921); 2.7–3.0 mm TL. Birth: 30–35 mm long (Hubbs 1921); 25 mm long (Fitch and Lavenberg 1975).
Snout to anus length	Ca. 50% of TL of embryo at 8.3 mm TL, decreasing to 40% of TL of embryo at 14.9 mm TL.
Yolk sac	Small, spherical, in thoracic region.
Gut	Large, thick (particularly the hind gut).
Air bladder	Large, shallow, elongate.
Teeth	None at this stage.
Total myomeres	30–32.
Last fin(s) to complete development	Pelvic.
Pigmentation	No pigment (except the eyes) in the embryonic stage.

JUVENILES (Figure 28-12)

Dorsal fin	VIII–XI, 13–16 (Tarp 1952); VIII–XI, 12–16 (Miller and Lea 1972).
Anal fin	III, 15–21 (Tarp 1952); III, 13–23 (Miller and Lea 1972).
Pectoral fin	18–22 (Tarp 1952; Miller and Lea 1972).
Mouth	Small (Tarp 1952); terminal, small.
Vertebrae	31–36 (Miller and Lea 1972).
Distribution	Close to jetties or rocky shores with sandy bottom nearby, in San Francisco Bay, Tomales Bay, Bodega Bay, and Moss Landing Harbor-Elkhorn Slough.

LIFE HISTORY

The range of the dwarf perch is from Cedros Island, Baja California, to Bodega Bay, California (Tarp 1952, Miller and Lea 1972). In the study area, dwarf perch have been reported in the shallow waters of San Francisco Bay (Aplin 1967), Richardson Bay (Green 1975), San Pablo Bay (Ganssle 1966), Tomales Bay (Bane and Bane 1971), Bodega Bay (Standing *et al.* 1975), and Moss Landing Harbor-Elkhorn Slough (Nybakken *et al.* 1977). This species was often observed along the piling jetties and rocky areas in the vicinity of Potrero and Hunters Point Powerplants, San Francisco Bay; the Oleum Powerplant, San Pablo Bay, near Marshall and Marconi Coves, Tomales Bay; and the Moss Landing Powerplant, Moss Landing Harbor.

The life history and ecology of the dwarf perch have been investigated by Hubbs (1921). The following is a summary of Hubbs's findings. The mature fish give birth from June through August, and mating takes place soon after birth. Fertilization occurs in the fall or several months after mating, since embryos were not found until the end of the year. The dwarf perch is a small embiotocid, yet the female can carry 2 to 25 embryos in her ovary. The older the fish, the more young it bears.

In this study, both juvenile and adult dwarf perch were common in San Francisco Bay, particularly south San Francisco Bay and on rocky shores in Marin County. A resident population apparently exists in San Francisco Bay, because this species has been observed throughout the year. Juvenile dwarf perch feed on small crustaceans (Hubbs 1921), on polychaetes and mollusks (Fitch and Lavenberg 1975), and on protozoa and terrestrial insects (Nybakken *et al.* 1977). The larger fish become herbivorous, eating algae (Hubbs 1921, Bane and Bane 1971).

Male dwarf perch are sexually mature at birth (Hubbs 1921), whereas females do not become mature until they are 1 year old (Fitch and Lavenberg 1975). Males live only 1 year, but females may live 2–3 years, although much older fish (5–6 years) were reported by Hubbs (1921). Discrepancies may be due to scale reading and the uncertainty of the accessory annuli. The dwarf perch is of no sport or commercial value, since it is too small to be used as a food fish.

References

Aplin 1967, Bane and Bane 1971, Feder *et al.* 1974, Fitch and Lavenberg 1975, Ganssle 1966, Green 1975, Hubbs 1921, Miller and Lea 1972, Nybakken *et al.* 1977, Tarp 1952, Standing *et al.* 1975.

WHITE SEAPERCH, *Phanerodon furcatus* (Girard)

Spawning	
Location	Tomales Bay (Benerjee 1971), mostly in coastal waters, may occur in San Francisco Bay and Moss Landing Harbor-Elkhorn Slough.

Season	Birth: young are born from May through August in Tomales Bay (Benerjee 1971), young are observed in September (Feder *et al.* 1974).
Salinity	Seawater to polyhaline.
Fecundity	Numbers of embryos 8–33 (Benerjee 1971), 9, based on 1 specimen (Bane and Bane 1971).

CHARACTERISTICS

LARVAE (embryos)

Length at hatching (birth)	Average 43.5 mm SL (Benerjee 1971), 38-mm free-swimming young collected in Tomales Bay (Bane and Bane 1971).
Total myomeres	35–36.
Pigmentation	No pigments in embryonic stage with exception of eyes (Benerjee 1971).

JUVENILES (Figure 28-13)

Dorsal fin	X–XI. 22–26 (Clothier 1950), IX–XI, 20–26 (Tarp 1952, Miller and Lea 1972, Hart 1973).
Anal fin	III, 30–33 (Clothier 1950), III, 29–34 (Tarp 1952, Miller and Lea 1972, Hart 1973).
Pectoral fin	20–21 (Tarp 1952, Miller and Lea 1972, Hart 1973).
Mouth	Terminal, small, directed slightly upward (Hart 1973).
Vertebrae	37–41 (Clothier 1950, Miller and Lea 1972).
Distribution	Coastal waters, San Francisco Bay, Tomales Bay, and Moss Landing Harbor-Elkhorn Slough.

LIFE HISTORY

The white seaperch ranges from Point Cabras, Baja California, to Vancouver Island, British Columbia (Roedel 1953, Miller and Lea 1972). In the study area, this species has been reported in San Francisco Bay (Miller and Gotshall 1965, Aplin 1967), Richardson Bay (Green 1975), San Pablo Bay (Ganssle 1966), and Carquinez Strait (Messersmith 1966). It has also been reported in Tomales Bay (Bane and Bane 1971), Bodega Bay (Standing *et al.* 1975), and Moss Landing Harbor-Elkhorn Slough (Nybakken *et al.* 1977). White seaperch were collected at the intake screens of the Potrero and Hunters Point Powerplants, San Francisco Bay, the Oleum Powerplant, San Pablo Bay, and the Moss Landing Powerplant, Moss Landing Harbor (this study).

In Tomales Bay, Benerjee (1971) observed the smallest white seaperch embryo (16.2 mm SL) in March, and the size of the embryo increased rapidly between March and August.

The female perch gives birth from early May through mid-August. He also observed that the number of embryos per female increases with the size of the parent and that the early developmental biology of the white seaperch is similar to those of other embiotocids found in the study area.

Right after birth, the young school together inshore along the bay (Benerjee 1971). In this study, juveniles were collected mostly in summer months. Stomach contents of juvenile white seaperch included amphipods, shrimps, and papershell clams (Bane and Bane 1971), isopods (DeMartini 1969), and polychates, decapods, and antherid eggs (Nybakken *et al.* 1977).

Anderson and Bryan (1970) found that the initial difference in growth between sexes of the white seaperch was not as obvious during their first year as in the shiner perch. White seaperch may not achieve maturity in the first year, rather, the male becomes mature in the second year and female may wait 2–3 years. Benerjee (1971) found that females at 165 mm FL carried embryos, in a later study (1973), Benerjee reported that a 165 mm FL fish was in the 2-year class. Females measure at a mean length of 170.9 mm SL were found to be in their third year by Anderson and Bryan (1970). The maximum age of the white seaperch is reported as 6–7 years (Anderson and Bryan 1970, Benerjee 1973). Because of their abundance and large size, up to 280 mm FL (Benerjee 1973), the white seaperch is one of the most important commercial and sport fish along the northern California coast and estuaries (Roedel 1953, Bane and Bane 1971, Feder *et al.* 1974).

References

Anderson and Bryan 1970, Aplin 1967, Bane and Bane 1971, Benerjee 1971, 1973, Clothier 1950, DeMartini 1969, Feder *et al.* 1974, Ganssle 1966, Green 1975, Hart 1973, Messersmith 1966, Miller and Gotshall 1965, Miller and Lea 1972, Nybakken *et al.* 1977, Roedel 1953, Standing *et al.* 1975, Tarp 1952.

RUBBERLIP SEAPERCH, *Rhacochilus toxotes* (Agassiz)

SPAWNING

Location	Mostly in the kelp beds in coastal waters, occasionally near piers and jetties in San Francisco Bay and Moss Landing Harbor-Elkhorn Slough.
Season	Birth: small embryos were observed in June and September (Feder *et al.* 1974), nearly ripe embryos were observed from April through June (Fitch and Lavenberg 1971), young are apparently born in spring, summer, and fall.
Salinity	Seawater.
Fecundity	21 embryos were found in a single 419-mm female (Feder *et al.* 1974).

CHARACTERISTICS

LARVAE (embryos)

Total myomeres	6–38.

JUVENILES (Figure 28-14)

Dorsal fin	IX–XI, 20–25 (Clothier 1950, Miller and Lea 1972), X–XI, 22–24 (Tarp 1952).
Anal fin	III, 28–30 (Clothier 1950), III, 27–30 (Tarp 1952, Miller and Lea 1972).
Pectoral fin	21–24 (Tarp 1952, Miller and Lea 1972).
Mouth	Fairly large (Tarp 1952), terminal, large, maxillary reaching anterior edge of orbit, upper jaw slightly protruding, thick lips, lower lip lobed.
Vertebrae	35–38.
Distribution	Along coastal waters, some found in San Francisco Bay and Moss Landing Harbor-Elkhorn Slough.

LIFE HISTORY

The distribution of the rubberlip seaperch is from Thuroe Head, Baja California, to Russian Gulch State Beach, Mendocino County, California (Miller and Lea 1972). This species has been reported in San Francisco Bay (Aplin 1967), Richardson Bay (Green 1975), Tomales Bay (Bane and Bane 1971), Bodega Bay (Standing *et al.* 1975), and Moss Landing Harbor-Elkhorn Slough (Nybakken *et al.* 1977). In this study, both juveniles and adults were collected at the intake screens of the Potrero and Hunters Point Powerplants, San Francisco Bay, and observed in anglers' catches at the fishing piers near the northern end of the Golden Gate Bridge. They were also taken at the intake screens of the Moss Landing Powerplant, Moss Landing Harbor.

Small embryos of this species were observed in June and September along the southern California coast (Feder *et al.* 1974), and nearly ripe embryos were reported from April to June by Fitch and Lavenberg (1971). The fish apparently give birth in the spring, summer, and fall months. Details of the life history of the black seaperch are still very limited in the literature.

Juveniles were collected at the intake forebay and intake screens of the Hunters Point Powerplant, and at the jetties and intake screens of the Potrero Powerplant. They feed mainly on small crustaceans such as amphipods, shrimp, and crabs (Bane and Bane 1971). They also eat polychaetes, bryozoans, mussels, and small snails (Feder *et al.* 1974).

The rubberlip seaperch is an important species for commercial as well as sport fisheries along the California coast, particularly in the Monterey Bay area (Fitch and Lavenberg

1971). The rubberlip seaperch can grow as large as 414 mm TL and 1265 grams in weight. It is one of the largest embiotocids, and is also reputed to be the finest food fish among the family (Bane and Bane 1971, Feder *et al.* 1974).

References

Aplin 1967, Bane and Bane 1971, Clothier 1950, Feder *et al.* 1974, Fitch and Lavenberg 1971, Green 1975, Miller and Lea 1972, Nybakken *et al.* 1977, Standing *et al.* 1975, Tarp 1952.

PILE PERCH, *Rhacochilus vacca* (Girard)

SPAWNING

Location	Shallow coastal waters, also occurring in San Francisco Bay, San Pablo Bay, Tomales Bay, Moss Landing Harbor-Elkhorn Slough.
Season	Mating: highest testis index value in September and October (Wares 1971) or October and November (Feder *et al.* 1974). Birth: April in southern California (Rechnitzer and Limbaugh 1952), June to August in Oregon (Wares 1971), August in British Columbia (Hart 1973), June to October in southern California (Feder *et al.* 1974).
Salinity	Seawater to polyhaline.
Fecundity	Number of embryos 7–61 (Wares 1971).

CHARACTERISTICS

EGGS

Shape	Spherical.
Diameter	0.5–0.7 mm for eggs and early embryos found in the ovarian cavity.
Yolk	Yellowish to whitish, granular.
Chorion	Transparent, smooth.

LARVAE (embryos)

Length at hatching (birth)	Early developed embryo: ca. 1.3–1.5 mm TL.
Snout to anus length	Ca. 60–65% of TL of embryos at 3.0–3.2 mm TL, ca. 50 % of TL of embryos at 6.4–9.0 mm TL.
Yolk sac	Small, in thoracic region.
Gut	Large, thick, the hind gut protruding.
Air bladder	Small, oval, near pectoral in the early embryo.

Teeth	None at this stage.
Total myomeres	35–38.
Pigmentation	None in the embryonic stage, with exception of eyes and air bladder, pigments cover entire head and body prior to birth.

JUVENILES (Figure 28-15)

Dorsal fin	X–XI, 22–23 (Clothier 1950), IX–XI, 21–25 (Tarp 1952, Miller and Lea 1972, Hart 1973).
Anal fin	III, 27–30 (Clothier 1950, Tarp 1952, Hart 1973), III, 25–31 (Miller and Lea 1972)
Pectoral fin	19–22, (Tarp 1952, Miller and Lea 1972, Hart 1973).
Mouth	Moderate in size (Tarp 1952), terminal, small, directed slightly upward (Hart 1973).
Vertebrae	35–37 (Clothier 1950), 34–39 (Miller and Lea 1972), 33–38 (Hart 1973).
Distribution	Coastal waters, San Francisco Bay, San Pablo Bay, and up to Suisun Bay, they were also found in Moss Landing Harbor-Elkhorn Slough.

LIFE HISTORY

The pile perch has been reported from Guadalupe Island, Baja California, to Port Wrangell, Alaska (Miller and Lea 1972). In the study area, pile perch were reported in San Francisco Bay (Aplin 1967), Richardson Bay (Green 1975), San Pablo Bay (Ganssle 1966), Tomales Bay (Bane and Bane 1971), Bodega Bay (Standing *et al.* 1975), and Moss Landing Harbor-Elkhorn Slough (Nybakken *et al.* 1977). This species is common in San Francisco Bay and San Pablo Bay.

Wares (1971) observed the highest testis index of male pile perch in September and October in Yaquina Bay, Oregon, and mating occurred in the fall. His studies further indicated that fertilization takes place about 3 months after mating, or from mid-December to early February. In this study, both eggs and early developed embryos were found in the ovarian cavity of female pile perch taken from the Oleum Powerplant intake structures in late February 1979. Apparently fertilization occurred in January of that year. The fact that both eggs and embryos of several different sizes were observed in the same ovarian cavity indicates a lengthy period of fertilization as each individual egg matures. Embryos were loosely settled in different compartments of the ovarian cavity. As the embryos grow larger, they are parallel to each other, arranged head to tail in order to use all available space within the cavity. Wares (1971) reported that pile perch give birth from July to August in Yaquina Bay, Oregon, indicating that the gestation period lasted about 6½ months, although the gestation period was estimated as 15 months by Wales (1929). In this study, judging from the small juveniles (ca. 70–80 mm TL) collected in late May and June in the vicinity of the Oleum Powerplant, the period of giving birth is estimated to be from late spring to early summer. The fecundity is positively correlated with size and age of the female fish (Wares 1971).

Juveniles were common in powerplant impingement catches in the summer and fall months. Apparently they were schooling together (this study). Juvenile pile perch feed on amphipods, crabs, (megalope), mud shrimp, and polychates, larger juveniles also take mollusks (Bane and Bane 1971, Wares 1971, Nybakken *et al.* 1977).

Male pile perch reach sexual maturity in their second year and females in their second or third year.

They can live up to 9–10 years (Wares 1971). The pile perch is a large embiotocid. A 9-year-old female can grow to 450 mm TL. It is an important commercial and sport

species along the California coast and estuaries (Hart 1973, Feder *et al.* 1974). They are very popular as sport fish off jetties and piers in San Francisco Bay.

References

Aplin 1967, Bane and Bane 1971, Clothier 1950, Feder *et al.* 1974, Ganssle 1966, Green 1975, Hart 1973, Miller and Lea 1972, Nybakken *et al.* 1977, Rechnitzer and Limbaugh 1952, Standing *et al.* 1975, Tarp 1952, Wales 1929, Wares 1971.

Characteristic Comparison: Surfperches

Characteristic	**Barred Surfperch**	**Kelp Surfperch**	**Shiner Perch**
Juveniles			
Dorsal fin	IX–XI, 21–27	VII–X, 13–16	VIII–XI, 18–23
Anal fin	III–IV, 24–29	III–IV, 20–25	III, 22–26
Pectoral fin	25–28	17–18	19–21
Mouth	Terminal, large, oblique, maxillary reaching anterior edge of pupil of eye, lower lip with frenum	Terminal, small directed slightly upward, lower lip without frenum	Terminal, small, directed slightly upward lower lip with frenum
Distinguishing characters	11 or more vertical bars on side of body; some mismatched at lateral line	Projected snout, deep, elongate caudal peduncle	Dark horizontal stripes on sides of body, 3 vertical yellow bars; males in breeding season almost entirely black
	Black Perch	**Striped Seaperch**	**Spotfin Surfperch**
Dorsal fin	IX-XI, 18–22	X–XII, 23–26	VII–IX, 20–25
Anal fin	III, 24-27	III, 29–33	III, 21–26
Pectoral fin	20–22	21–24	23–27
Mouth	Terminal, small, with thick lips, lower lip with frenum	Terminal, small, directed slightly upward, lower lip with frenum	Terminal, large, but lower jaw extends beyond upper, lower lip without frenum
Distinguishing characters	Patch of large scales below pectorals; back and sides with dark vertical bars, sometimes obscured in darker specimens	Horizontal stripes cover entire side of body	A black blotch at top of spiny dorsal fin; a black spot in middle of anal fin

Characteristic Comparison: Surfperches

Characteristic	Walleye Surfperch	Silver Surfperch	Rainbow Seaperch
Juveniles			
Dorsal fin	VII–XI, 25–29	VIII–X, 25–29	IX–XI, 20–24
Anal fin	III, 30–35	III, 29–35	III,20–24
Pectoral fin	25–28	26–28	21–23
Mouth	Terminal, fairly large, maxillary reaching anterior edge of orbit, lower lip without frenum	Terminal, moderately large, maxillary reaching anterior edge of orbit, lower lip without frenum	Terminal, maxillary fairly long, upper jaw protruding slightly over lower jaw, lower lip with frenum
Distinguishing characters	Black tips on pelvic fins, black border on caudal and anal fins	5–6 dusky bars on sides of body	Body with horizontal strips and vertical bars; abdominal region flat
	Tule Perch	**Dwarf Perch**	**White Seaperch**
Dorsal fin	XV–XIX, 9–15	VIII–IX, 12–16	IX–XI, 20–26
Anal fin	III, 20–26	III, 13–23	III, 29–34
Pectoral fin	17–19	18–22	18–21
Mouth	Terminal, small, lower lip without frenum	Terminal, small, lower lip with frenum	Terminal, large, directed slightly upward, lower lip without frenum
Distinguishing characters	Oblique bars or no bars on sides of body; lives only in freshwater	Series of horizontal stripes on abdominal region; irregular dark vertical bands on dorsal region	Caudal fin deeply forked; soft dorsal with black line along base; anterior portion of soft dorsal rays not elongate

Characteristic Comparison: Surfperches

Characteristic	**Rubberlip Seaperch**	**Pile Perch**
Juveniles		
Dorsal fin	IX-XI, 20–25	IX–XI, 21–25
Anal fin	III, 27–30	III, 25–31
Pectoral fin	21–24	19–22
Mouth	Terminal, upper jaw slightly protruding, maxillary reach anterior edge of orbit, lips extremely thick, lower lip with frenum	Terminal, small, directed slightly upward, lower lip with frenum
Distinguishing characters	Large, thick, whitish lips; no enlarged scales below pectorals	Caudal fin deeply forked; anterior portion of soft dorsal elongate; a broad dark bar across side of body near high point of soft dorsal

Figure 28.—Embiotocidae: Surfperches.

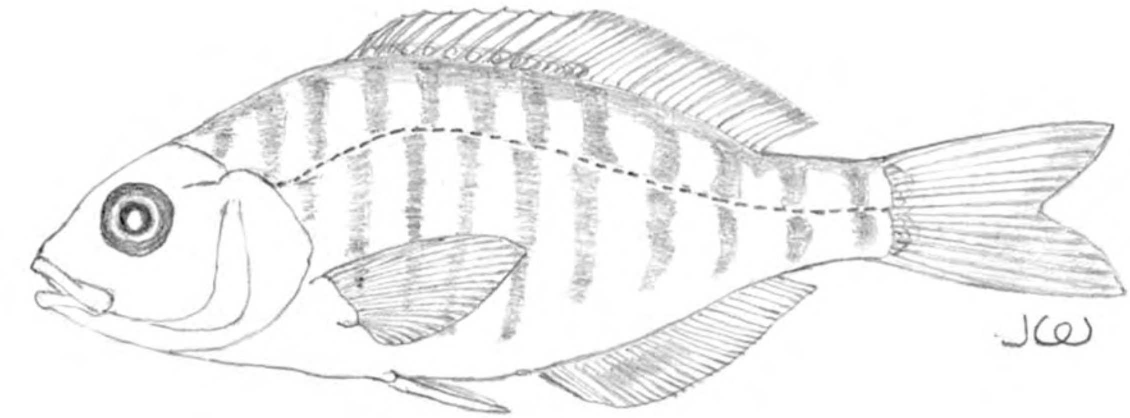


FIGURE 28-1.—*Amphistichus argenteus*, barred surfperch, 86 mm TL.

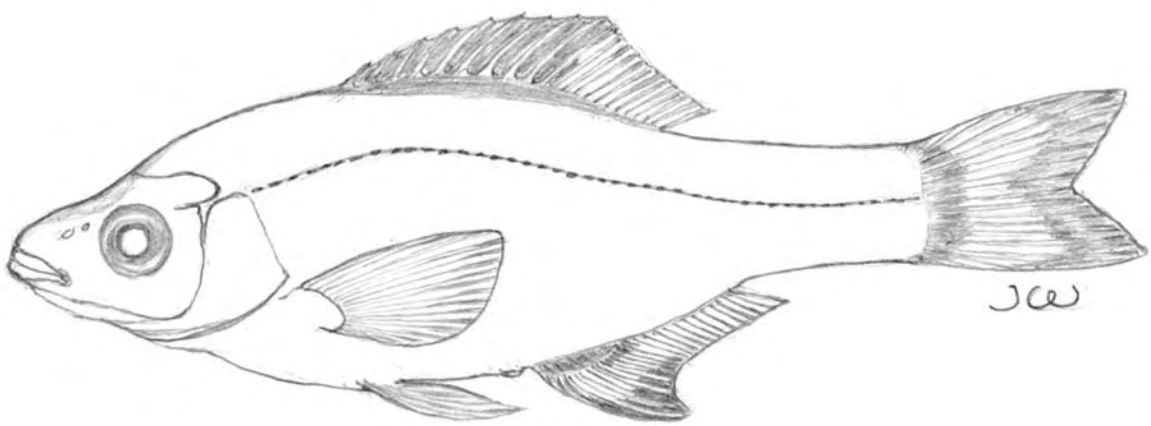


FIGURE 28-2.—*Brachyistius frenatus*, kelp perch juvenile, 98 mm TL.

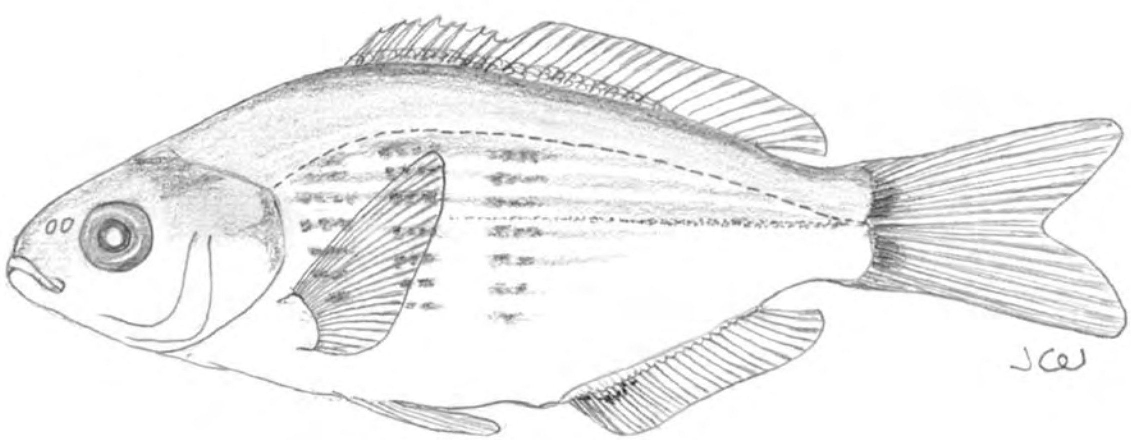


FIGURE 28-3.—*Cymatogaster aggregata*, shiner perch juvenile, 51 mm TL.

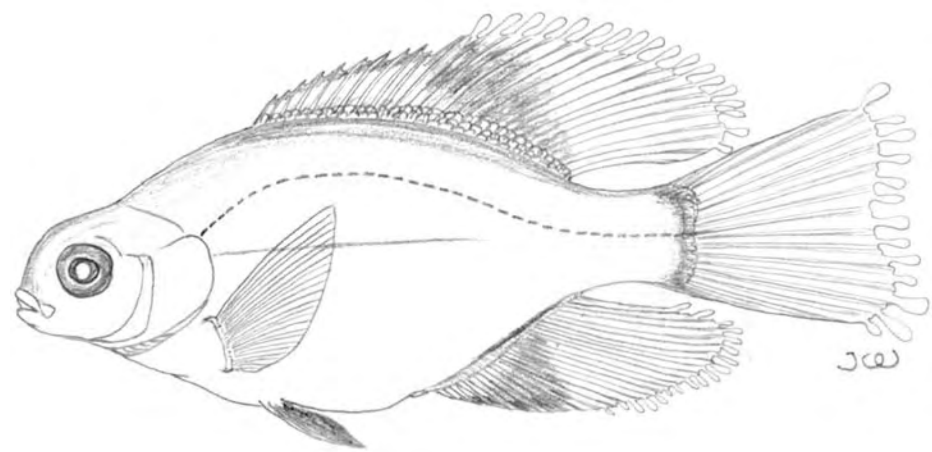


FIGURE 28-4.—*Embiotoca jacksoni*, black perch juvenile, 54 mm TL.

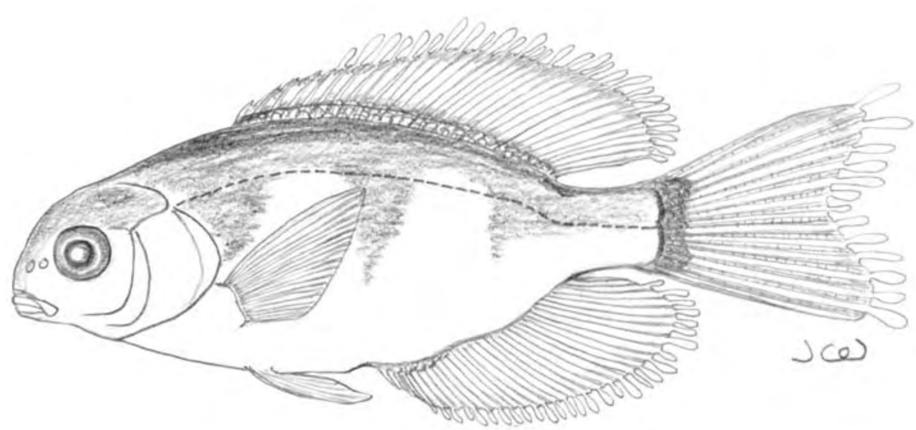


FIGURE 28-5. *Embiotoca jacksoni*, black perch juvenile, 72 mm TL.

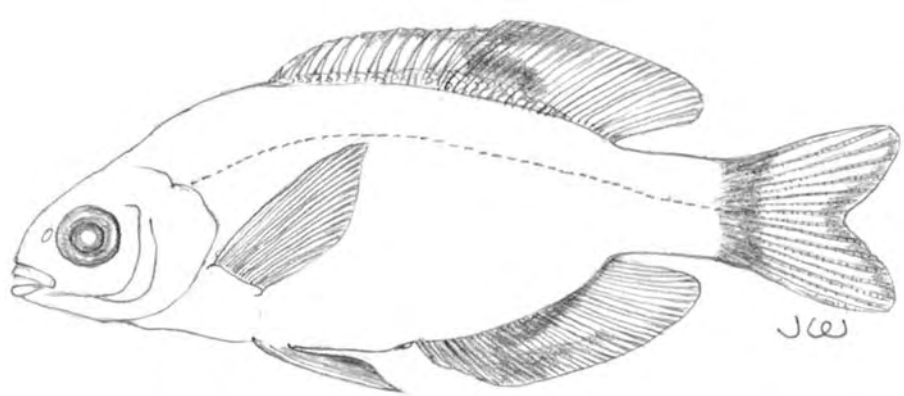


FIGURE 28-6.—*Embiotoca lateralis*, striped surfperch juvenile, 70 mm TL.

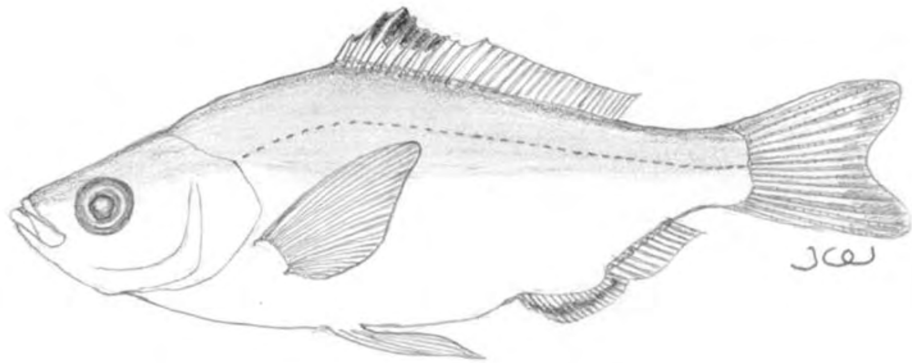


FIGURE 28-7.—*Hyperprosopon anale*, spotfin surfperch juvenile, 86 mm TL.

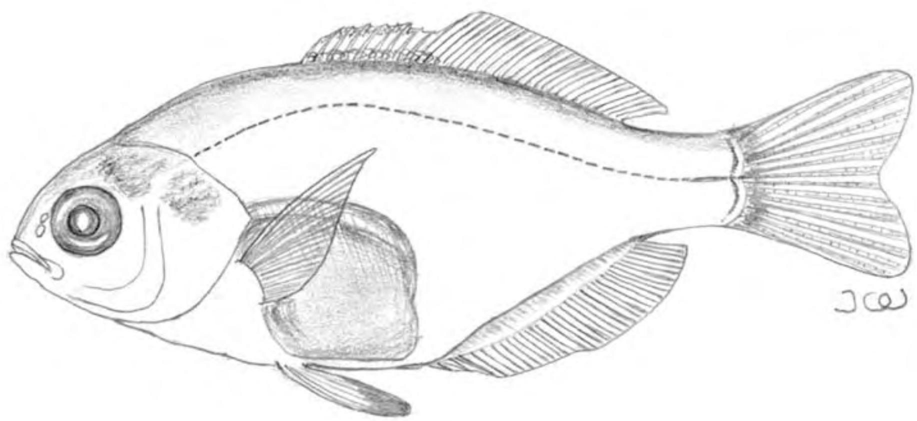


FIGURE 28-8.—*Hyperprosopon argenteum*, walleye surfperch juvenile, 61 mm TL.

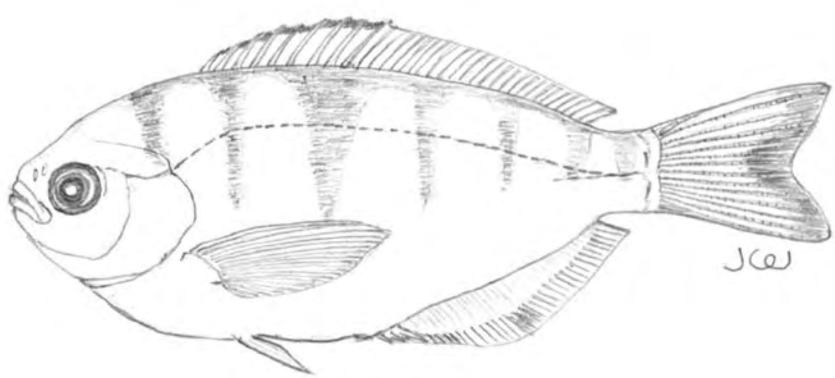


FIGURE 28-9.—*Hyperprosopon ellipticum*, silver surfperch juvenile, 92 mm TL.

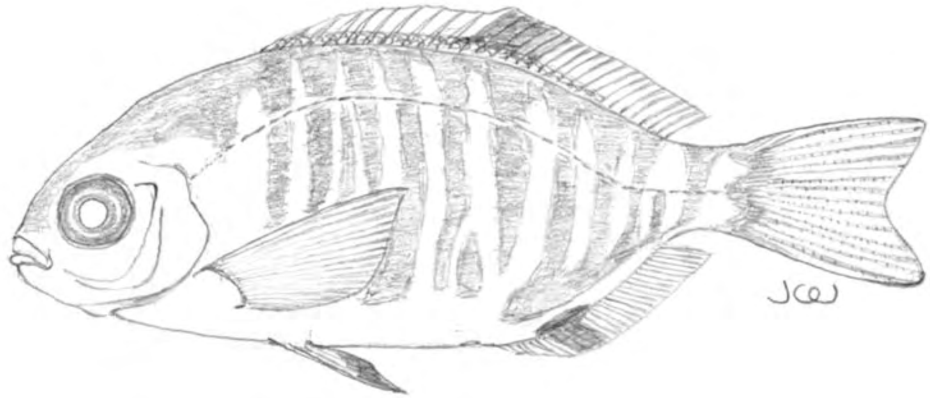


FIGURE 28-10.—*Hypsurus caryi*, rainbow seaperch juvenile, 67 mm TL.

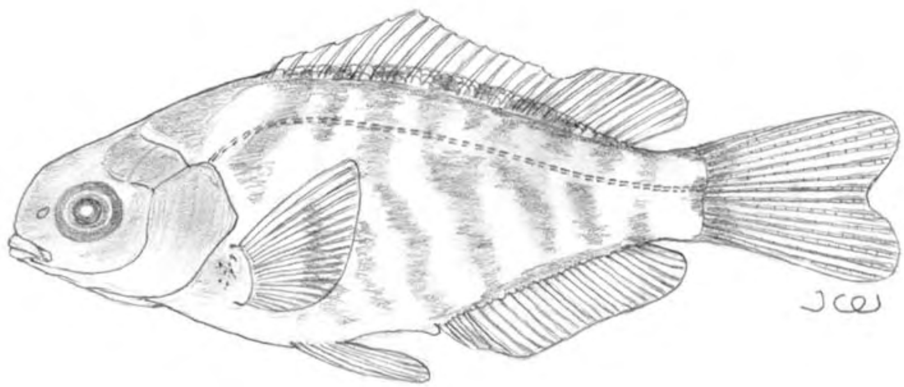


FIGURE 28-11.—*Hysterocarpus traski*, tule perch juvenile, 36 mm TL.

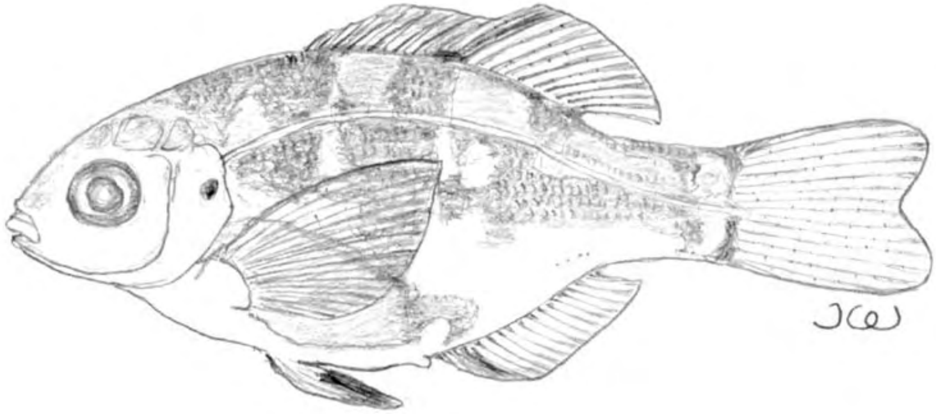


FIGURE 28-12.—*Micrometrus minimus*, dwarf perch juvenile, 40 mm TL.

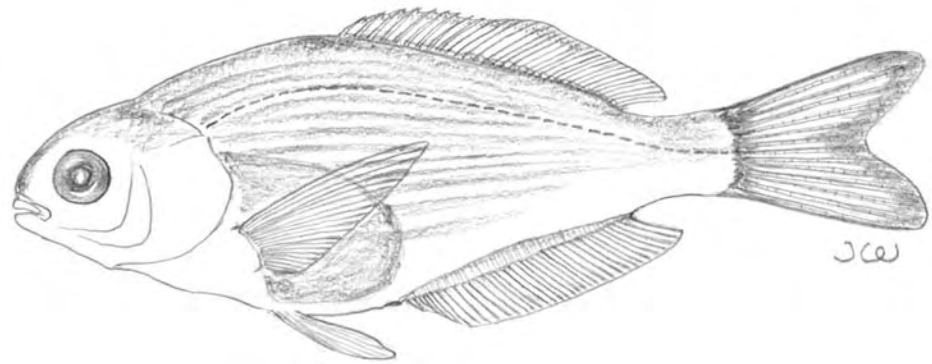


FIGURE 28-13.—*Phanerodon furcatus*, white seaperch juvenile, 67 mm TL.

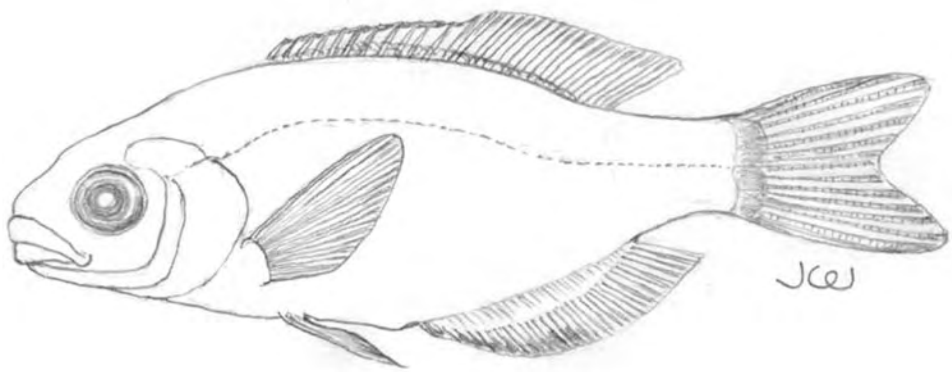


FIGURE 28-14.—*Rhacochilus toxotes*, rubberlip seaperch juvenile, 100 mm TL.

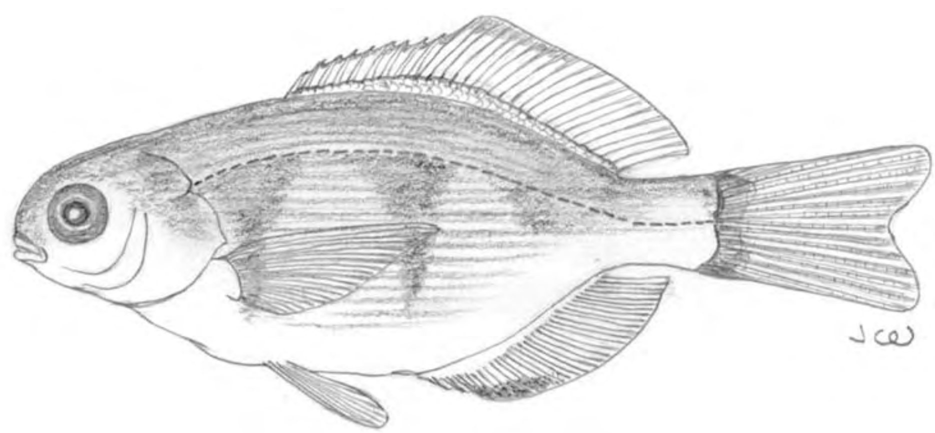


FIGURE 28-15.—*Rhacochilus vacca*, pile perch juvenile, 82 mm TL.

29. Labridae – Wrasses

Three species of labrida are found along the coast of California (Bailey *et al.* 1970, Miller and Lea 1972). Only one species, the senorita, *Oxyjulis californica*, was collected in this study.

References

Bailey *et al.* 1970, Miller and Lea 1972.

SENORITA, *Oxyjulis californica* (Guenther)

SPAWNING

Season	May–October (Bolin 1930); May–August (Fitch and Lavenberg 1975); June–July.
Salinity	Seawater.

CHARACTERISTICS

EGGS

Shape	Spherical (Bolin 1930).
Diameter	Ca. 0.74 mm (Bolin 1930).
Oil globule	Single oil globule (Bolin 1930, Orton 1953).
Chorion	Transparent (Bolin 1930, Orton 1953).
Egg mass	Broadcast singly.
Adhesiveness	Non-adhesive (Bolin 1930).
Buoyancy	Pelagic (Bolin 1930).

LARVAE (FIGURE 29-1)

Snout to anus length	Ca. 53% of TL of larvae at 2.1–2.6 mm TL.
Yolk sac	Very large, elongate, protruding, head recessed (Bolin 1930, Orton 1953).
Oil globule	Single, pigmented, in front of yolk sac (Bolin 1930, Orton 1953).
Gut	Straight.
Total myomeres	26.
Preanal myomeres	13.
Postanal myomeres	13.

Pigmentation	Scattered melanophores on different parts of body (Bolin 1930, Orton 1953). Scattered melanophores on body (with exception of dorsal portion of trunk); two large melanophores near caudal region, which eventually form two dark bands.
Distribution	Pelagic in coastal water (Bolin 1930, Orton 1953), in embayment of Moss Landing Harbor (Nybakken *et al.* 1977).

JUVENILES (Figure 29-2)

Dorsal fin	IX–X, 13 (Clothier 1950, Miller and Lea 1972, Fitch and Lavenberg 1975).
Anal fin	III, 13 (Clothier 1950, Miller and Lea 1972).
Mouth	Terminal, pointed.
Vertebrae	26–27 (Clothier 1950, Miller and Lea 1972).
Distribution	Surface to 60-m-deep water from Baja California to San Francisco Bay (Miller and Lea 1972).

LIFE HISTORY

The range of the senorita is from Cedros Island, Baja California, to Sausalito, on San Francisco Bay, but in recent years this species has not been seen north of Santa Cruz (Miller and Lea 1972, Fitch and Lavenberg 1975). However, a single juvenile specimen 74 mm long TL was captured in a beach seine near Golden Gate Bridge in July 1980 (M. Giusti 1980, personal communication). Larvae of this species were observed in Moss Landing Harbor (Nybakken *et al.* 1977).

Spawning occurs in the summer months (Bolin 1930, Fitch and Lavenberg 1975). Specimens taken in the Moss Landing area showed spawning to occur in June and July. Eggs are spherical, non-adhesive, and pelagic (Bolin 1930). Acutal spawning behavior and fecundity have not been described.

Larvae are pelagic (Bolin 1930, Orton 1953). They were collected in the plankton samples taken in Moss Landing Harbor during June and July (Nybakken *et al.* 1977).

Major food items for juvenile and adult senorita are small gastropods, crustaceans, worms, larval fish, and ectoparasites from large predatory fish (Fitch and Lavenberg 1975).

Senorita reach maturity at the age of 1 year. There is no commercial fishery for this species, and little interest in them by sport fishermen (Fitch and Lavenberg 1975).

References

Bolin 1930; Clothier 1950; Fitch and Lavenberg 1975; Giusti 1980, personal communication; Miller and Lea 1972; Nybakken *et al.* 1977; Orton 1953.

Figure 29.—Labridae: Oxyjulis californica, señorita.

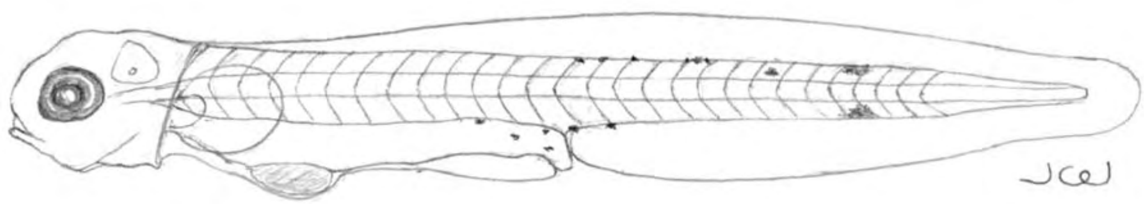


FIGURE 29-1.—Prolarva, 2.7 mm TL.

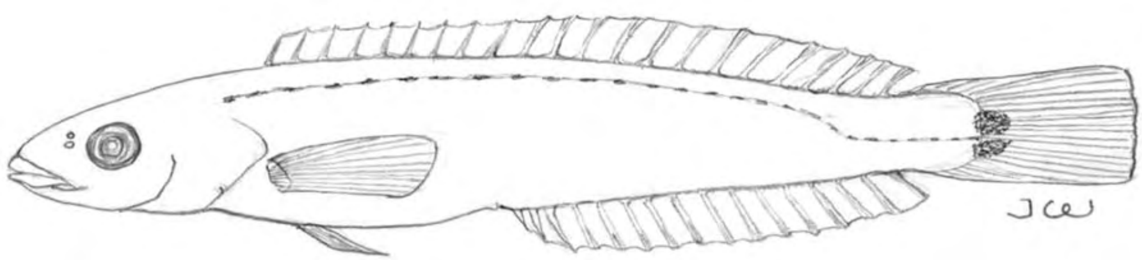


FIGURE 29-2.—Juvenile, 74 mm TL.

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30. Clinidae – Clinids

At least five species of clinids are known to the study area (Miller and Lea 1972). Four of them were collected in this study: striped kelpfish (*Gibbonsia metzi*, giant kelpfish, *Heterostichus rostratus*, sarcastic fringehead, *Neoclinus blanchardi*, and onespot fringehead, *Neoclinus uninotatus*. Kelpfishes are usually associated with kelp and seaweed beds, while fringeheads are found in varied habitats. Sarcastic fringehead were uncommon in this study (only five specimens were collected in Moss Landing Harbor), and this species is not included.

References

Miller and Lea 1972.

STRIPED KELPFISH, *Gibbonsia metzi* Hubbs

SPAWNING

Location	Shallow coastal waters. Occurs in San Francisco Bay, Tomales Bay, and Moss Landing Harbor.
Season	In March (Bane and Bane 1971); October–May, with a peak in February; transparent young found in April and July, so apparently the spawning occurs from March to June (Feder *et al.* 1974).
Salinity	Seawater to polyhaline.
Substrates	Rocky areas and kelp beds (R. MacFadden 1980, personal communication).
Fecundity	Ca. 2,300 (Bane and Bane 1971).

CHARACTERISTICS

EGGS (Figure 30-1)

Shape	Spherical.
Diameter	Unfertilized mature eggs, ca. 1.3 mm, fertilized eggs 1.4–1.7 mm.
Yolk	Granular.
Oil globule	Single, large (this study).
Chorion	Transparent.
Egg mass	Deposited in clusters (R. MacFadden 1980, personal

	communication); egg has filaments tangled in clusters.
Adhesiveness	Assumed adhesive (R. MacFadden 1980, personal communication).
Buoyancy	Demersal.

LARVAE (Figures 30-2, 30-3, 30-4, 30-5)

Length at hatching	Judging by the smallest prolarval specimen taken in the study, the hatching size is ca. 7.0 mm TL or slightly less.
Snout to anus length	Ca. 40–46% of TL of larvae at 6.2–15.0 mm TL.
Yolk sac	Spherical, in jugular-thoracic region.
Oil globule	Single, large, bright yellow, in front portion of yolk sac; some larvae have dispersed oil globules.
Gut	Straight, thick, with segmentation structure in yolk-sac stage; twisted at least twice in postlarvae.
Air bladder	In prolarvae a small shallow air bladder located near pectoral; in postlarvae, a large oval air bladder developed in front and above anal region, and the small one near the pectoral seems to become a rudimentary structure.
Teeth	Pointed, sharp, apparent in postlarval stage.
Size at completion of yolk-sac stage	Ca. 7.0–8.0 mm TL.
Total myomeres	49–53.
Preanal myomeres	17–20.
Postanal myomeres	30–33.
Last fin to complete development	Pelvic fin and anterior portion of dorsal fin.
Pigmentation	One or two large melanophores on midventral region. One large melanophore in dorsal portion of anus, and a series of dotted melonphores (ca. 25–30) along postanal region.
Distribution	Pelagic, shallow inshore water of San Francisco Bay, Tomales Bay, and Moss Landing Harbor.

JUVENILES (Figure 30-6)

Dorsal fin	XXXIV–XXXVII, 7–10 (Miller and Lea 1972, Hart 1973).
Anal fin	II, 24–29 (Miller and Lea 1972); II, 24–27 (Clothier

	1950, Hart 1973).
Pectoral fin	11–13 (Miller and Lea 1972); ca. 12 (Hart 1973).
Mouth	Terminal, moderate in size, directed slightly upward (Hart 1973); terminal oblique.
Vertebrae	51–52 (Clothier 1950); 50–53 (Miller and Lea 1972); 49 (Hart 1973).
Distribution	Kelp beds and inshore (Feder *et al.* 1974); eel grass, seaweed in shallow water of San Francisco Bay, Tomales Bay, and Moss Landing Harbor-Elkhorn Slough.

LIFE HISTORY

The distribution of striped kelpfish is from San Bartolome and Hondo Canyon, Baja California, to Nootka Island, British Columbia (Hart 1973, Davis 1977). They prefer embayments of higher salinity and have been reported in Tomales Bay (Bane and Bane 1971), Bodega Bay (Standing *et al.* 1975), and Moss Landing Harbor-Elkhorn Slough (Kakowski 1972, Nybakken *et al.* 1977). In this study, striped kelpfish, mostly in their larval and juvenile stages, were collected in San Francisco Bay, Tomales Bay, and Moss Landing Harbor.

Bane and Bane (1971) described the spawning season to be in March. Judging by data collected in this study, the spawning period extended from October through May, with a peak in February and March. Ripe specimens taken in San Francisco Bay and Moss Landing Harbor in the winter months show that at least a limited spawn may occur then (this study). Underwater observations (R. MacFadden 1980, personal communication) have indicated that striped kelpfish deposit demersal eggs in the kelp beds and rocky areas, as do other clinids. Egg masses attached on the kelp which were washed to the beach were observed in Horseshoe Cove in 1981; therefore, some might be laid in surface waters in the kelp canopy.

Striped kelpfish larvae are pelagic and swim in schools (Limbaugh 1951, Davis 1977). In this study, larvae of this species were found to be transparent and swimming near the surface of shallow inshore waters of San Francisco Bay, Moss Landing Harbor, and Tomales Bay. The largest numbers of larvae were collected by plankton tows or with a fine-mesh beach seine along the eastern shore of Tomales Bay. Eldridge (1977) reported two types of clinid larvae in Richardson Bay.

Some clinid larvae are very similar. The crevice kelpfish, *Gibbonsia montereyensis*, and the striped kelpfish have a comparable pigment pattern (Marliave 1975), but striped kelpfish larvae have a lower total myomere count (less than 49), and crevice kelpfish larvae have not been observed in this study area.

As juveniles become more opaque and gradually gain adult coloration, they settle into coastal tidepools and areas with kelp and other seaweeds. Juvenile striped kelpfish feed on small crustaceans, mollusks, invertebrates, and algae (Bane and Bane 1971, Feder *et al.* 1974).

Age of maturity is not clear in the literature. In this study, eggs were stripped from several 2–year old fish. The striped kelpfish is a relatively small fish and has no commercial importance (Feder *et al.* 1974).

References

Bane and Bane 1971; Clothier 1950; Davis 1977; Eldridge 1977; Feder *et al.* 1974; Hart 1973; Kukowski 1972b; Limbaugh 1951; MacFadden 1980, personal communication; Marliave 1975; Miller and Lea 1972; Standing *et al.* 1975.

GIANT KELPFISH, Heterostichus rostratus Girard

SPAWNING

Location	Coastal intertidals to 30 m, concentrates inshore (Feder *et al.* 1976); may occur in San Francisco Bay.
Season	March–July (Feder *et al.* 1974); based on time of larval fish collection, spawning occurs in February–March.
Temperature	Ca. 12˚C and greater.
Salinity	Seawater.
Substrates	Kelp beds and seaweed.

CHARACTERISTICS

EGGS

Shape	Spherical, with filaments (Limbaugh 1951).
Yolk	Purple (Limbaugh 1951); pink to greenish (Feder *et al.* 1974).
Egg mass	Eggs are laid among branches of seaweed and attached by means of adhesive filaments (Limbaugh 1951).
Adhesiveness	Adhesive (Limbaugh 1951, Feder *et al.* 1974).
Buoyancy	Demersal.

LARVAE (Figures 30-7, 30-8)

Snout to anus length	Ca. 43–47% of TL of larvae at 6.5–11.2 mm TL.
Yolk sac	In jugular-thoracic position.

Gut	Straight, thick in early postlarval stage.
Air bladder	Midway between pectorals and anus or slightly closer to pectorals.
Teeth	Sharp, pointed, apparent in postlarval stage.
Total myomeres	55–58.
Preanal myomeres	19–20.
Postanal myomeres	36–38.
Pigmentation	In early postlarvae, several melanophores scattered on midventral region. A single large melanophore on dorsal area of anus, a series of dotted melanophores (ca. 10 to 35) along postanal region.
Distribution	Pelagic, mostly near kelp beds in coastal waters, occasionally in San Francisco Bay and Moss Landing Harbor.

JUVENILES

Dorsal fin	XXXIII–XXXVII, 12–13 (Clothier 1950); XXXIII–XXXVIII, 11–13 (Miller and Lea 1972).
Anal fin	II, 33–34 (Clothier 1950); II, 31–35 (Miller and Lea 1972).
Pectoral fin	12–14 (Miller and Lea 1972).
Mouth	Slightly superior, lower jaw is longer than upper jaw.
Vertebrae	56–58 (Clothier 1950, Miller and Lea 1972).
Distribution	Mostly settle on kelp beds and other types of seaweed in coastal waters, occasionally entering embayments.

LIFE HISTORY

Miller and Lea (1972) described the distribution of the giant kelpfish as being from Cape San Lucas, Baja California, to British Columbia. Adult fish have been reported around piers in San Francisco Bay (Miller and Gotshall 1965).

In this study larvae of the giant kelpfish were taken in the vicinity of the Potrero Powerplant in San Francisco Bay, and juveniles were observed in Moss Landing Harbor.

Spawning occurs from March through July, and the transparent larvae appear from April through August (Feder *et al.* 1974). Limbaugh (1951) reported that giant kelpfish larvae school year-round, and thus the spawning period may be protracted. Female fish deposit their sticky, threaded eggs among the branches of kelp and other seaweeds (Limbaugh 1951). After spawning, male fish guard the eggs (Feder *et al.* 1974). Since adult fish were taken in San Francisco Bay (Miller and Gotshall 1965) and larvae were collected in the vicinity of the Potrero Powerplant, some spawning may occur in bays, not just along the coast.

Larvae are transparent. They swim in small schools in waters of less than 10 m and prefer a sandy patch or rocky areas (Limbaugh 1951, Feder *et al.* 1974).

Early juveniles remain pelagic schoolers until about 60 mm TL. When they assume adult body coloration, they become solitary and settle in kelp beds and in other seaweeds (Feder *et al.* 1974).

Age of maturity is not well documented in the literature, although this species is common in coastal kelp beds. Feder *et al.* (1974) claimed that the giant kelpfish is a moderately good eating fish, but there is no commercial fishery.

References

Clothier 1950, Feder *et al.* 1974, Limbaugh 1951, Miller and Gotshall 1965, Miller and Lea 1972.

ONESPOT FRINGEHEAD, *Neoclinus uninotatus* Hubbs

SPAWNING

Location	Near 10 m in coastal waters (Feder *et al.* 1974); judging by the size and location of larvae taken, spawning of onespot fringehead may occur in bays and sloughs.
Season	April–May (Feder *et al.* 1974); April–June (Fitch and Lavenberg 1975); larvae collected in spring, summer, and fall (Nybakken *et al.* 1977); most of the months of the year.
Temperature	Ca. 12°C and greater.
Salinity	Seawater-polyhaline.
Substrates	Cans, tires, pipes, shoes, depressions scooped out from debris and other shelter homes (Feder *et al.* 1974, Fitch and Lavenberg 1975).
Fecundity	3,550 eggs per batch for a female fish of 155 mm TL.

CHARACTERISTICS

EGGS (Figure 30-9)

Shape	Spherical.
Diameter	Unfertilized mature eggs, 1.2–1.3 mm.

Yolk	Orange color (Fitch and Lavenberg 1975); unfertilized mature eggs yellowish, granular.
Oil globule	Orange oil globule (Feder *et al.* 1974); unfertilized mature eggs: single, large oil globule, ca. 0.2–0.3 mm in diameter, bright yellow–orange color with numerous small oil globules in the yolk.
Chorion	Transparent, with fin wrinkle structure.
Egg mass	Deposited in clusters (Fitch and Lavenberg 1975).
Adhesiveness	Each egg has a bundle of fine adhesive filaments (Feder *et al.* 1974, Fitch and Lavenberg 1975).
Buoyancy	Demersal.

LARVAE (Figures 30-10, 30-11)

Length at hatching	Judging by the smallest prolarvae taken in this study, the newly hatched onespot fringehead is ca. 3.0 mm TL.
Snout to anus length	Ca. 34–39% of TL of larvae at 4.8–8.1 mm TL.
Yolk sac	Spherical, in thoracic region.
Gut	Short, thick, coiled in a single loop.
Air bladder	Small, oval, near pectoral fins.
Size at completion of yolk-sac stage	Ca. 3.5–4.5 mm TL.
Total myomeres	44–48.
Preanal myomeres	12–15.
Postanal myomeres	31–34.
Pigmentation	In prolarvae and early postlarvae, one large melanophore in thoracic region between pectorals and one on the dorsal area of anus, and a series of dotted melanophores (ca. 30–35) located in postanal region; in late postlarval stage, an additional melanophore on preopercle and a series of melanophores (ca. 25) along the base of dorsal fin.
Distribution	Pelagic, in shallow bays and sloughs (Nybakken *et al.* 1977).

JUVENILES (Figure 30-12)

Dorsal fin	XXIII–XXVII, 14–17 (Miller and Lea 1972).
Anal fin	II, 26–31 (Miller and Lea 1972).
Pectoral fin	14–16 (Miller and Lea 1972).

Mouth	Terminal, large, but maxillary still short of the posterior margin of the eye in early juveniles.
Vertebrae	47–48 (Miller and Lea 1972).
Distribution	Shallow coastal waters and bays at epibenthic level, use protected substrates such as tires, cans, and other shelters (Feder *et al.* 1974, Fitch and Lavenberg 1975).

LIFE HISTORY

The onespot fringehead occurs from San Diego Bay to Bodega Bay (Hubbs 1927, Miller and Lea 1972). In the study area and adjacent waters, this species has been reported in San Francisco Bay (Ruth 1964, Green 1975), Bodega Bay (Standing *et al.* 1975), and Moss Landing Harbor-Elkhorn Slough (Kukowski 1972b, Nybakken *et al.* 1977). In this study, both larvae and adults were found to be common in Moss Landing Harbor-Elkhorn Slough, but were not observed in San Francisco Bay and Tomales Bay.

Fitch and Lavenberg (1975) reported that the spawning season of the onespot fringehead extends from April through June, at least, and individual females produce more than one batch of eggs each season. This may explain why onespot fringehead larvae were found in Moss Landing Harbor-Elkhorn Slough in different seasons (Nybakken *et al.* 1977).

Onespot fringhead have adapted well to man's littering the ocean bottom with bottles, cans, and other objects. They are often found inhabiting these containers. When the eggs are spawned, the filaments on the eggs are used to cement them to the upper surface of their home, be it natural or man-made. The male fish remains with the eggs to guard them until they hatch (Feder *et al.* 1974, Fitch and Lavenberg 1975).

The fact that larvae were observed in Moss Landing Harbor-Elkhorn Slough and not in San Francisco Bay and Tomales Bay may indicate that the Moss Landing area is the northernmost significant spawning ground. Tomales Bay is known to be the northern border of the distribution range (Miller and Lea 1972).

Larvae, with their transparent bodies and short guts, are pelagic. All clinid larvae collected in Moss Landing Harbor-Elkhorn Slough by Nybakken *et al.* were identified as onespot fringehead (1977). In this study, a few adult sarcastic fringehead (*Neoclinus blanchardi*) were captured in the Moss Landing area. Some of the larvae collected at Moss Landing-Elkhorn Slough may belong to this species, since the early life history of sarcastic fringehead is not clear in the literature. Reliable separation between the onespot fringehead and the sarcastic fringehead is impossible at the present time.

A single early juvenile onespot fringehead (25 mm TL), was taken in a plankton tow in front of the intakes at the Moss Landing Powerplant. It appears that juveniles descend to the bottom early and become epibenthic in habit like the adults. Juveniles feed on small crustaceans as their major diet source (Fitch and Lavenberg 1975).

Age of maturity is unknown. The gravid female fish observed in the Moss Landing area ranged in size from 143 to 165 mm TL (this study). Longevity has been reported up to 7 years (Fitch and Lavenberg 1975). This species has no sport or commercial value, but they are kept occasionally in aquaria (Fitch and Lavenberg 1975), because they exhibit interesting territorial behavior (Feder *et al.* 1974).

References

Feder *et al.* 1974, Fitch and Lavenberg 1975, Green 1975, Hubbs 1927, Kukowski 1972b, Miller and Lea 1972, Nybakken *et al.* 1977, Ruth 1964, Standing *et al.* 1975..

Characteristic Comparison: Clinids

Characteristic	Striped Kelpfish	Giant Kelpfish	Onespot Fringehead
Larvae			
Total myomeres	49–53	55–58	44–48
Preanal myomeres	17–20	19–20	12–15
Postanal myomeres	30–33	36–38	31–54
Pigmentation	One large melanophore in thoracic region between pectorals; dashed melanophores on midventral region; a few large melanophores in anal region; a series of melanophores (25–30) along postanal region	Several melanophores scattered on midventral region; a few on dorsal areas of anal region; ca. 10–25 along postanal region	A few stellate melanophores on head; one in thoracic region; one on preopercle; ca. 25 along base of dorsal fin; ca. 30 along postanal region; rest of body usually unpigmented
Juveniles			
Dorsal fin	XXXIV–XXXVII, 7–10	XXXIII–XXXVIII, 11–13	XXXIII–XXXVII, 14–17
Anal fin	II, 24–29	II, 31–35	II, 26–31
Pectoral fin	11–13	12–14	14–16
Vertebrae	49–53	56–58	47–48
Distinguishing characters	More than one cerrus on top of eye; caudal fin round	No cerri on top of eye; caudal fin forked	One cerrus on top of eye; caudal fin round

Figure 30.—Clinidae: *Gibbonsia metzi*, striped kelpfish.

FIGURE 30-1.—Egg, late embryo, 1.6 mm diameter.

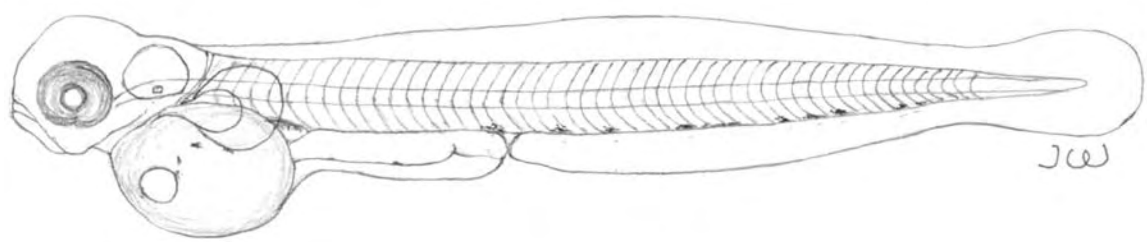


FIGURE 30-2.—Prolarva, 7 mm TL.

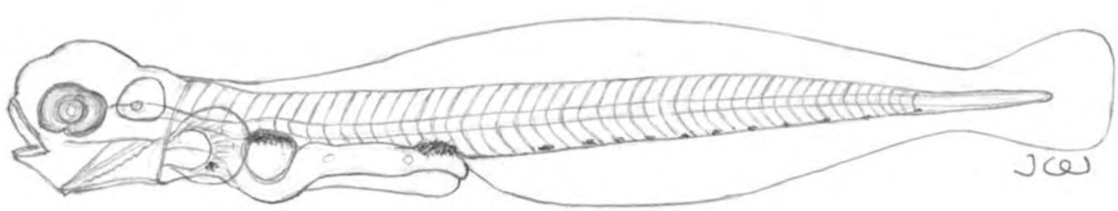


FIGURE 30-3— Postlarva, 8 mm TL.

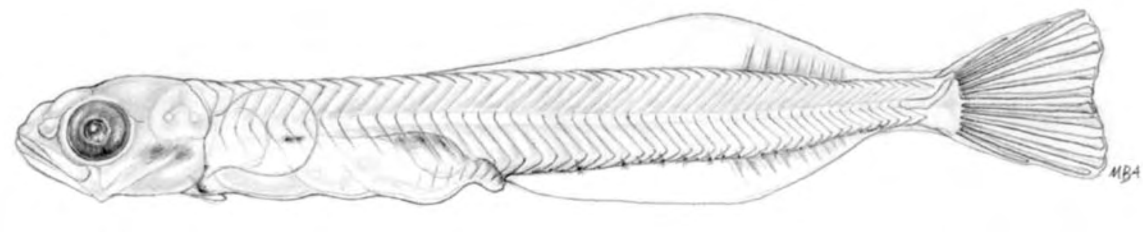


FIGURE 30-4— Postlarva, 15.6 mm TL.

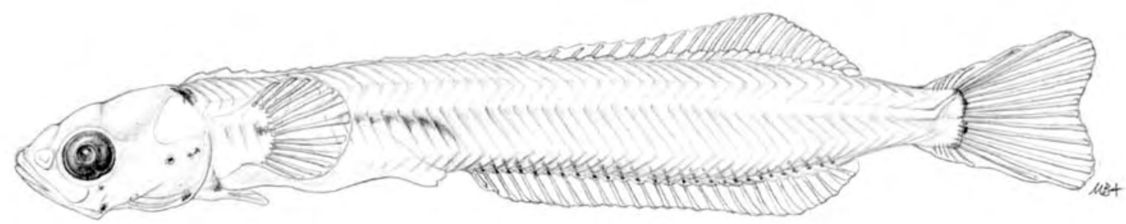


FIGURE 30-5.—Postlarva, 23 mm TL.

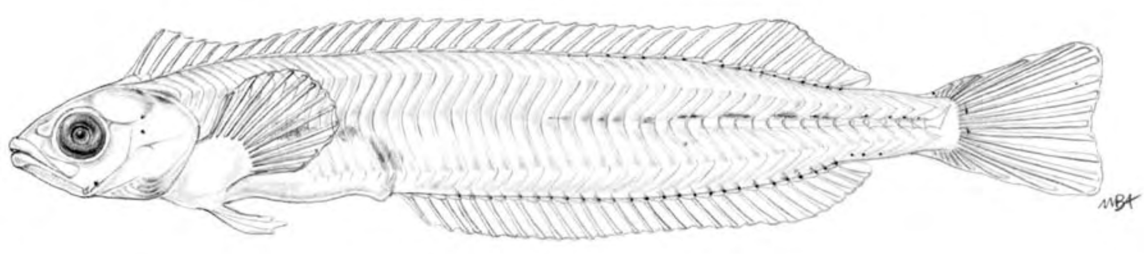


FIGURE 30-6.—Juvenile, 32.5 mm TL.

Clinidae: *Heterostichus rostratus*, giant kelpfish

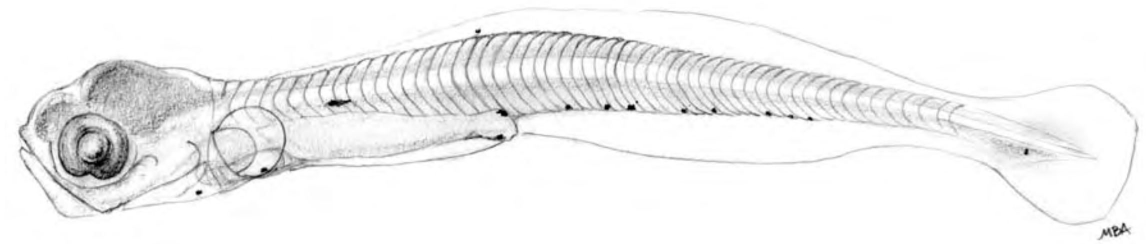


FIGURE 30-7.—Postlarva, 8 mm TL.

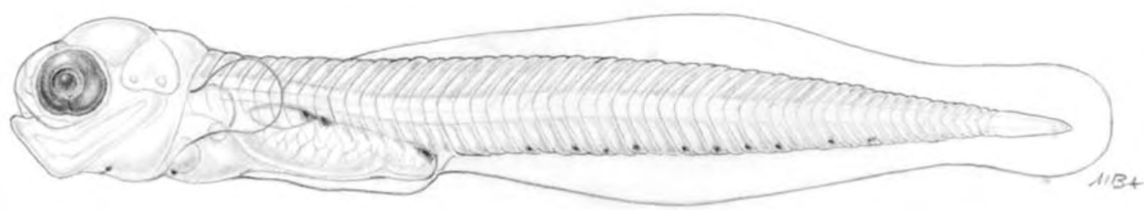


FIGURE 30-8.—Postlarva, 8.5 mm TL.

Clinidae: *Neoclinus uninotatus*, onespot fringehead.

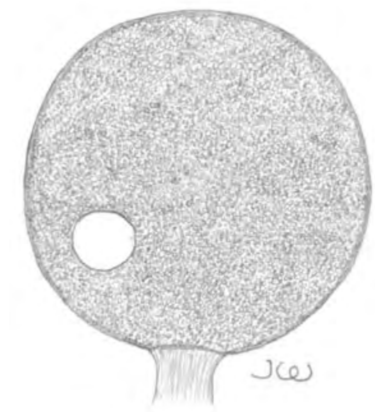


FIGURE 30-9.—Unfertilized egg, 1.2 mm diameter.

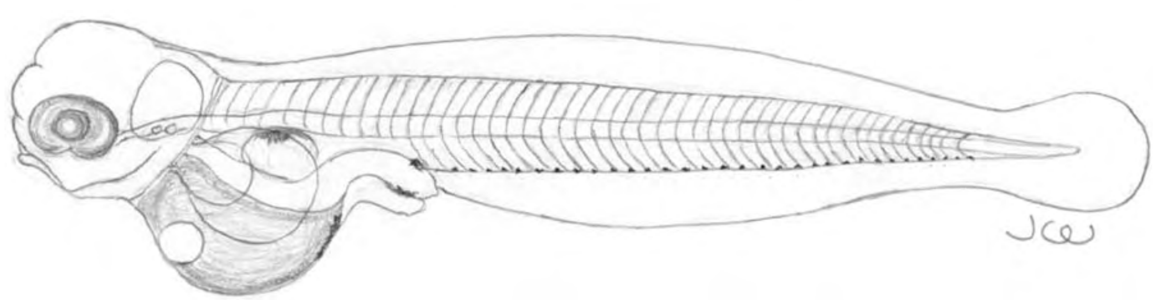


FIGURE 30-10.—Prolarva, 3.6 mm TL.

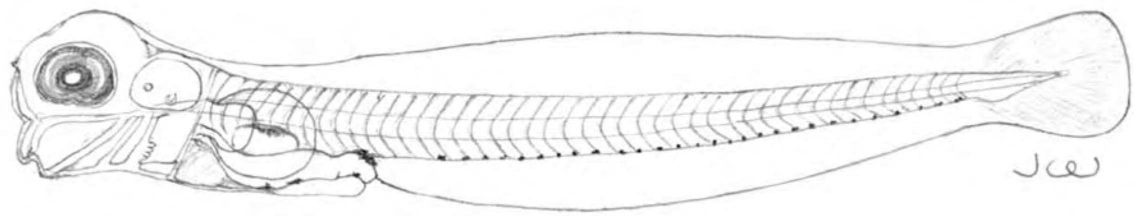


FIGURE 30-11.—Postlarva, 6 mm TL.

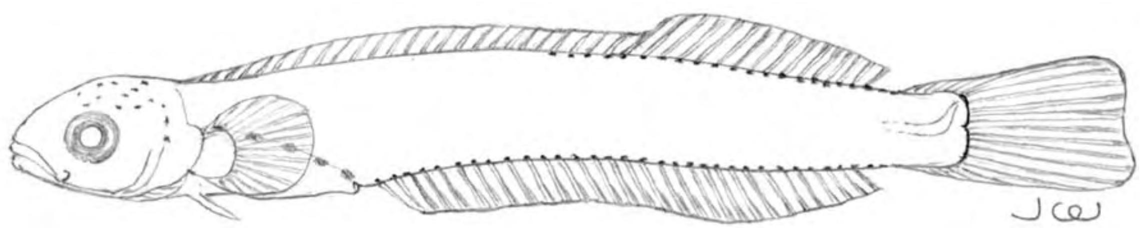


FIGURE 30-12.—Juvenile, 24.8 mm TL.

31. Stichaeidae – Pricklebacks

Pricklebacks are inshore and tidepool fishes and can be found in crevices of the rocky intertidal areas or among seaweeds. Five species of stichaeids have been reported in Tomales Bay (Bane and Bane 1971), nine species in Monterey Bay area (Kukowski 1972b), and at least three species in the Sacramento-San Joaquin Estuary:

	Area		
Species	**Sacramento-San Joaquin Estuary**	**Tomales Bay**	**Monterey Bay**
Stone cockscomb, *Alectrias alectrolophus*			x
High cockscomb, *Anoplarchus purpurescens*	x	x	x
Monkeyface prickleback, *Cebidichthys violaceus*	x	x	x
Mosshead warbonnet, *Chirolophis nugator*		x	x
Ribbon pricleback, *Phytichtys chirus*			x
Crisscross prickleback, *Plagiogrammus hopkinsi*			x
Bluebarred pricleback, *Plectobranchus evides*			x
Black prickleback, *Xiphister atropurpureus*	x(?)	x	x
Rock prickleback, *Xiphister mucosus*	x	x	x

Eldridge (1977) found two types of stichaeid larvae in Richardson Bay. In this study the larvae of high cockscomb, monkeyface prickleback, rock prickleback, and at least two types of Xiphister spp. were collected in the Sacramento-San Joaquin Estuary and adjacent waters.

References

Bane and Bane 1971, Eldridge 1977, Kukowski 1972b.

HIGH COCKSCOMB, *Anoplarchus purpurescens* (Gill)

SPAWNING

Location	Intertidal beaches (Schultz and DeLacy 1932); lower and mid-intertidal areas (Marliave 1975), such as Marconi Cove in Tomales Bay.

Season	February and March (Schultz and DeLacy 1932); February in British Columbia (Peppar 1965); January and February in British Columbia (Marliave 1975); mating in early spring (Bane and Bane 1971); January to March in San Francisco Bay and Tomales Bay.
Temperature	8°C (Schultz and DeLacy 1932); 11 °C when prolarvae were taken.
Salinity	Seawater.
Substrates	Pebble, stone, shell, and sand (Schultz and DeLacy 1932); boulders (Marliave 1975); rocky jetties.
Fecundity	828–3,022 for fish at 78–101 mm TL (Schultz and DeLacy 1932); egg masses having 2,001 to 3,183 eggs (Peppar 1965); 2,700 eggs in a single spawning act (Hart 1973).

CHARACTERISTICS

EGGS

Shape	Spherical.
Diameter	1.367–1.492 mm, with an average 1.441 mm (Schultz and DeLacy 1932); fertilized eggs average 1.372 mm (Peppar 1965); 1.4 mm (Marliave 1975).
Yolk	Lime green to white during early development, becoming silvery gray (Marliave 1975), eggs gray (Bane and Bane 1971).
Oil globule	Single, 0.326–0.409 mm in diameter, sometimes an additional small one; pale yellowish (Schultz and DeLacy 1932); oil globule yellowish (Bane and Bane 1971).
Perivitelline space	0.5 mm wide (Schultz and DeLacy 1932).
Egg mass	Deposited in clusters (Schultz and DeLacy 1932, Marliave 1975).
Buoyancy	Demersal.

LARVAE (Figures 31-1, 31-2, 31-3)

Length at hatching	7.4–7.6 mm TL (Peppar 1965); 7.5 mm TL (Peppar 1975).
Snout to anus length	40% of TL (Marliave 1975); 41–42 % in prolarvae at 7.2 mm TL to postlarvae at 13.1 mm TL.
Yolk sac	Oval (Peppar 1965); oval, thoracic.
Oil globule	Single oil droplet in anterior yolk sac (Peppar 1965).

Gut	Straight.
Air bladder	None (Marliave 1975).
Teeth	None on jaw for specimens of 10 mm TL.
Size at completion of yolk-sac stage	Ca. 8.0–8.5 mm TL (Peppar 1965).
Total myomeres	56–61.
Preanal myomeres	20–23.
Postanal myomeres	36–40.
Pigmentation	A pair of large melanophores on the antero-lateral surface of the yolk sac, a few along dorsal surface of the gut and anus; 10–14 along midventral region, and a row of ca. 36–47 small melanophores along postanal region (Peppar 1965); a pair of melanophores on the antero-lateral yolk sac, a series (ca. 13) of melanophores along midventral region and a series of melanophors (ca. 36) along postanal region; a few stellate melanophores scattered along the middorsum.
Distribution	Pelagic, mostly found in intertidal areas near jetties and rock coves.

JUVENILES (Figure 31-4)

Dorsal fin	LIV–LX (Peden 1966a,b,c, Miller and Lea 1972); LV–LVII (Hart 1973).
Anal fin	6–42 (Peden 1966a,b,c); I–II, 35–41 (Miller and Lea 1972); 39 or 40 (Hart 1973).
Mouth	Terminal, moderately large, oblique (Hart 1973).
Vertebrae	58–64 (Miller and Lea 1972); 58–61 (Hart 1973).
Distribution	Lower intertidal areas (Barton 1982); under larger boulders and rocks and in crevices of jetties.

LIFE HISTORY

The high cockscomb ranges from Santa Rosa Island, California, to the Pribilof Islands, Bering Sea (Miller and Lea 1972). This species is widely distributed in Canadian Pacific Coast intertidal zones (Hart 1973). In this study area, high cockscomb have been reported in Tomales Bay and Bodega Bay (Bane and Bane 1971). They were observed in the vicinity of Marconi Cove, Tomales Bay.

Spawning takes place in February and March along the Canadian Pacific coast (Schultz and DeLacy 1932, Peppar 1965, Marliave 1975) and from January to March in the San Francisco Bay area. During spawning, males exhibit sexual dimorphism, with bright orange to red coloration on their fins. Females deposit clustered eggs under boulders and rocks or on shells in the lower intertidal zone. Parental care is provided by the female (Schultz and DeLacy 1932, Peppar 1965), or by the male as well (Marliave 1975). Fish coil around the egg masses. Incubation is complete in 13 days at 10–12°C or 16 days at 7–9°C (Peppar 1965). Generally, eggs hatch in 3 weeks or less (Hart 1973).

Newly hatched larvae are generally 7.4–7.6 mm TL (Peppar 1965), and swim in the shallow intertidal areas (this study). High cockscomb larvae are often associated with the larvae of striped kelpfish, penpoint gunnel, tidepool sculpin, Pacific staghorn sculpin, and arrow goby. Peppar (1965) observed that high cockscomb become negatively phototactic and cease being planktonic after a few days. In the laboratory, however, fed larvae remained positively phototactic after 3 days of age and starved larvae concentrated in the shaded perimeter of the experimental tank (Marliave 1975).

Juveniles settle on the bottom of intertidal zones. The major food item for the early young (less than 30 mm TL) is copepods (Barraclough and Fulton 1968, Barraclough *et al.* 1968), the larger juveniles take green algae, amphipods, flatworms, and roundworms, mostly during daylight (Peppar 1965). The consumption of algae may be incidental, since the high cockscomb is a carnivorous fish (Barton 1982).

The high cockscomb matures at 2 or 3 years. Females show a slightly faster rate of growth than males and are generally larger (Peppar 1965). This species may reach 20 cm TL (Hart 1973), but most are less then 10 cm TL (Peppar 1965). The high cockscomb has no known sports value.

References

Bane and Bane 1971, Barraclough and Fulton 1968, Barton 1982, Hart 1973, Marliave 1975, Miller and Lea 1972, Peden 1966a,b,c, Peppar 1965, Schultz and DeLacy 1932.

MONKEYFACE PRICKLEBACK, *Cebidichthys violaceus* (Girard)

SPAWNING

Location	Crevices of rocky pools in bays or on outer coast (Fitch and Lavenberg 1971, Baxter 1974); intertidal rocky pools in Tomales Bay and Bodega Bay.
Season	Spring (Fitch and Lavenberg 1971); larvae were taken from January through May.
Temperature	Larvae were collected in water of 10 C.
Salinity	Larvae collected in seawater to polyhaline salinities.
Substrates	Rocks (Fitch and Lavenberg 1971, Baxter 1974).
Fecundity	Estimated 6,000–8,000 (Fitch and Lavenberg 1971, Baxter 1974).

CHARACTERISTICS

EGGS

Shape	Mature eggs are spherical.
Diameter	Ca. 2.7 mm (Fitch and Lavenberg 1971, Baxter 1974).
Egg mass	In ball or cluster (Fitch and Lavenberg 1971, Baxter 1974).
Adhesiveness	Adhesive, adhering to rocks (Fitch and Lavenberg 1971, Baxter 1974).
Buoyancy	Demersal.

LARVAE (Figure 31-5, 31-6)

Snout to anus length	Ca. 44–45% of TL of larvae at 7.5–8.0 mm TL.
Yolk sac	Oval to elongate, thoracic.
Oil globule	Single.
Gut	Straight or slightly wavy, with segmented structure.
Air bladder	None.
Size at completion of yolk-sac stage	Ca. 8.0 mm TL.
Total myomeres	68–72.
Preanal myomeres	24–29.
Postanal myomeres	42–44.
Pigmentation	Stellate melanophores scattered (in one row) on midventral dorsal surface of gut and anal regions; dotted melanophores on postanal region and a wide speckled band near caudal peduncle.
Distribution	Pelagic, found in San Francisco Bay near Angel Island, Potrero Powerplant, and in Horseshoe Cove.

JUVENILES (Figure 31-7)

Dorsal fin	XXII–XXV, 40–43 (Miller and Lea 1972).
Anal fin	I–II, 39–42 (Miller and Lea 1972).
Pectoral fin	10–11.
Mouth	Terminal, thick lips.
Vertebrae	65–71 (Miller and Lea 1972).
Distribution	Intertidal areas near bottom.

LIFE HISTORY

The monkeyface prickleback was reported to range from San Quintin Bay, Baja California, to Crescent City, California (Miller and Lea 1972). Recently the northern range was extended to Harris Beach State Park, Oregon (Barton 1978). Locally they have been reported from the Golden Gate Bridge to Shell Beach (Baxter 1974), Dillon Beach, and Bodega Head (Bane and Bane 1971, Baxter 1974).

Spawning occurs in spring (Fitch and Lavenberg 1971) or from March to May (Baxter 1974). Judging by the larvae taken in the San Francisco Bay area, spawning occurs from January to May. Eggs are adhesive and are laid in the form of a ball with an estimated 6,000–8,000 eggs in the cluster. They are tended by a parent, presumably the female (Schultz and DeLacy 1932, Fitch and Lavenberg 1971), which guards the mass by coiling around it (Bane and Bane 1971).

Monkeyface prickleback larvae are pelagic and have been observed in the vicinity of Golden Gate Bridge and Potrero Powerplant, San Francisco Bay. Descriptions of the larval stages of this species in the literature are limited, and therefore the larval identification is tentative. Monkeyface prickleback larvae have an elongated body similar to those of the high cockscomb and rock gunnel (Marliave 1975); however, the monkeyface prickleback larvae have a large dark blotch in front of the caudal penduncle.

Juveniles about 3 inches (75 mm) TL are found in kelp beds and rocky intertidal areas (Fitch and Lavenberg 1971). Small (<80 mm) monkeyface prickleback feed primarily on amphipods, while the larger ones (>80 mm) feed mostly on algae (Barton 1982). Feeding behavior changes from carnivorous to herbivorous as the fish increases in size (Montgomery 1977).

Monkeyface prickleback mature at 3–4 years (Fitch and Lavenberg 1971). Adults have a large fleshy lump on the tops of their heads (Fitch and Lavenberg 1971).

There is no commercial fishery for monkeyface priclebacks, but there is a poke-pole sport fishery during ebb tide in crevices of breakwaters and rocky intertidal areas (Fitch and Lavenberg 1971, Baxter 1974).

References

Bane and Bane 1971, Barton 1978, 1982, Baxter 1974, Fitch and Lavenberg 1971, Marliave 1975, Miller and Lea 1972, Montgomery 1977, Schultz and DeLacy 1932.

ROCK PRICKLEBACK, *Xiphister mucosus* (Girard)

SPAWNING

Location	Under boulders of lower intertidal zones (Marliave 1975, Marliave and DeMartini 1977).

Season	Larvae were collected from January through March.
Temperature	Larvae were collected at 13.8–14.0°C.
Salinity	Seawater to polyhaline where larvae were collected.
Substrates	Boulders, pebbles, and shells (Marliave 1975).
Fecundity	2,000–15,000 (Marliave 1975), average 7,276 eggs in ripe females (Marliave and DeMartini 1977).

CHARACTERISTICS

EGGS

Shape	Mature eggs, spherical.
Diameter	Ca. 2.5 mm (Marliave 1975).
Yolk	Mature eggs, pale yellow to white.
Oil globule	Many small oil globules in mature eggs.
Chorion	Mature eggs have 2 layers: outer layer has a viscous substance, the inner layer smooth.
Egg mass	In clusters.
Adhesiveness	Adhesive (Fitch and Lavenberg 1975).
Buoyancy	Demersal.

LARVAE (Figure 31-8, 31-9)

Length at hatching	11 mm TL (Marliave 1975).
Snout to anus length	43–45% of TL of prolarvae at 10.0 TL to postlarvae at 13.2 TL.
Yolk sac	Spherical.
Oil globule	Single, 0.3–0.4 mm in diameter, in anterior of yolk sac.
Gut	Straight.
Air bladder	None.
Teeth	None for prolarvae at 10.0–10.8 mm TL; a few pointed teeth in postlarvae (ca. 13 mm TL).
Total myomeres	80–83.
Preanal myomeres	30–33.
Postanal myomeres	47–53.
Pigmentation	For both *X. mucosus* and *X. atropurureus*, ca. 7 pairs of melanophores on dorsal surface of gut, 12 small melanophores on dorsal tail musculature and 25 melanophores on the ventral tail musculature (Marliave 1975). In this study a pair of large

	melanophores in thoracic region between pectorals. Ca. 7–11 pairs of melanophores along dorsal surface of gut and anus; a series of melanophores (25–30) on postanal region (Marliave 1975).
Distribution	Pelagic (Marliave 1975); pelagic larvae were taken near the Potrero Powerplant and in Horseshoe Cove of San Francisco Bay, at Moss Landing Powerplant of Moss Landing Harbor, and near Marconi Cove of Tomales Bay.

JUVENILES (Figure 31-10)

Dorsal fin	LXXI–LXXVIII (Miller and Lea 1972); LXXI–LXXVII (Hart 1973).
Anal fin	I, 46–50 (Miller and Lea 1972); 40–52 (Hart 1973).
Pectoral fin	12 (Miller and Lea 1972).
Mouth	Terminal, large (Hart 1973).
Vertebrae	3–83 (Miller and Lea 1972).
Distribution	Juveniles school inshore in kelp beds or rocky intertidal areas (Marliave 1975); in small pools high in the intertidal zone (Barton 1982).

LIFE HISTORY

The distribution of the rock prickleback is from Pt. Arguello Boat Station, California, to Port San Juan, Alaska (Clemens and Wilby 1961, Miller and Lea 1972, Hart 1973). This species has been reported in Monterey Bay (Kukowski 1972b) and in Tomales Bay (Bane and Bane 1971).

Spawning takes place from winter to summer on the British Columbia coast (Marliave 1975). In this study area, judging from the larvae taken, peak spawning is the winter months. Two types of stichaeid larvae were observed in Richardson Bay (Eldridge 1977); they may be rock and black prickleback (*X. atropuxpureus*), since these two species occur sympatrically in the study area. Larvae were collected in San Francisco Bay, and some spawning in the Bay was assumed. Eggs area usually found under boulders in the intertidal areas, and are tended by male fish, who wrap themselves around the egg masses. However, the rock prickleback exhibits no territorial behavior during incubation (Marliave and DeMartini 1977). Each egg mass contains the entire annual output of ova of a female. The male may mate with different females during the season (Marliave and DeMartini 1977).

Larvae are pelagic (Marliave 1975, this study). In this study, larvae were observed in the open water in the vicinity of the Potrero Powerplant on San Francisco Bay and also in Marconi Cove of Tomales Bay, in the shallow cove, they were seen swimming with penpoint gunnel (*Apodichthys flavidus*) and striped kelpfish (*Gibbonsia metzi*) on many occasions.

Juveniles of rock prickleback are found intertidally (Ricketts *et al.* 1968, Wourms and Evans 1974). They school in the kelp beds and rocky areas before settling on the bottom (Bane and Bane 1971, Marliave 1975). They are also found in small pools high in the intertidal zone (Barton 1982). Major food sources of juvenile rock prickleback are algae (Bane and Bane 1971) and other vegetation (Barton 1982).

Rock prickleback mature at 5 years (Fitch and Lavenberg 1975). Female fish are generally larger than males, and may live longer (Fitch and Lavenberg 1975, Marliave and DeMartini 1977). The adult rock prickleback is of some interest to the sport fisherman who fish in the intertidal zone (T. Keegan 1980, personal communication).

References

Bane and Bane 1971; Barton 1982; Clemens and Wilby 1961; Eldridge 1977; Fitch and Lavenberg 1975; Hart 1973; Keegan 1980, personal communication; Kukowski 1972b; Marliave 1975; Marliave and DeMartini 1977; Miller and Lea 1972; Ricketts *et al.* 1968, Wourms and Evans 1974.

PRICKLEBACKS, *Xiphister* spp.

SPAWNING

Location	Probably in coastal or bay intertidal areas.
Season	Larvae were collected from January through March.
Salinity	Larvae were collected from seawater through mesohaline.

CHARACTERISTICS

LARVAE

Snout to anus length	Ca. 43–47% of TL of larvae at 6.6–9.0 mm TL.
Oil globule	Single, ca. 0.25–0.3 mm in diameter.
Gut	Straight.
Total myomeres	72–78.
Preanal myomeres	26–30.
Postanal myomeres	45–50.
Pigmentation	The pigmentation patterns of Xiphister spp. larvae are very similar to both those of X. atropurpureus and X. mucosus larvae as described by Marliave (1975).
Distribution	Pelagic, in San Francisco Bay, Moss Landing Harbor, and Tomales Bay.

LIFE HISTORY *(Note on Xiphister spp. larvae)*

The black prickleback and rock prickleback occur sympatrically in the study area (Miller and Lea 1972). Morphologically, the pigmentation of both species are almost identical (Marliave 1975), and the vertebra counts of these two species overlap (Miller and Lea 1972). Thus, an accurate separation of larvae of these two species, particularly in the lower myomere ranges, could not be done.

References

Marliave 1975, Miller and Lea 1972.

Characteristic Comparison: Pricklebacks

Characteristic	High Cockscomb	Monkeyface Prickleback	Rock Prickleback
Spawning			
Location	Intertidal	Intertidal	Intertidaal
Season	January–March	January–May	January–March
Eggs			
Diameter(mm)	Ca. 1.3–1.5	Ca. 2.7	Ca. 2.5
Oil globule	Single, yellowish	Single	Mature eggs: many small
Larvae			
Length of hatch (mm)	7.4–7.6	–	11
Total myomers	56–61	68–72	80–83
Preanal myomeres	20–23	24–29	30–33
Postanal myomers	36–40	42–44	47–53
Pigmentation	Pair of large melanophores on antero-lateral surface of yolk sac; a few on dorsal surface of gut and anus; 10–14 along midventral region; a row of ca. 36 small melanophores in postanal region	Stellate melanophores scattered on midventral, dorsal surfaces of gut and anal regions; dotted melanophores on postanal region; a wide speckled band near caudal peduncle	7–11 pairs of melanophores on dorsal surface of gut; 12 small melanophores on dorsal tail musculature, 25–30 melanophores on ventral tail musculatore
Juveniles			
Dorsal fin	LIV–LX	XXIII–XXV, 40–43	LXXI—LXXVIII
Anal fin	I-II, 35–41	I–II, 39–42	I, 46–50
Distinguishing	Fleshy crest on head, dorsal fin all spiny	Lateral line just below dorsal fins, which as spines and soft rays	Dorsal fin all spiny, one large anal spine.

Figure 31.—Stichaeidae: *Anoplarchus purpurescens*, high cockcomb.

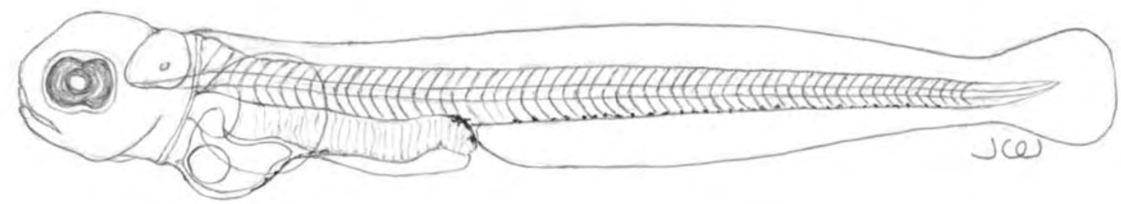


FIGURE 31-1.—Prolarva, 7 mm TL.

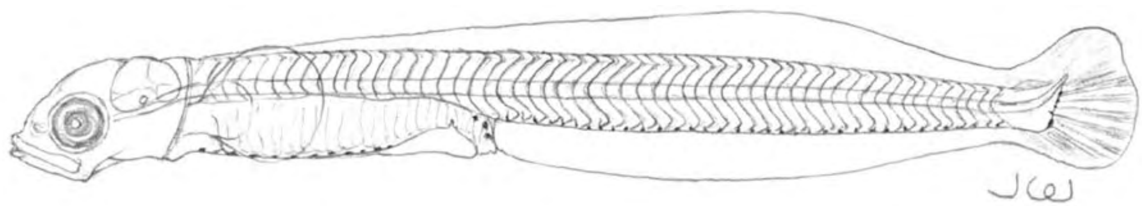


FIGURE 31-2.—Postlarva, 12.1 mm TL.

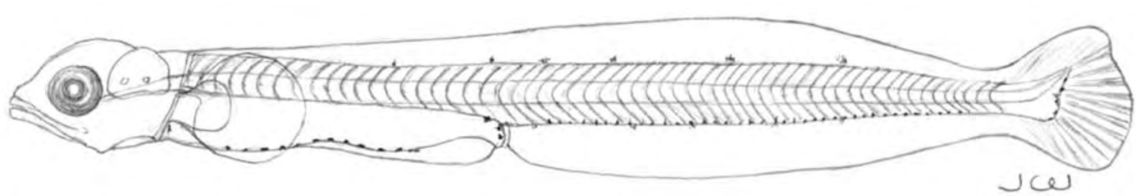


FIGURE 31-3.—Postlarva, 12.3 mm TL.

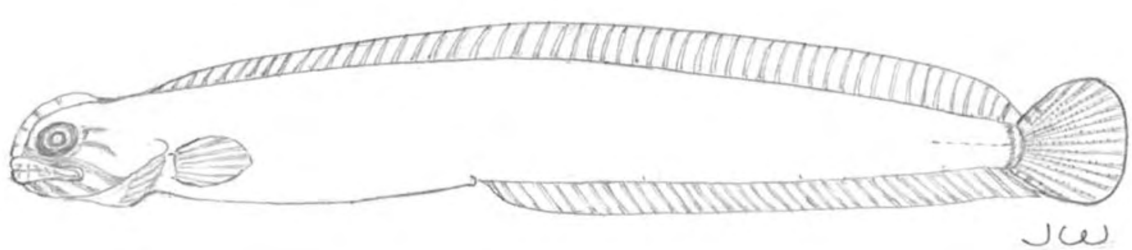


FIGURE 31-4.—Juvenile, 58 mm TL.

Stichaeidae: *Cebidichthys violaceous*, monkeyface prickleback.

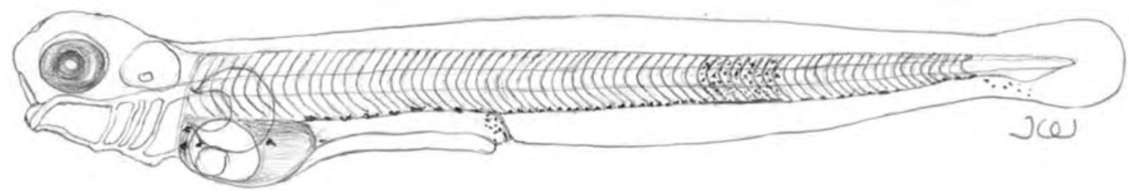


FIGURE 31-5.—Prolarva, 8.1 mm TL.

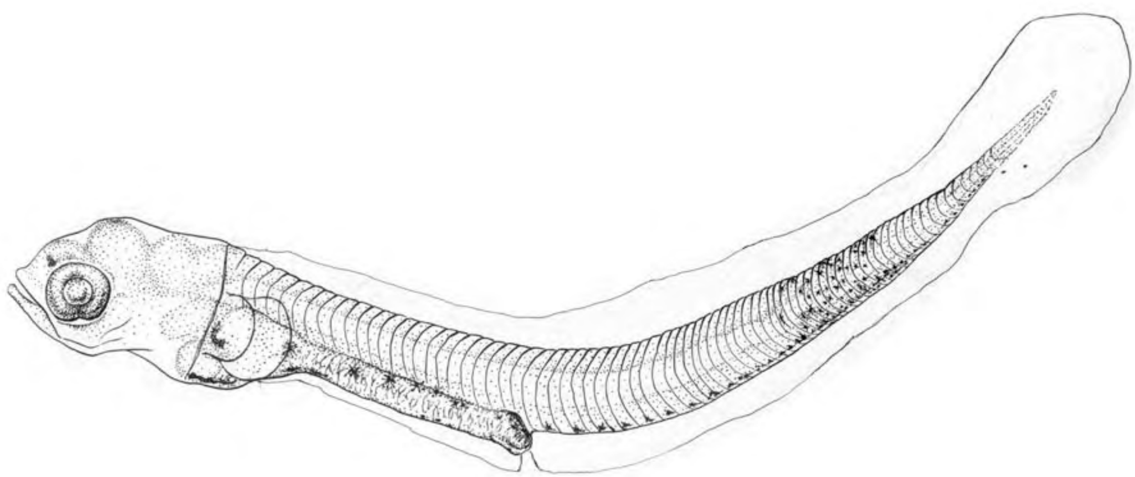


FIGURE 31-6.—Postlarva, 6.9 mm TL.

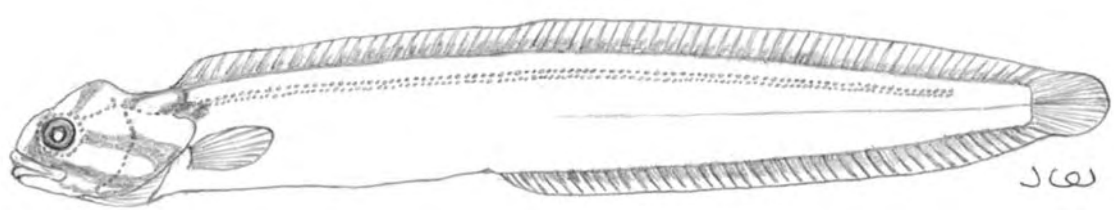


FIGURE 31-7. Juvenile, 126 mm TL.

Stichaeidae: *Xiphister mucosus*, rock prickleback.

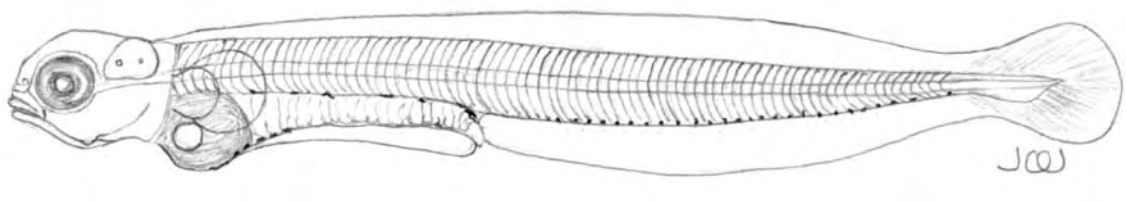


FIGURE 31-8.—Prolarva, 10.6 mm TL.

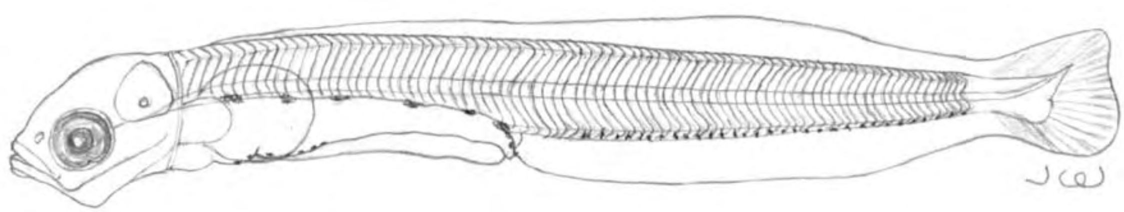


FIGURE 31-9.—Postlarva, 13.2 mm TL.

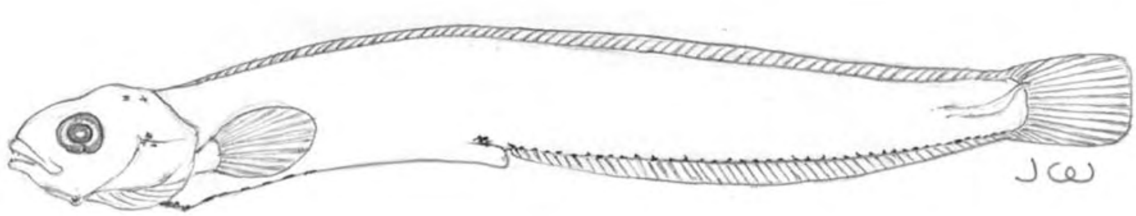


FIGURE 31-10.—Juvenile, 19.8 mm TL.

32. Pholidae – Gunnels

Nine species of gunnels are found along the Pacific coast of the United States and Canada (Robins *et al.* 1980). Three of them were observed in this study: the penpoint gunnel, *Apodichthys flavidus*, the saddleback gunnel, *Pholis ornata*, and the rockweed gunnel, *Xererpes fucorum*. According to Miller and Lea (1972), the San Francisco Bay area is within the range of distribution of the red gunnel, *Pholis schultzi*. However, this species was not found in this study nor by other investigators. On the basis of availability of specimens, only the penpoint gunnel is discussed in this chapter.

The body of a gunnel is compressed and elongated like an eel. The dorsal fin is completely spiny, as in the pricklebacks, but the anus of the gunnels extends midway or more than 50% of TL. In the majority of pricklebacks the anus is located at less than 50 % of TL (Marliave 1975).

References

Robins *et al.* 1980, Marliave 1975, Miller and Lea 1972).

PENPOINT GUNNEL, *Apodichthys flavidus* (Girard)

SPAWNING

Location	Inshore rocky areas (lower intertidal and subtidal) within vegetated areas along the coast, estuaries or inlets (Clemens and Wilby 1961, Wilkie 1966, Marliave 1975).
Season	January (Clemens and Wilby 1961); December to March (Wilkie 1966); April (Marliave 1975); January and February.
Temperature	Larvae were collected at 9.5–11.2°C.
Salinity	Seawater to mesohaline (Wilkie 1966).
Substrates	Rocks (Clemens and Wilby 1961, Wilkie 1966).

CHARACTERISTICS

EGGS

Shape	Spherical.
Diameter	3.0 mm (Marliave 1975).
Yolk	Whitish (Wilkie 1966, Bane and Bane 1971)
Chorion	Transparent.

Egg mass	Deposited is clusters (Wilkie 1966, Bane and Bane 1971).
Adhesiveness	Adhesive.
Buoyancy	Demersal.

LARVAE (Figure 32-1, 32-2)

Length at hatching	13 mm TL (Wilkie 1966, Marliave 1975).
Snout to anus length	Ca. 60% of TL of larvae at 13.2–13.8 mm TL.
Gut	Straight, thick, with segment-like structure.
Teeth	Sharp, pointed, apparent in postlarvae.
Total myomeres	95–100.
Preanal myomeres	51–57.
Postanal myomeres	41–46.
Pigmentation	Ca. 10 large melanophores along dorsal surface of gut and anus; melanophores also along postanal and dorsum near caudal region (Wilkie 1966, Marliave 1975); ventral surface of gut has a row of small melanophores (Marliave 1975); in this study, 2 large melanophores were found in thoracic area between pectoral fins; a series of small melanophores along the midventral region; and 3 pairs of large stellate melanophores along the postanal region and the dorsum near the caudal region.
Distribution	Pelagic, along coastal waters and bays (Richardson and Pearcy 1977), Horseshoe Cove and vicinity of Potrero Powerplant on San Francisco Bay, Marconi Cove of Tomales Bay.

JUVENILES (Figure 32-3)

Dorsal fin	XC–XCIV (Miller and Lea 1972).
Anal fin	I, 36–42 (Miller and Lea 1972); I, 38–42 (Hart 1973).
Pectoral fin	Ca. 14 (Hart 1973); 15–16.
Mouth	Terminal, small, with thick lips (Hart 1973).
Vertebrae	96–101 (Miller and Lea 1972).
Distribution	In coastal or bay water blending with vegetation such as *Sargassum* spp., *Ulva* spp., and *Zostera* spp., settling on the bottom at ca. 25 mm TL (Wilkie 1966).

LIFE HISTORY

The penpoint gunnel has been found from Santa Barbara Island, California, to Kodiak Island, Alaska (Wilimovsky 1954, Hubbard and Reeder 1955, Clemens and Wilby 1961). This species is reported to be common in Tomales Bay (Bane and Bane 1971) and Bodega Bay (Standing *et al.* 1975). In this study, the species was collected in Horseshoe Cove and the vicinity of the Portrero Powerplant, San Francisco Bay, and in Marconi Cove, Tomales Bay.

In British Columbia estuaries, spawning of the penpoint gunnel takes place from December through March (Wilkie 1966); locally it is from December to as late as April (Marliave 1975). Larval pholidae were collected in Richardson Bay in winter by Eldridge (1977). Judging from the time larvae were taken in this study, the penpoint gunnel breeds in January and February in San Francisco Bay and Tomales Bay.

Eggs are spherical, whitish, and in clusters. The egg mass is coiled around by one or both parents (Clemens and Wilby 1961, Wilkie 1966). The incubation period is about 2-½ months (Wilkie 1966).

Newly hatched larvae average about 13 mm TL, and the body is transparent and positively photoactic (Wilkie 1966). Pelagic larvae were reported between 2 and 28 km offshore outside of Yaquina Bay, Oregon (Richardson and Pearcy 1977). In this study, the larvae were observed in San Francisco Bay and Tomales Bay.

Juveniles about 25 mm TL started to settle on the bottom where algae such as *Sargassum* spp., *Ulva* spp., and *Zostera* spp. are abundant. Coloration of juveniles varies, so that they blend in with their surroundings (Wilkie 1966). He also reported that juvenile gunnels are more active during daytime than night. Primary food items include small crustaceans (Bane and Bane 1971) and mollusks (Hart 1973).

The age of maturity of the penpoint gunnel has not been documented in the literature. This species has no commercial value, but is often captured incidentally by sport fishermen.

References

Bane and Bane 1971, Clemens and Wilby 1961, Eldridge 1977, Hart 1973, Hubbard and Reeder 1955, Marliave 1975, Miller and Lea 1972, Richardson and Pearcy 1977, Standing *et al.* 1975, Wilkie 1966, Wilimovsky 1954.

Figure 32.—Pholidae: *Apodichthys flavidus*, penpoint gunnel.

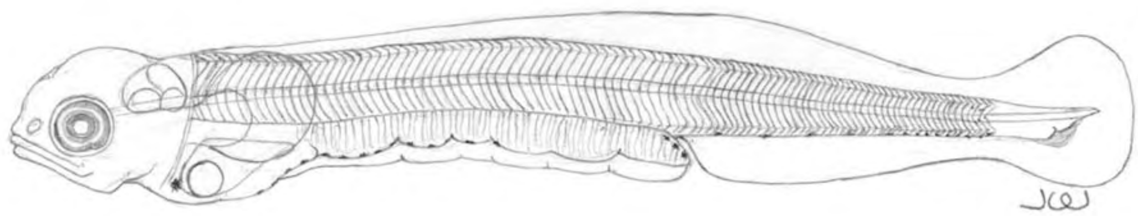


FIGURE 32-1—Prolarva, 12.3 mm TL.

FIGURE 32-2.—Postlarva, 24.4 mm TL.

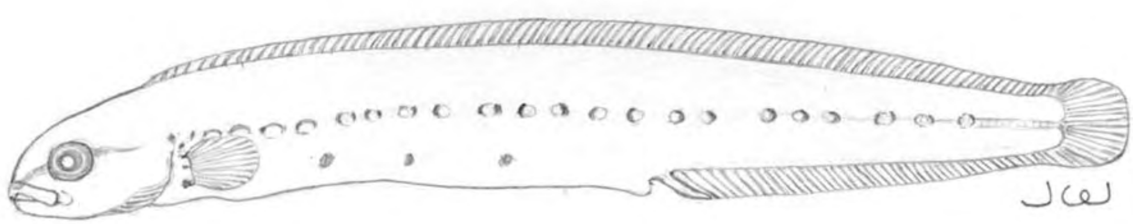


FIGURE 32-3.—Juvenile, 46 mm TL.

33. Ammodytidae – Sand Lances

Three species of sand lances are known to the North America (Robins *et al.* 1980): the American sand lance, *Ammodytes americanus*, the northern sand lance, *Ammodytes dubius*, and the Pacific sand lance, *Ammodytes hexapterus*. The Pacific sand lance is discussed in this chapter.

References

Robins *et al.* 1980.

PACIFIC SAND LANCE, *Ammodytes hexapterus* (Pallas)

SPAWNING

Location	Shallow water (Fitch and Lavenberg 1975); Richardson Bay (Eldridge 1977); Moss Landing Harbor-Elkhorn Slough (Nybakken *et al.* 1977); shallow intertidal with sandy bottoms of San Francisco Bay, Tomales Bay, and Moss Landing Harbor-Elkhorn Slough.
Season	November to March (Fitch and Lavenberg 1975); larvae collected from February to April along the Oregon coast (Richardson and Pearcy 1977); in February in Richardson Bay (Eldridge 1977); February and March in Moss Landing Harbor-Elkhorn Slough (Nybakken *et al.* 1977); from December to March in Tomales Bay.
Temperature	Ca. 1.7–8.0°C (Williams *et al.* 1964); ca. 8.0–15.0°C.
Salinity	Seawater to mesohaline.
Substrate	Sandy bottom or jetty and rocky shore with sandy beach nearby.

CHARACTERISTICS

EGGS

Shape	Spherical to irregular (Williams *et al.* 1964).
Diameter	0.67–0.91 mm (Williams *et al.* 1964).
Yolk	Dull yellow, opaque (Williams *et al.* 1964).
Oil globule	0–3 oil globules; oil globule ca. 0.17–0.33 mm in diameter (Williams *et al.* 1964).

Chorion	Transparent (Williams *et al.* 1964).
Perivitelline space	Narrow (Williams *et al.* 1964).
Egg mass	It is assumed that eggs are broadcast singly into the water column.
Adhesiveness	Slightly adhesive (Williams *et al.* 1964).
Buoyancy	Demersal (Williams *et al.* 1964).

LARVAE (Figure 33-1, 33-2, 33-3)

Length at hatching	Ca. 4.3 mm TL (Williams *et al.* 1964); ca. 4.0–5.0 mm TL.
Snout to anus length	Ca. 60–64% of TL of prolarvae and postlarvae; anus slightly posterior to the middle of TL (Kobayashi 1961).
Yolk sac	Oval to flat, small, in the thoracic region.
Oil globule	Mostly single, located in middle to posterior portion of yolk sac.
Gut	Straight.
Air bladder	None.
Teeth	None at this stage.
Size at completion of yolk-sac stage	Ca. 5.0–5.5 mm TL.
Total myomeres	63–68; 70–71 (Kobayashi 1961).
Preanal myomeres	36–42.
Pigmentation	In prolarvae, dashed melanophores on thoracic region and a single large melanophores on the dorsal portion of anus; a series of melanophores on the dorsal surface of gut and postanal regions. In postlarvae, more pigmentation is in hypleural region; pigments on upper margin of intestine and base of anal fin (Kobayashi 1961).
Distribution	Pelagic, in shallow as well as open waters of the Sacramento-San Joaquin Estuary, Tomales Bay, and Moss Landing Harbor-Elkhorn Slough, along coastal waters of Oregon (Richardson and Pearcy 1977).

JUVENILES (Figure 33-4)

Dorsal fin	54–59 (Miller and Lea 1972, Hart 1973); 56 (Kobayashi 1961).
Anal fin	24–30 (Miller and Lea 1972, Hart 1973); 30 (Kobayashi 1961).

Pectoral fin	Ca. (Hart 1973); 13 (Kobayashi 1961).
Mouth	Terminal, moderate in size, directed forward and up (Hart 1973); terminal and projecting.
Vertebrae	65–70 (Miller and Lea 1972); 64–74 (Kobayashi 1961).
Distribution	Intertidal and offshore (Fitch and Lavenberg 1975); coastal waters, bays, estuaries.

LIFE HISTORY

The Pacific sand lance has been reported to be distributed from Balboa Island, Baja California, to Alaska, the Bering Sea, and the Sea of Japan (Kobayashi 1961, Miller and Lea 1972, Hart 1973). This species is also found in Arctic waters, Hudson Bay, the northwest Atlantic Ocean, and in Europe (Leim and Scott 1966, Richards *et al.* 1963). In the study area, Pacific sand lance have been reported in San Francisco Bay (Aplin 1967). Larvae were taken in Richardson Bay (Eldridge 1977) and San Francisco Bay (M. Hearne 1979, personal communication). They were also observed in Moss Landing Harbor-Elkhorn Slough (Nybakken *et al.* 1977). The species was collected in San Francisco Bay, Tomales Bay, and Moss Landing Harbor-Elkhorn Slough.

Judging from the location (such as the vicinity of Marconi Cove, Tomales Bay) of the prolarvae taken, the spawning of the Pacific sand lance takes place within bays and estuaries. The breeding season falls in the period December–March.

Eggs are demersal, but will suspend in turbulent waters (Williams *et al.* 1964). A similar characteristic has been observed for the American sand lance, *Ammodytes americanus*, in mid-Atlantic estuaries (Wang and Kernehan 1979).

The identification of the early life stages of the sand lances is still in question (Fritzsche 1978). However, the description of the eggs and larvae of the Pacific sand lance from Long Island Sound seemed to be correct, since the eggs of Pacific sand lance are smaller in diameter (0.67–0.91 mm), (Williams *et al.* 1964) than American sand lance eggs (ca. 1.20–1.26 mm in diameter, Wang and Kernehan 1979).

Newly hatched larvae were taken from seawater to mesohaline salinities in the estuary. They were taken in good numbers (20–25) per collection, indicating that the larvae swim in schools. Fitch and Lavenberg (1975) described larvae of the Pacific sand lance in intertidal zones as well as offshore. Kobayashi (1961) collected the larvae and early juveniles of this species in surface waters in the Sea of Okhotsk and the Bering Sea.

Early juvenile stages are still pelagic, the adult burrowing behavior is gradually developed (Hart 1973). Major food items of the juvenile sand lance include copepods, other small crustaceans, and eggs of many forms (Hart 1973, Fitch and Lavenberg 1975).

The age at maturity of the Pacific sand lance is not well documented in the literature. This species is commonly preyed upon by lingcod, chinook salmon, halibut, fur seals, and other marine animals (Hart 1973), and thus appears to be an important forage species.

References

Aplin 1967; Eldridge 1977; Fitch and Lavenburg 1975; Fritzsche 1978; Hart 1973; Hearne 1979, personal communication; Kobayashi 1961; Leim and Scott 1966; Miller and Lea 1972; Nybakken *et al.* 1977; Richards *et al.* 1963; Richardson and Pearcy 1977; Wang and Kernehan 1979; Williams *et al.* 1964.

Figure 33.—Ammodytidae: *Ammodytes hexapterus*, Pacific sandlance.

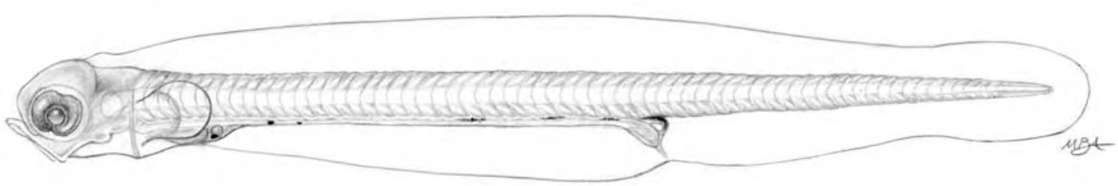


FIGURE 33-1.—Prolarva 5.3 mm TL.

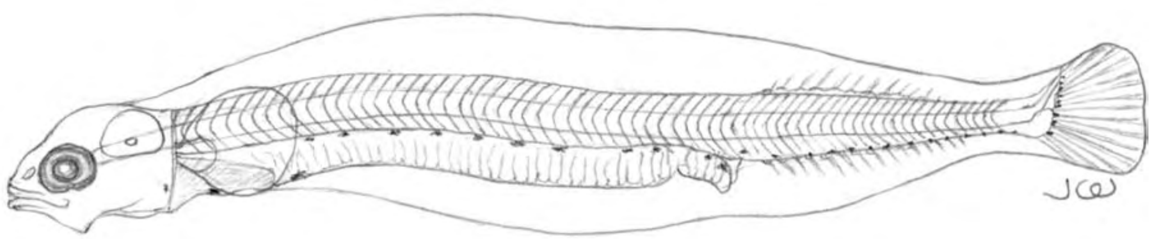


FIGURE 33-2.—Postlarva, 12.1 mm TL.

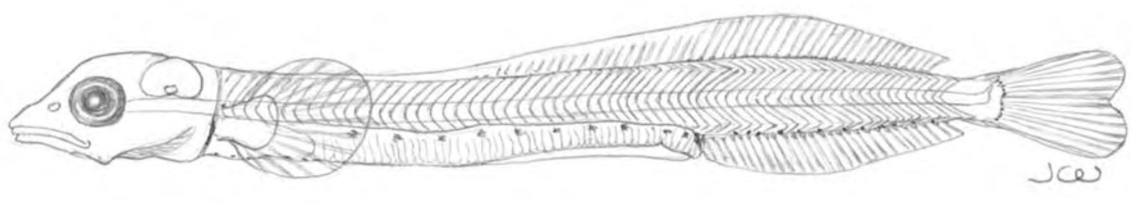


FIGURE 33-3.—Postlarva, 19.4 mm TL.

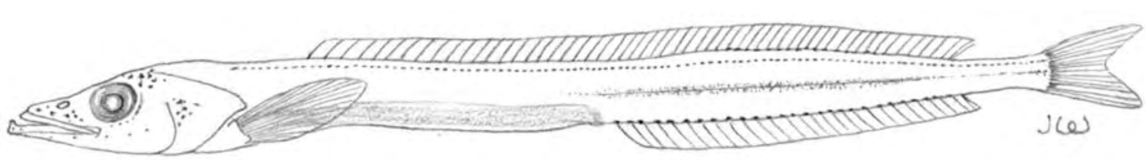


FIGURE 33-4.—Juvenile, 50 mm TL.

34. Gobiidae – Gobies

There are eight species of gobies inhabiting the Sacramento-San Joaquin Estuary (MacDonald 1972b, Miller and Lea 1972). Of these eight species, six are native and two are introduced:

Species	Origin	Habitat
Yellowfin goby, *Acanthogobius flavimanus*	Introduced	Bays, Delta – euryhaline
Arrow goby, *Clevelandia ios*	Native	Bays – euryhaline
Blackeye goby, *Coryphopterus nicholsi*	Native	Coastal waters, bays – seawater-oligohaline
Tidewater goby, *Eucyclogobius newberryi*	Native	Lagoons, coastal streams – euryhaline
Longjaw mudsucker, *Gillichthys mirabilis*	Native	Bays, tidal sloughs – euryhaline
Cheekspot goby, *Ilypnus gilberti*	Native	Bays – seawater-oligohaline
Bay goby, *Lepidogobius lepidus*	Native	Bays – seawater-oligohaline
Chameleon goby, *Tridentiger trigonocephalus*	Introduced	Bays – seawater-mesohaline

The arrow goby is the most abundant native goby in this estuary. The blackeye goby mostly inhabits coastal reefs, and occasionally enters bays. The tidewater goby is rare and is currently found only in Rodeo Lagoon and possible a few coastal streams in Marin County. The longjaw mudsucker is most common in south San Francisco Bay, but it is also found in San Pablo Bay. The Cheekspot goby is sparsely distributed in San Pablo Bay and central and south San Francisco Bay, and the bay goby is common in the higher salinity bays of this estuary. In the 1950s, the yellowfin goby and chameleon goby were accidentally introduced through the ballast systems of ships traveling from Asia into San Francisco Bay and Los Angeles Harbor (Brittan *et al.* 1963, 1970; Hubbs and Miller 1965; MacDonald 1975; Haaker 1979). The yellowfin goby has been very successful in expanding its range throughout the estuary and some of the associated inland waterway systems (Moyle 1976). The chameleon goby, a poorly described species, is mostly found in south San Francisco Bay.

Goby larvae are generally pelagic and disperse throughout the seawater-oligohaline waters of the estuary. The exception is tidewater goby larvae, which are also found in freshwater. Sample collections from the estuary usually contain large numbers of larvae, but few juvenile and adult fish, because of the burrowing behavior of the older animals. In juvenile and adult goby, the pelvic fins are fused, and they are used to cling to rocks and other firm substrates to hold position during strong tides and currents. When swimming, goby make short dashes, using jerky movements.

The longjaw mudsucker and yellowfin goby are often used as bait fish by sport fishermen, and larval and juvenile goby are important in the food chain as forage for predators.

All eight species of goby are discussed in this chapter.

References

Brittan *et al.* 1963; Brittan *et al.* 1970; Haaker 1979; Hubbs and Miller 1965; MacDonald 1972b, 1975; Miller and Lea 1972; Moyle 1976.

YELLOWFIN GOBY, *Acanthogobius flavimanus* (Temminck and Schlegel)

SPAWNING

Location	Tidal mudflats of coast and estuary (Miyazaki 1940, Dotsu and Mito 1955); tidal flats of south and central San Francisco Bay, San Pablo Bay; these and Tomales Bay, Elkhorn Slough and Moss Landing Harbor.
Season	February through May in Japan (Miyazaki 1940); January through March in Kyushu, Japan (Dotsu and Mito 1955); larvae collected from December through July.
Temperature	7.5–13˚C (Dotsu and Mito 1955); ca. 10–15 when prolarvae were collected.
Salinity	Seawater to mesohaline.
Substrates	Hollow bamboo segments (Miyazaki 1940); sand, mud, and ceramic tubes (Dotsu and Mito 1955); mostly in sand and mud bottoms.
Fecundity	6,000–32,000 (Miyazaki 1940); 18,000 for a single female 156 mm TL.

CHARACTERISTICS

EGGS

Shape	Spherical for mature eggs, teardrop or club-shaped for fertilized eggs (Dotsu and Mito 1955).
Diameter	5.0–5.8 mm in long axis; 0.9–1.0 mm (average of 0.96 mm) in short axis (Dotsu and Mito 1955).
Yolk	Yellowish, granular.
Oil globule	Many oil globules in early embryo stage; consolidated into one in late embryo stage (Dotsu and Mito 1955).
Chorion	Transparent, smooth, thick and elastic (Dotsu and Mito 1955).
Perivitelline space	Very wide in long axis and narrow in short axis in early developmental stages (Dotsu and Mito 1955).

Egg mass	Deposited on roof or wall of breeding chamber, in single layers; may be very dense per unit area (Dotsu and Mito 1955).
Adhesiveness	Adhesive at anchoring point with short filaments (Dotsu and Mito 1955).
Buoyancy	Demersal; attached to substrate (Dotsu and Mito 1955).

LARVAE (Figures 34-1, 34-2, 34-3, 34-4)

Length at hatching	4.6–5.0 mm TL (Dotsu and Mito 1955); 4.4 mm TL.
Snout to anus length	46–48% of TL of prolarvae and postlarvae.
Yolk sac	Spherical, in thoracic region.
Oil globule	Single oil globule in anterior yolk sac (Dotsu and Mito 1955).
Gut	Straight.
Air bladder	Small, oval, just to rear of pectorals in prolarvae; large, oval, midway between pectorals and anus in postlarve.
Teeth	Small, pointed in postlarve.
Size at completion of yolk-sac stage	Ca. 5.0 mm TL; 5.0–5.5 mm.
Total myomeres	32 (Dotsu and Mito 1955); 31–33.
Preanal myomeres	14 (Dotsu and Mito 1955); 13–14.
Postanal myomeres	18 (Dotsu and Mito1955); 18–19.
Last fin(s) to complete development	Fused pelvic fin.
Pigmentation	Stellate melanophores on thoracic, postanal, and caudal regions and dorsal anus; in early postlarvae, a large melanophore midway between anus and caudal fin on the ventrum and one on dorsum; fused in late postlarvae.
Distribution	Pelagic, found mostly in seawater to mesohaline in central and south San Francisco Bay and San Pablo Bay; some drift into Suisun Bay. They were also taken in Moss Landing Harbor and Elkhorn Slough.

JUVENILES (Figure 34-5)

Dorsal fin	VIII, 14 (Dotsu and Mito 1955).
Anal fin	12–13 (Dotsu and Mito 1955).
Pectoral fin	20–22.

Mouth	Maxillary does not extend beyond the center of eyes (Moyle 1976); terminal to subterminal, large.
Vertebrae	33 (Dotsu and Mito 1955); 32–34 (R. Lavenberg 1980, personal communication).
Distribution	Benthic (burrows) and epibenthic along Pacific coast adjacent to central and south San Francisco Bay, San Pablo Bay, Suisun Bay, the Delta, and lower reaches of tributaries, irrigation ditches, and canals. Yellowfin goby are also found in Rodeo Lagoon, Tomales Bay, and Moss Landing Harbor-Elkhorn Slough.

LIFE HISTORY

The yellowfin goby, an estuarine fish native to Japan, Korea, and northern China (Tomiyama 1936, Miyazaki 1940, Fowler 1961) was accidentally introduced into the Sacramento-San Joaquin Estuary in the 1950s, through the ballast systems of ships (Brittan *et al.* 1963, Messersmith 1966). Currently, this species is not only abundant within the estuary, but also has been observed along the coast form Elkhorn Slough to Tomales Bay (Miller and Lea 1972, Kukowski 1972a). A second yellowfin goby population is reported in Los Angeles, Long Beach Harbor, and Newport Bay (Haaker 1979), and was conceivably established in the same manner in San Francisco Bay. In this study yellowfin goby have been observed throughout the estuary, including the lower portion of the tributaries draining into the estuary. No specimens were collected in O'Neill Forebay and San Luis Reservoir in 1979–1981, although the species had previously been reported from these locations (Brittan *et al.* 1970, Moyle 1976).

Judging from the larvae collected in this study, spawning is estimated to occur from December through July in the Sacramento-San Joaquin Estuary. Spawning of the yellowfin goby was observed by Dotsu and Mito (1955) in Kyushu, Japan; eggs are deposited in a single layer on the wall or roof of a Y-shaped burrow, ca. 15–35 cm deep, constructed in intertidal mudflats. The female may leave the burrow after spawning or may join the male in guarding the eggs. The incubation period is approximately 28 days at 13°C.

Yellowfin goby larvae are pelagic (Miyazaki 1940, Dotsu and Mito 1955). In this study, newly hatched larvae swam out of the burrow and remained near the bottom. Yellowfin goby larvae were seldom caught in surface plankton tows, but were captured by a pump-net sampling device in which the depth of the intake pipe could be adjusted; goby larvae were often collected by this device when the intake pipe was located near the bottom. Yellowfin goby prolarvae were found in higher salinity waters such as central and south San Francisco Bay, San Pablo Bay, and near the sandbar of Rodeo Lagoon. After the yolk sac is absorbed, the larvae disperse rapidly. Some larvae begin to ascend to Carquinez Strait and Suisun Bay as early as late February. This upstream movement is similar to that of the naked goby, *Gobiosoma bosci*, along the mid-Atlantic coast, which uses tidal changes to move into the estuaries. The larvae float on the surface of the water column during flood tide and descend to near the bottom while the tide ebbs (Massman *et al.* 1963).

Juveniles settle on the bottom at about 13 cm TL (Miyazaki 1940). Pelvic fins fuse into a sucking disc, and the fish are able to cling to substrates or crawl into burrows. Juvenile yellowfin goby prefer tidal sloughs with a muddy bottom and peatmoss banks. Brittan *et al.* (1970) reported that the yellowfin goby has spread as far as San Luis Reservoirs, Merced County. Apparently, some juveniles traveled through the Tracy pumping station and were transported via the canal systems further south. Major food items for small juvenile yellowfin goby are harpacticoid copepods (Miyazaki 1940) and other copepods (Dotsu and Mito 1955); the large juveniles ear amphipods, mysid shrimp, and small fish.

In Japan, some yellowfin goby reach maturity after 1 year (Miyazaki 1940, Dotsu and Mito 1955); however, other populations mature after 2 years, and the maximum life span is 3–4 years (Miyazaki 1940). The majority die after spawning (Miyazaki 1940). In the California population, yellowfin goby mature in 2–3 years (Brittan *et al.* 1970). Mature yellowfin goby collected in the study generally ranges form 85 to 204 mm TL and were 1 year or older (M. Carlin 1979, personal communication). One specimen was 288 mm TL.

Yellowfish goby are considered as an important game fish and human food in Japan (Miyazaki 1940, Dotsu 1978). In California they are used mainly as bait fish and commonly called bullhead. Some Asians in the San Francisco Bay area catch and consume yellowfin goby (Moyle 1976).

Yellowfin goby adapt well to different salinities and sudden changes in salinity (Brittan *et al.* 1970). This species shares a similar habitat with other gobies, marine cottids, and surfperches in the higher salinity bays, and with freshwater sculpins, catfishes, cyprinids, osmerids, and striped bass in the lower salinity areas. The impact of yellowfin goby on the local fish community is poorly known at the present. Since yellowfin goby larvae were not found in the upper estuary and reproduction had almost totally ceased in Rodeo Lagoon when the salinity was 5.0 ppt or less (Wang 1982), it appears that the yellowfin goby's spawning migration in the Sacramento-San Joaquin Estuary is from fresher to more saline water. In a landlocked freshwater environment they may die off eventually because of lack of spawning g success. If this hypothesis is correct, the yellowfin goby population may not be a problem in California's inland freshwater systems. This species may expand its distribution along the coast.

References

Brittan *et al.* 1963, 1970; Carllin 1979, personal communication; Dotsu (or Dotu) 1978; Dotsu and Mito 1955; Fowler 1961; Haaker 1979; Kukowski 1972a; Massman *et al*. 1963; Messersmith 1966; Miller and Lea 1972; Miyazaki 1940; Moyle 1976; Tomiyama 1936; Wang 1982.

ARROW GOBY, *Clevelandia ios* (Jordan and Gilbert)

SPAWNING

Location	Lagoons, estuaries, and tidal sloughs (MacDonald 1972a); intertidal mud or sand flats of central and south San Francisco Bay, San Pablo Bay, coastal waters; also observed in Moss Landing Harbor, Elkhorn Slough, and Tomales Bay.
Season	December through August, with a peak of March to June (Prasad 1959); December through September (MacDonaled 1972); year-round.
Temperature	Ca. 15˚C (Prasad 1959); ca. 10˚C and greater.
Salinity	Seawater to polyhaline.
Substrate	Mud or sand (MacDonald 1972a); mud, sand, and gravel.
Fecundity	750–1,000 eggs at one time; actual count of ripe ova 800–1,200 (Prasad 1959); 15–25 at one laying (MacGinitie 1935); ca. 425–450 mature ova in female of 50.0–53.0 mm TL.

CHARACTERISTICS

EGGS

Shape	Elliptical, club-shaped (Prasad 1959, Brothers 1975).
Diameter	Mature eggs, long axis 0.735 mm and short axis 0.645 mm (MacGinitie 1935); unfertilized eggs spherical, 0.735 mm; fertilized eggs near elliptical long axis 1.170–1.300 mm and short axis 0.715–0.790 mm (Prasad 1959); ripe eggs 0.62–0.65 mm (Brothers 1975).
Yolk	Honey color, translucent (Prasad 1959); yellowish, granular.
Oil globule	Many small oil globules in early incubating stages consolidate to one globule prior to hatching (Prasad 1959).
Perivitelline space	Prior to early embryo stages, the space is wide through the long axis and narrow through the short axis (Prasad 1959).
Egg mass	Deposited in single layer, but threads of adjacent eggs may join together as in a bunch of grapes (Prasad 1959).
Adhesiveness	Restricted to anchoring point.

Buoyancy	Demersal.

LARVAE (Figures 34-6, 34-7, 34-8)

Length at hatching	2.75–3.20 mm TL (Prasad 1959); 3.0 mm TL (Brothers 1975).
Snout to anus length	Ca. 46–59% of TL of prolarvae and postlarvae.
Yolk sac	Almost round (Prasad 1959); spherical, thoracic.
Oil globule	Single (Prasad 1959); ca. 0.2–0.3 mm in diameter an located in anterior or center of yolk sac.
Gut	Straight, thick.
Air bladder	Small, oval, near pectorals in prolarvae; midway between pectorals and anus or near anus in postlarvae.
Teeth	Small, pointed, developed in postlarvae.
Size at completion of yolk-sac stage	Ca. 3.5–4.5 mm TL.
Total myomeres	34–36.
Preanal myomeres	16–19.
Postanal myomeres	16–19.
Last fin(s) to complete development	Fused pelvic fin.
Pigmentation	In prolarvae, a few melanophores on dorsal surface of gut and postanal regions; in postlarvae, a few melanophores on dorsal gut near anus; dashed melanophores along midventral region; a few melanophores in postanal region; two larger stellate melanophores midway between anus and caudal peduncle; one on dorsum and one on ventrum, the dorsal one diminished in late postlarvae.
Distribution	Pelagic (Prasad 1959); common in Richardson Bay (Eldridge 1977); most of them remain in more saline central and south San Francisco Bay and San Pablo Bay; some are found in Suisun Bay, and they are also common in Tomales Bay, Moss Landing Harbor, and Elkhorn Slough (Prasad 1969, Nybakken *et al.* 1977, this study).

JUVENILES (Figure 34-9)

Dorsal fin	IV–VI; O–I, 14–17 (Miller and Lea 1972).
Anal fin	O–I, 14–17 (Miller and Lea 1972).
Pectoral fin	18–21.

Mouth	Terminal, large, maxillary extending beyond posterior margin of the eye.
Vertebrae	36–37 (Miller and Lea 1972); 35–36 (R. Lavenberg 1980, personal communication).
Distribution	Richardson Bay (Eldridge 1977); mostly lower bays and along coast; some in San Pablo Bay and Suisun Bay; abundant in Lake Merritt in 1980, 1981; very abundant in Tomales Bay, Elkhorn Slough and Moss Landing Harbor.

LIFE HISTORY

The arrow goby ranges from the Gulf of California to the Straits of Georgia, British Columbia, inhabiting coastal lagoons, estuaries, and tidal sloughs (Miller and Lea 1972, MacDonald 1972a, Hart 1973). The arrow goby has been reported as the most abundant goby in Richardson Bay (Eldridge 1977) and in Moss Landing Harbor and Elkhorn Slough (Prasad 1959, Nybakken *et al.* 1977). In this study, the arrow goby was observed throughout the seawater-oligohaline portion of the Sacramento-San Joaquin Estuary and Tomales Bay, and is probably the most abundant native goby in the study area.

Spawning is higher in winter, spring, and summer (Prasad 1959), although they appear to spawn year-round, since larvae were captured monthly in the study area. In earlier investigations, both MacGinitie (1935) and Prasad (1959) observed eggs of arrow goby laid on the bottom of an aquarium and attached to the sand granules. Recently, Brothers (1975) reported that arrow goby eggs are deposited on walls of a burrow which is approximately 10 cm deep in bottom substrates. In this study, many adult arrow goby were excavated from ghost shrimp burrows, as has also been reported by MacDonald (1972a). It is conceivable that arrow goby may use other invertebrate burrows as their spawning sites. Mature eggs were obtained by stripping female gobies. Different sizes of ova found in the ovaries indicated that arrow gobies have a lengthy breeding period. Eggs hatch in 10–12 days at 15°C, with no parental care during the incubation (Prasad 1959).

Newly hatched arrow goby larvae are pelagic (Prasad 1959). Large numbers of yolk-sac larvae were observed in the vicinity of the Moss Landing Powerplant intake areas in winter and spring months, indicating that they swim out of burrows soon after hatching. In the Sacramento-San Joaquin Estuary, the bulk of the larval population remain in the higher salinity San Francisco Bay, South Bay, and San Pablo Bay; they are also observed in Carquinez Strait and Suisun Bay. MacDonald (1972a) reported that arrow goby can tolerate salinity changes, and there is apparently some upstream migration of arrow goby larvae.

Juvenile arrow goby begin to settle on the bottom and burrow at approximately 10–14 cm TL (MacDonald 1972a). They prefer tidal sloughs, lagoons, and coves with sand and mud bottoms where tidal action is slight (Prasad 1959). In this study, large numbers of juvenile arrow goby were observed in such locations as Hunters Point in the South Bay, Lake Merritt, Marconi Cove in Tomales Bay, and the upper portion of Elkhorn Slough. As Prasad (1959) has reported, the juvenile arrow goby do not move into deeper water during the ebbing tide; rather, they hide in burrows or beneath rocks and cobbles. Juveniles often find shelter in vegetation to avoid extreme water temperature changes (MacDonald 1972a). Major food items of juvenile arrow goby include copepods, ostracods, nematodes, and other small invertebrates (Prasad 1959, MacDonald 1972a).

Arrow goby become mature after 1 year, and their lifespan is estimated to be 3 years (Brothers 1975). Arrow goby have no commercial or sport value because of their small size (most less than 50 mm TL), although the planktonic larvae may be important as forage for predators.

References

Brothers 1975; Eldridge 1977; Hart 1973; Lavenberg 1980, personal communication; MacDonald 1972a; MacGinitie 1935; Miller and Lea 1972; Nybakken *et al.* 1977; Prasad 1959.

BLACKEYE GOBY, *Coryphopterus nicholsi* (Bean)

SPAWNING

Location	Subtidal and intertidal coastal waters (Ebert and Turner 1962); may occur in bays.
Season	Nests found from April through October (Ebert and Turner 1962); ripe ovaries observed from February through August (Wiley 1973); January through August.
Temperature	12.9–16.6˚C (Ebert and Turner 1982).
Salinity	Seawater.
Substrate	Rocky areas with sandy bottom, small holes in reefs (Ebert and Turner 1962, Wiley 1973).
Fecundity	1,700 per nest by one female (Ebert and Turner 1962); 3,274–4,788 (Wiley 1973).

CHARACTERISTICS

EGGS

Shape	Ovarian ripe eggs spherical, 0.4–0.7 mm; fertilized eggs, elongate, pointed, spindle shape (Ebert and Turner 1962); long axis 2.2 mm, short axis 0.5 mm.
Diameter	Long axis 2.10 mm, short axis 0.84 mm (Ebert and Turner 1962); long axis 2.2 mm, short axis 0.5 mm.

Yolk	Ripe eggs, orange (Wiley 1973); preserved fertilized eggs, yellowish.
Chorion	Transparent, smooth.
Perivitelline space	Wide in long axis and narrow in short axis (Ebert and Turner 1962, Wiley 1973).
Egg mass	Deposited on substrate in single layer (Ebert and Turner 1962).
Adhesiveness	Adhesive at the adhering point; but without threads (Ebert and Turner 1962, Wiley 1973).
Buoyancy	Demersal.

LARVAE (Figure 34-11, 34-12)

Length at hatching	2.97 mm TL (Ebert and Turner 1962); ca. 2.5–2.8 mm TL.
Snout to anus length	Ca. 43–49% of TL of larvae at 2.8–7.1 mm TL.
Yolk sac	Yellowish, spherical, thoracic, medium to small.
Gut	Straight, thick.
Air bladder	Small, oval, near pectoral fin s or toward midpoint between pectoral fins and anus.
Size at completion of yolk-sac stage	Ca. 3.0 mm TL.
Total myomeres	25–26.
Preanal myomeres	9–10.
Postanal myomeres	14–17.
Last fin(s) to complete development	Fused pelvic fin.
Pigmentation	A few stellate melanophores on dorsal surface of gut; a series of melanophores (10–15) along postanal region; a short series of small melanophores dorsally in front of caudal peduncle.
Distribution	Pelagic in coastal and oceanic waters (Wiley 1973); mostly in coastal waters; occasionally estuaries and bays, such as San Francisco Bay and Moss Landing Harbor.

JUVENILES

Dorsal fin	V–VI; I–II, 9–14 (Miller and Lea 1972); first dorsal spines IV–VI; second dorsal rays 12–15 (Wiley 1973), V–VII, 12–14 (Hart 1973).

Anal fin	O–I, 11–12 (Miller and Lea 1972); I, 11–14 (Wiley 1973); 11–12 rays (Hart 1973).
Pectoral fin	21–24 (Wiley 1973); ca. 22 (Hart 1973).
Mouth	Terminal, moderate in size, directed forward (Hart 1973).
Vertebrae	26 (Miller and Lea 1972); 26 (R. Lavenberg 1980, personal communication).
Distribution	Early juveniles, pelagic; larger juveniles found along coastal rocky reefs (Wiley 1972); in bays, such as San Francisco Bay and Moss Landing Harbor.

LIFE HISTORY

The blackeye goby has been reported from Point Rompiente, Baja California, to Queen Charlotte Islands, British Columbia (Miller and Lea 1972, Hart 1973). In this study, this species was seldom observed in San Francisco Bay but was common in Moss Landing Harbor.

Ebert and Turner (1962) found the nests of blackeye goby off Hermosa Beach, in southern California, from April through October; Wiley (1973) observed mature eggs of this species near Laguna Beach, southern California, from February through August. Judging from the eggs and larvae taken in this study, blackeye goby apparently spawn from January through August. Wiley (1973) observed that the male goby exhibits a protruding urogenital papilla, a dark pelvic fin, and aggressive territorial behavior during spawning. The female goby deposits eggs on the underside of a rock, and then the male takes over to guard and aerate them until hatching. At Hermosa Beach, the spawning temperature was reported as 12.9–14.66˚C (Ebert and Turner 1962). Ova have been collected in two distinctive sizes, indicating that blackeye goby are able to spawn more than once during the breeding season (Wiley 1973).

The fish, from newly hatched larvae through the early juvenile stages, are pelagic swimmers and can be found far from shore (Wiley 1973). In the study area, larvae were collected from south San Francisco Bay to Suisun Bay. Apparently the blackeye goby larvae can survive at low salinities, as reported by Hart (1973).

The larger juveniles (ca. 21–28 mm TL and greater) gradually settle into their demersal habitat in rocky reefs. Major food items for juveniles are small crustaceans such as copepods and amphipods. They also feed on other small organisms such as mollusk larvae, echinoderms, and bryozoans (Hart 1973, Wiley 1973).

Females are sexually mature at 2–5 years, males at 3–5 years (Wiley 1973). Fitch and Lavenberg (1975) reported that blackeye goby are mature after their first winter. The blackeye goby has no sport or commercial value, because of its scarcity, but the larvae may be eaten by predators (Fitch and Lavenberg 1975).

References

Ebert and Turner 1962: Fitch and Lavenberg 1975; Hart 1973; Lavenberg 1980, personal communication; Miller and Lea 1972; Wiley 1973.

TIDEWATER GOBY, *Eucyclogobius newberryi* (Girard)

SPAWNING

Location	Shallow water along Pacific coastal streams and lagoons (Swift 1980). Locally in Rodeo Lagoon, Estero de San Antonio, and Estero Americano (Wang 1982).
Season	In prespawning condition throughout the year; peaks from April through June in southern California (Goldberg 1977); major spawning periods are July and from late August through November in Rodeo Lagoon, although larvae were found in every month (Wang 1982).
Temperature	15.5–18.3˚C in southern California; judging by the localities of the newly hatched prolarvae taken, spawning temperatures in Rodeo Lagoon are estimated at 13.5–21.0˚C (Wang 1982).
Salinity	Mesohaline to freshwater (Wang 1982).
Substrate	Sandy burrows (Swift 1980), shallow weedy inshore areas or ditches with gravel, sand, or clay mud bottom.
Fecundity	640–800 per batch for ripe specimens measuring 43–47 mm TL (Wang 1982).

CHARACTERISTICS

EGGS (Figure 34-13)

Shape	Mature eggs, spherical to oval (Wang 1982).
Diameter	Mature eggs, long axis 1.1–1.3 mm; short axis 0.8–1.1 mm (Wang 1982).
Yolk	Yellowish, granular (Wang 1982).
Oil globule	One large oil globule, ca. 0.2–0.3 mm in diameter, and many small oil globules (Wang 1982).
Chorion	Transparent, smooth. Mature eggs have a layer of adhesive material wrapped around the chorion which eventually becomes the attaching filaments of the fertilized eggs (Wang 1982).

Egg mass	Deposited in burrows (Swift 1980).
Adhesiveness	Attaching filaments on the proximal end of the egg are adhesive (Wang 1982).
Buoyancy	Demersal.

LARVAE (Figures 34-14, 34-15)

Length at hatching	Ca. 4.0 mm TL or less.
Snout to anus length	Ca. 51–52% of TL of prolarvae at 4.2–5.2 mm TL; ca. 49–51 % of postlarvae at 8.6–12.3 mm TL.
Yolk sac	Spherical to oval, small, thoracic.
Oil globule	Single, located usually in anterior portion of yolk sac (Wang 1982).
Gut	Straight in prolarvae and early postlarvae; forms a hook or twists in postlarvae (Wang 1982).
Air bladder	Large, elongate, midway between pectoral fin and anus (Wang 1982).
Teeth	Sharp, pointed in postlarvae (Wang 1982).
Total myomeres	32–34 (Wang 1982).
Preanal myomeres	16–17 (Wang 1982).
Postanal myomeres	15–17 (Wang 1982).
Last fin(s) to complete development	Fused pelvic fin (pelvic disc) (Wang 1982).
Pigmentation	In prolarvae, stellate melanophores along dorsal surface of gut and postanal regions, and dashed to dotted melanophores along midventral region. In postlarvae, large stellate melanophores on snout, head and middorsal regions (some specimens collected in fall lacked that pigmentation). Scattered melanophores found in postanal portion of middorsal surface and melanophores along dorsal surface of gut, midventral, and postanal regions. A single black spot at distal end of mandible. Some large postlarvae (ca. 11 mm TL and greater) have a series on vertebral column (Wang 1982).
Distribution	Planktonic forms can be found inshore at Rodeo Lagoon and in Estero Americano below Valley Ford on Franklin School Road.

JUVENILES (Figure 34-16)

Dorsal fin	VI–VIII; I, 9–12 (Miller and Lea 1972).
Anal fin	I, 8–11 (Miller and Lea 1972); I, 9–12.

Pectoral fin	18–22.
Mouth	Terminal and large, and maxillary extends to posterior margin of the eye (Moyle 1976); middle of pupil to posterior margin of the eye.
Vertebrae	33–35 (Miller and Lea 1972); 33–34 (R. Lavenberg 1980, personal communication).
Distribution	On bottom or existing on submerged plants in shallow weedy areas of coastal lagoons and estuaries.

LIFE HISTORY

The tidewater goby is a small native goby (mostly less than 50 mm TL) found along the Pacific coast of California from the Smith River, Del Norte County, south to Agua Hedionda Lagoon, San Diego County (Swift 1980). Local records for the tidewater goby from the California Academy of Sciences show it inhabitating Paper Mill (or Lagunitas) Creek and Rodeo Lagoon; it was also found in the mouth of Corte Madera Creek (Hubbs and Miller 1965); in the vicinities of Lake Merced in San Francisco, the Aquatic Park and Lake Merritt in the urban East Bay area, and in the mouth of Novato Creek of San Pablo Bay (Swift 1980) and adjacent to the Sacramento-San Joaquin Estuary.

The tidewater goby was reported in Waddell Creek (Shapovalov and Taft 1954); Elkhorn Slough (Nybakken *et al.* 1977); and Salmon Creek near Bodega Bay (P. Moyle 1982, personal communication). In this study the tidewater goby has been found in Rodeo Lagoon, Estero de San Antonio, and Estero Americano. However, it was not found at the other sites within the Sacramento-San Joaquin Estuary, in spite of many searches.

Goldberg (1977) observed that the tidewater goby has an asynchronous ovarian cycle, *i.e.*, individuals are in different developmental stages throughout the year. In this study the spawning peak of this species in Rodeo Lagoon can be separated in to two periods: from late March through July, and from late August through November, although larvae were observed in every month. The water temperature during these periods, when prolarvae were taken, ranged from 13.5 to 21.0°C, and the salinities were recorded as mesohaline near the ocean side (the highest salinity in Rodeo Lagoon was 14.0 ppt) and from oligohaline to freshwater in the inland areas. In Rodeo Lagoon the spawning sites are generally concentrated near the ocean side in spring–summer and near the road bridge in summer–fall.

Spawning fish, with much darker body coloration, were often found in the shallow ditches and inshore areas of the lower lagoon during the breeding season, but the actual nesting and mating behavior was not observed. Swift (1980) described male tidewater goby digging a vertical burrow approximately 100–200 mm into the sandy bottom in water which was 25–50 cm deep. The proximal end of the egg bears a bundle of adhesive filaments used to attach to the wall of the burrow. The male fish guards the nest after the female finished the deposition of eggs. Goldberg (1977) stated that an individual female is able to spawn more than once, but the exact spawning frequency per female could not be determined.

Planktonic larvae were captured with an ichthyoplankton net in shallow water over sandy, hard clay and gravel bottoms in Rodeo Lagoon. In the late yolk-sac larval stage (ca. 5.0 mm TL), dense pigmentation covered both dorsal and ventral body surfaces. The larvae are found inshore using vegetation as shelter.

Juvenile and adult tidewater goby are benthic inhabitants, as described by Swift (1980). In the laboratory, juvenile tidewater goby were observed resting on the bottom or in submerged vegetation of the aquarium. Their swimming pattern was fluid, without the jerky movements common to other goby species. Swift (1980) reported mollusks, insects, and crustaceans as food for the tidewater goby. Stomach analysis of a juvenile goby in this study revealed a diet of small crustaceans such as copepods, amphipods, and mysid shrimp.

In this study, concentrated rings on the periphery of the cycloid scales found on the ripe fish, and the rings on the otolith as a cross-reference, showed they are 1- or 1+ year-old fish. Post-spawning individuals were also observed, but there were no 2-year-old fish collected in Rodeo Lagoon. Swift (1980) stated that some tidewater goby live as long as their third summer in the northern range of the species. The tidewater goby has no sport or commercial value, because of its small size and scarcity.

Both Moyle (1976) and Swift (1980, personal communication) believe that the population of the tidewater goby at this locale, as well as in the entire range, is continuing to decline. The tidewater goby has a short lifespan, and needs a specific brackish–freshwater habitat. Rodeo Lagoon receives large amounts of freshwater from inland streams and underground water, it occasionally receives seawater over the sandbar from the Pacific Ocean during high tides. This special environment is necessary to completion of the life cycle and to the continued existence of this small native goby. Some management recommendations on protection have been proposed to the National Park Service by the author (Wang 1982).

References

Goldberg 1977; Hubbs and Miller 1965; Lavenberg 1980, personal communication; Messersmith 1966; Miller and Lea 1972; Moyle 1982, personal communication; Moyle 1976; Nybakken *et al.* 1977; Shapovalov and Taft 1954; Swift 1980; Swift 1980, personal communication; Wang 1982.

LONGJAW MUDSUCKER, *Gillichthys mirabilis* Cooper

SPAWNING

Location	Saltwater ponds and tidal water sloughs such as Alviso Salt Pond of south San Francisco Bay (De Vlaming 1972); Elkhorn Slough (Nybakken *et al.*

	1977); south of Dumbarton Bridge of the South Bay; San Pablo Bay; near Kirby Park of Elkhorn Slough, south Tomales Bay.
Season	January through July (Weisel 1947); January through September (Barlow 1961); January through May (Walker *et al.* 1961); December through June (De Vlaming 1972); January through June typical for the northern half of its distribution along California coast (Barlow and De Vlaming 1972); November through June in San Francisco Bay and Tomales Bay and all seasons in Elkhorn Slough (Nybakken *et al.* 1977).
Temperature	18˚C (Weisel 1947); ca. 10˚C and greater.
Salinity	Hypersaline (Barlow 1961, Barrow and De Vlaming 1972); hypersaline and mesohaline (this study).
Fecundity	4,000–9.000 (Weisel 1947), 8,000–27,000 (Barlow 1961).

CHARACTERISTICS

EGGS

Shape	Unfertilized eggs are spherical: fertilized eggs are club-shaped (Weisel 1947).
Diameter	2.27–3.37 mm in long axis; 1.06–1.13 mm in short axis (Weisel 1947).
Chorion	Transparent at 24-hour stage; many fine gelatinous threads start to cover the surface of chorion (Weisel 1947).
Perivitelline space	Very wide in long axis and short in short axis after fertilization (Weisel 1947).
Egg mass	Clusters of eggs attached to central stalks (Weisel 1947).
Adhesiveness	Numerous adhesive threads at proximal end of the egg (Weisel 1947).
Buoyancy	Demersal (Weisel 1947).

LARVAE (Figures 34-17, 34-18, 34-19, 34-20, 34-21)

Length at hatching	Less than 3.5 mm TL (Walker *et al.* 1961); ca. 3.0–4.0 mm TL.
Snout to anus length	48–53% of TL of prolarvae and postlarvae.
Yolk sac	Yellowish, spherical, thoracic.
Oil globule	Single oil globule located in anterior or central region of yolk sac.

Gut	Straight, thick in prolarvae, twisted in postlarvae.
Air bladder	Oval, small, behind pectoral fin in prolarvae and early postlarvae, more posterior in postlarvae.
Teeth	Sharp and pointed in postlarvae.
Size at completion of yolk-sac stage	Ca. 4.5–5.0 mm TL.
Total myomeres	29–32.
Preanal myomeres	14–17.
Postanal myomeres	14–16.
Last fin(s) to complete development	Pectoral and first dorsal.
Pigmentation	Single series of very large melanophores along midventral, dorsal surface of gut, and postanal regions; a few melanophores on lower and upper jaws and distal end of mandible; a few dotted and dashed melanophores along lateral line near caudal peduncle in late postlarvae.
Distribution	Pelagic (Barlow 1961); in shallow inshore waters. South San Francisco Bay (Barlow 1961, this study); Elkhorn Slough (Nybakken *et al.* 1977); San Pablo Bay and south Tomales Bay. Late postlarvae descend to bottom (Barlow 1961).

JUVENILES (Figure 34-22)

Dorsal fin	IV–VIII; I–III, 9–14 (Barlow 1961, Miller and Lea 1972).
Anal fin	I–II, 8–14 (Barlow 1961); I–III, 8–14 (Miller and Lea 1972).
Pectoral fin	18–23 (Barlow 1961).
Mouth	Terminal, large, maxillary extends beyond posterior margin of the eye, but the distal end of maxillary does not become extremely elongate in the early juvenile.
Vertebrae	31–33 (Barlow 1961); 31–32 (R. Lavenberg 1980, personal communication).
Distribution	Settle on bottom (Barlow 1961); settle on bottom or in burrows of South Bay, San Pablo Bay, Elkhorn Slough, south Tomales Bay.

LIFE HISTORY

The Longjaw mudsucker has been found from Bahia Magdalena, Baja California, to Tomales Bay (Steindachner 1876, Roedel 1953), it was reported as far as Puget Sound in another record (Jordan and Starks 1896). A relict population also exists in the upper part at the Gulf of California (Hubbs 1948, 1960; Barlow 1961, 1963). The longjaw mudsucker was introduced into the Salton Sea by the CDFG in 1930 (Barlow 1961) and has thrived. Along the Pacific coast, San Francisco Bay probably contains the northernmost reproducing populations of this species (Barlow 1961). In this study, it was collected in Moss Landing Harbor-Elkhorn Slough, San Francisco Bay (the majority from the South Bay), and Tomales Bay. Larvae of longjaw mudsucker were observed at the south end of Tomales Bay near the mouth of Grand Canyon Creek, indicating a spawning population of Longjaw mudsucker in Tomales Bay.

Spawning commences from December through June in the Alviso salt ponds of the South Bay (De Vlaming 1972). A typical spawning period for longjaw mudsucker in their northern distribution is from January through June (Barlow and De Vlaming 1972). In this study, judging from the time when larvae were collected, the spawning period occurs from January through June in San Francisco Bay and year-round in Elkhorn Slough. This protracted reproduction is similar to that of arrow goby. Weisel (1947) described egg clusters attached to the walls of burrows by means of adhesive threads. The male fish guards the nest until hatching. Incubation takes 10–12 days at 18°C. Weisel (1947) also stated that Longjaw mudsucker spawn only once or, rarely, twice during a single season. However, Walker *et al.* (1961) found that this species breeds two to three times a year at an interval of 2–3 months in the Salton Sea. Individuals spawn more than once in the Alviso salt ponds in the South Bay (De Vlaming 1972). In this study, many longjaw mudsucker adults were excavated from their burrows in upper Elkhorn Slough (near the railroad track). Ova of different sizes found in the ovary indicate that longjaw mudsucker have a lengthy spawning period and that they are multiple spawners during the breeding season.

Barlow (1963) stated that longjaw mudsucker larvae are pelagic, and Nybakken *et al.* (1977) took large numbers of larvae in surface tows in Elkhorn Slough. In this study, larvae were collected by vertical pump sampler as well as with a surface plankton net. They are apparently distributed at all levels in the water column. The bulk of the longjaw mudsucker larvae were collected in shallow (less than 1.5 mm) ditches of upper Elkhorn Slough. The larvae move in and out in those ditches depending on tidal conditions. Larval movement can be long-range as well as a short. In the Sacramento-San Joaquin Estuary, longjaw mudsucker larvae were also observed in Montezuma Slough at Suisun Bay.

The late postlarvae and early juveniles descend to the bottom at 8–12 mm TL (Barlow 1963). At these stages, the body gradually becomes covered with dense pigmentation. On the basis of pigmentation pattern and larval behavior, Barlow (1963) further suggested that longjaw mudsucker larvae are not as well adapted for the pelagic life (in open water) as the related genera *Clevelandia* and *Ilypnus*, which have sparse melanophores and a transparent body in stages of comparable size. This may explain why the longjaw mudsucker is doing so well in the South Bay and Elkhorn Slough, where the tide and current are minimal. Major food items for juveniles are copepods, nematodes, fly larvae, other small invertebrates, and small fish (Walker *et al.* 1961). Longjaw mudsucker become sexually mature at less than 1 year, and the maximum life expectancy is about 2 years (Walker *et al.* 1961). The largest specimen taken in this study was 14.7 cm TL, from Elkhorn Slough. Longjaw mudsucker are commonly used as bait fish. They are very hardy, as they can breathe air when they are out of water (Todd and Ebeling 1966, Courtois 1976). This species serves as food for seabirds and predaceous fishes (Fitch and Lavenberg 1975).

References

Barlow 1961, 1963; Barlow and De Vlaming 1972; Courtois 1976; De Vlaming 1972; Fitch and Lavenberg 1975; Hubbs 1948, 1960; Jordan and Starks 1896; Lavenberg 1980, personal communication; Miller and Lea 1972; Nybakken *et al.* 1977; Roedel 1953; Steindachner 1876; Todd and Ebeling 1966; Walker *et al.* 1961; Weisel 1947.

CHEEKSPOT GOBY, *Ilypnus gilberti* (Eigenmann and Eigenmann)

SPAWNING

Location	Shallow coastal waters and estuaries. Richardson Bay (Eldridge 1977); San Francisco Bay, the South Bay, and probably San Pablo Bay.
Season	Mature ova found in all seasons (Brothers 1975); larvae were taken from September through December (Eldridge 1977); throughout the year.
Salinity	Seawater to polyhaline.
Substrate	Sandy areas or mud flats with little vegetation (Brothers 1975).
Fecundity	Ca. 250–1,800 in total, and 150–300 per burrow by one female (Brothers 1975).

CHARACTERISTICS

EGGS

Shape	Unfertilized eggs are spherical; fertilized eggs are club-shaped (Brothers 1975).
Diameter	Ripe eggs, 0.62–0.65 mm; in fertilized eggs the length of the egg capsule (or long axis) is 3.3 mm (Brothers 1975).
Yolk	Yellowish in mature eggs.
Chorion	Mature eggs, transparent.

Perivitelline space	Wide in long axis and narrow in short axis.
Egg mass	Deposited in burrows in a single layer, packed closely together (Brothers 1975).
Adhesiveness	Adhesive at the proximal end of the eggs, with filaments for anchoring to substrates (Brothers 1975).
Buoyancy	Demersal.

LARVAE (Figure 34-23)

Length at hatching	3.1 mm TL (Brothers 1975).
Snout to anus length	Ca. 47–50% of TL of prolarvae and postlarvae.
Yolk sac	Spherical, small, thoracic (Brothers 1975).
Gut	Straight (Brothers 1975); straight and thick.
Air bladder	Oval, small, behind pectoral fin in late prolarvae and early postlarvae; midway between pectoral fin and anus in postlarvae.
Teeth	Sharp, pointed, apparent in late postlarvae.
Total myomeres	32–34.
Preanal myomeres	16–18.
Postanal myomeres	15–17.
Last fin(s) to complete development	Pectoral and fused pelvic.
Pigmentation	Stellate melanophores on midventral and dorsal surfaces of gut region. Usually 4–5 large stellate melanophores evenly spaced along postanal region (Brothers 1975). A large stellate melanophore on dorsum midway between anus and caudal peduncle; melanophores also found at distal end of mandible and hypleural region
Distribution	Pelagic (Barlow 1963); found mostly on high tide in Richardson Bay (Eldridge 1977), planktonic in San Francisco Bay, San Pablo Bay, Moss Landing Harbor, and Elkhorn Slough.

JUVENILES (Figures 34-25, 34-26)

Dorsal fin	V; O–I, 13–17 (Miller and Lea 1972).
Anal fin	O–I, 12–16 (Miller and Lea 1972).
Pectoral fin	21–22.
Mouth	Terminal, large, maxillary extends to between posterior margin of pupil and posterior margin of the eye.

Vertebrae	32–34 (Miller and Lea 1972); 32–36 (R. Lavenberg 1980, personal communication).
Distribution	Benthic or burrowing in intertidal mud flats (Brothers 1975). Common in the South Bay; sparse in San Francisco Bay, San Pablo Bay, and Moss Landing Harbor-Elkhorn Slough. Some collected by Tetra Tech, Inc., in Suisun Bay in 1976.

LIFE HISTORY

The cheekspot goby ranges from the Gulf of California to Walker Creek in Tomales Bay (Miller and Lea 1972). Various life stages of this species were collected in the Sacramento-San Joaquin Estuary, and juvenile life stages were identified by Eldridge (1977) in Richardson Bay. Existence of a reproductive population of the cheekspot goby in this study area is apparent.

Spawning takes place in the intertidal mud flats in southern California throughout the year, although some may take a short rest during the fall (Brothers 1975). In this study, larvae were taken sparsely year-round,; they seemed to be more common in the vicinity of Hunters Point and Candlestick Park in the spring and summer months. The cheekspot goby deposits eggs in a single layer in a slightly enlarged chamber which is approximately 15 cm deep (Brothers 1975). The walls of this sandy burrow are coated with a mucopolysaccharide, probably secreted from the fish's mouth or body. The male fish is responsible for guarding the nest. Females often deposit more than one batch of eggs during the breeding season.

The larvae are pelagic (Barlow 1963, Brothers 1975). Their distribution seems to be patchy in San Francisco Bay and San Pablo Bay, but they are common in the South Bay. Larvae were also observed in Carquinez Strait and Suisun Bay. Apparently those were transported by tides and currents from the lower bays.

In this study area Brothers (1975) had difficulty separating arrow goby larvae from cheekspot goby larvae when they are less than 65 mm TL. Cheekspot goby, arrow goby, and yellowfin goby have similar spawning habits and have an overlapping spawning period, and their larvae are always present in the same collections, particularly in the South Bay. However, the majority of them can be separated and identified by using the pigmentation patterns along the postanal region (see characteristic keys at the end of this chapter), although some errors are inevitable because of their similarity.

Juveniles prefer sandy and muddy bottoms and assume benthic or burrowing habits. They are rarely collected by conventional sampling method (Brothers 1975). Juvenile cheekspot goby feed on copepods, amphipods, ostracods, and san grains (Brothers 1975).

Brothers (1975) was the first person to investigate the biology of the cheekspot goby. He reported that this species matures in 1–3 years and he estimated less than 10% mature in their first year. Individuals may live up to 5 years or more. The cheekspot is not abundant in the Sacramento-San Joaquin Estuary. Their role as forage fish in the food chain is probably insignificant.

References

Barlow 1963, Brothers 1975, Eldridge 1977, Lavenberg 1980, personal communication; Miller and Lea 1972.

BAY GOBY, *Lepidogobius lepidus* (Girard)

SPAWNING

Location	Intertidal mudflats (Grossman 1979a,b); in south and central San Francisco Bay, San Pablo Bay, and coastal Pacific intertidal areas; also in Moss Landing Harbor-Elkhorn Slough and Tomales Bay.
Season	Large yolk-filled eggs were found from September through March, and the peak of spawning was from January to March in Morro Bay (Grossman 1979a,b); larvae were taken from April through September in Humboldt Bay (Eldridge and Bryan 1972).
Temperature	Ca. 10˚C when prolarvae were taken.
Salinity	Seawater to polyhaline.
Substrate	Mud (Grossman 1979a,b); mud and sand.

CHARACTERISTICS

EGGS

Shape	Spherical initially; mature unfertilized eggs become elliptical when soaked in water.
Diameter	Mature eggs ca. 1.3–1.8 mm in long axis and ca. 0.8–1.0 mm in short axis.
Yolk	Yellowish, granular.
Oil globule	Mature eggs have many small oil globules scattered in the yolk.
Chorion	Mature eggs, transparent and smooth, except at anchoring point.
Perivitelline space	Mature eggs when soaked in water wide in long axis and narrow in short axis.
Egg mass	Mature eggs form small clusters but do not adhere to one another.
Adhesiveness	Adhesive only at anchoring point.

Buoyancy	Demersal.

LARVAE (Figures 34-27, 34-28, 34-29, 34-30, 34-31)

Length at hatching	Ca. 2.5–3.0 mm.
Snout to anus length	Ca. 50–57% for prolarvae and early postlarvae at 3.2–3.8 mm TL; ca. 44–50% for postlarvae at 11.8–14.8 mm TL.
Yolk sac	Yellowish, spherical, thoracic.
Oil globule	Single, in anterior yolk sac.
Gut	Straight or slightly waved, thick.
Air bladder	Small, behind pectoral fin in prolarvae and early postlarvae; midway between pectoral fin and anus or close to anus in postlarvae.
Teeth	Pointed, very small, apparent in late postlarval stage.
Size at completion of yolk-sac stage	Ca. 3.5–3.8 mm TL.
Preanal myomeres	17–19.
Postanal myomeres	18–20.
Last fin(s) to complete development	Fused pelvic fin.
Pigmentation	In prolarvae and early postlarve, three groups of stellate melanophores appear on middorsum: midway between pectoral and anus, above anus, and midway between anus and caudal peduncle; a series of melanophores along midventral and dorsal surfaces of gut and postanal regions. In postlarvae most of the pigmentation disappears except in postanal and caudal regions.
Distribution	Larvae are pelagic (Grossman 1979a,b); larvae and early juveniles are pelagic; Moss Landing Harbor-Elkhorn Slough; also observed in San Pablo Bay, south and central San Francisco Bay, and Tomales Bay.

JUVENILES (Figures 34-32, 34-33)

Dorsal fin	VII–VIII; O–I, 14–18 (Miller and Lea 1972); VII, 16–18 (Hart 1973).
Pectoral fin	Ca. 20 (Hart 1973); 20–22.
Mouth	Terminal, moderate in size (Hart 1973); terminal to subterminal, and maxillary extends to mid-eye.

Vertebrae	37–38 (Miller and Lea 1972); 37 (R. Lavenberg 1980, personal communication).
Distribution	Large juveniles are benthic (Grossman 1979a,b); pelagic in early juveniles and benthic or in burrows at ca. 20–25 mm TL; found in San Francisco Bay, San Pablo Bay, the South Bay, and (seldom) in Suisun Bay. They are also found in Moss Landing Harbor-Elkhorn Slough and Tomales Bay.

LIFE HISTORY

Distribution of the bay goby has been known from Cedros Islands, Baja California, to Vancouver Island, including the Strait of Georgia, and Denman Island, British Columbia (Miller and Lea 1972, Hart 1973). They occasionally ascend to the upper estuary, above Carquinez Strait (Ganssle 1966, Messersmith 1966). In this study, bay goby were collected in most areas of the Sacramento-San Joaquin Estuary below Suisun Bay. They were also observed in Moss Landing Harbor-Elkhorn Slough and Tomales Bay.

Grossman (1979a,b) observed ripe bay goby in the Morro Bay area from September through March, and estimated that spawning peaks from January to March. In this study, the majority of larval bay goby were collected in San Francisco Bay from November through May, with peaks in April and May. The spawning behavior of the bay goby is not clear in the literature, but Grossman (1979a,b) found that juvenile and adult bay goby use burrows as shelter from predators and dehydration during ebb tides. It is possible that bay goby may reproduce in the burrows, as do most other gobies found along the California coast (De Vlaming 1972, Wiley 1973, Brothers 1975). Eggs were stripped from ripe adults collected at Hunters Point and Moss Landing Harbor in April and May. Different sizes of ova in the ovaries indicated that the bay goby is probably an asynchronous multiple spawner during the breeding season.

Newly hatched larvae are rather small (ca. 3.0 mm TL or less). Bay goby larvae have a 3–4 month planktonic life (Grossman 1979a,b). Both postlarvae and early juveniles have little body pigmentation. They occur sympatrically with arrow goby, cheekspot goby, and yellowfin goby in San Francisco Bay. The bulk of the bay goby larval population seems to concentrate near the Golden Gate Bridge and Angel Island.

Juveniles descend to the bottom when they reach ca. 25 mm TL. Large blotches of melanophores, leopard spot-like in appearance, form above the lateral line region of the body. They prefer to occupy the burrows of blue mud shrimp, geoduck clams, and other burrowing animals as their shelters (Grossman 1979a,b). Juveniles feed on copepods, amphipods, other small crustaceans, and unidentified detrital particles.

Few bay goby reach sexual maturity at the end of the first year, but most do in their second year. The life span is about seven years (Grossman 1979a,b). The bay goby has no value as human food, because of its small size (ca. 90 mm TL mostly), but their lengthy planktonic larval stage make them important in the food chain as forage for predators.

References

Brothers 1975; De Vlaming 1972; Eldridge and Bryan 1972; Ganssle 1966; Grossman 1979a,b; Hart 1973; Lavenberg 1980, personal communication; Messersmith 1966; Miller and Lea 1972; Wiley 1973.

CHAMELEON GOBY, *Tridentiger trigonocephalus* (Gill)

SPAWNING

Location	Intertidal mudflats, oyster beds (Dotsu 1958); south San Francisco Bay (such as the vicinity of Hunters Point, San Mateo, and Dumbarton Bridge); Aquatic Park near Berkeley, San Pablo Bay.
Season	May through September in Kyushu Japan (Dotsu 1958); well-developed eggs found at Los Angeles Harbor in May, and egg masses found in September (Haaker 1979); larvae were taken from June through October in San Francisco Bay, and spawning estimated from May through September.
Temperature	Ca. 20˚C (Dotsu 1958).
Salinity	Seawater to mesohaline (Haaker 1979).
Substrate	Calm shells, oyster shells (Dotsu 1958); beer cans, bottles (Haaker 1979); probably rocky jetties.
Fecundity	1,248–9,700 for specimens 29–47 mm TL (Dotsu 1958).

CHARACTERISTICS

EGGS

Shape	Mature eggs and newly fertilized eggs initially spherical; later become pyriform, with a pointed tip at distal end (Dotsu 1958).
Diameter	Mature eggs, spherical, 0.50–0.60 mm, fertilized eggs, elliptical; 1.4 mm at long axis and 0.6 mm at short axis (Dotsu 1958).
Yolk	Yellowish, translucent (Dotsu 1958).
Oil globule	More than 10 oil globules in early development stages, which consolidate into one oil globule prior to hatching (Dotsu 1958).
Chorion	Transparent, smooth (Dotsu 1958).

Perivitelline space	Very wide at long axis and narrower at short axis in the early developmental stages (Dotsu 1958).
Egg mass	Deposited in single layer, and can be very dense per unit area (Dotsu 1958).
Adhesiveness	Adhesive at basal end, where a bundle of filaments attaches to substrates (Dotsu 1958).
Buoyancy	Demersal.

LARVAE (Figures 34-34, 34-35, 34-36)

Length at hatching	2.4 mm TL (Dotsu 1958); 2.2 mm TL.
Snout to anus length	44–51% of TL of prolarvae and postlarvae at 2.4–9.7 mm TL.
Yolk sac	Spherical, thoracic (Dotsu 1958).
Oil globule	Single, large (Dotsu 1958); single, in anterior yolk sac.
Gut	Straight in prolarvae and early postlarvae (Dotsu 1958); twisted in one loop near posterior portion of intestine in postlarvae.
Air bladder	Oval, small, near pectoral fins in prolarvae and early postlarvae, midway between pectoral fins and anus in postlarvae (Dotsu 1958).
Teeth	Pointed, sharp in postlarvae.
Size at completion of yolk-sac stage	Ca. 2.6–2.9 mm TL.
Total myomeres	24–26.
Preanal myomeres	10–14.
Postanal myomeres	13–15.
Last fin(s) to complete development	Fused pelvic fin.
Pigmentation	A few melanophores along postanal and caudal regions (Dotsu 1958); in prolarvae, large stellate melanophores I midventral, dorsal surface of gut, and postanal regions and one large stellate melanophore o dorsum between anus and caudal penduncle; in late prolarvae and postlarvae, most of the pigmentation disappears except for a few melanophores scattered on postanal region; two horizontal stripes and a caudal spot develop in late postlarval and juvenile stages.
Distribution	Pelagic (Dotsu 1958); found in San Francisco Bay, particularly the South Bay and Aquatic Park.

JUVENILES (Figures 34-37)

Dorsal fin	VI, 13 (Dotsu 1958); VI, I, 11–12 (Miller and Lea 1972).
Anal fin	11 (Dotsu 1958); I, 10–11 (Miller and Lea 1972) I, 11.
Pectoral fin	21 (Dotsu 1958); 20–22.
Mouth	Terminal to subterminal, maxillary extends to mid-eye.
Vertebrae	26 (Miller and Lea 1972); 26–27 (R. Lavenberg 1980, personal communication).
Distribution	Juveniles become benthic at 15 mm TL and greater (Dotsu 1958); benthic or epibenthic in clam shells, cans, bottles, polychaete tubes, crevices of jetties, and on vegetation.

LIFE HISTORY

The chameleon goby is a native fish of China, Korea, eastern Siberia, and Japan (Tomiyama 1936, Fowler 1961). They were introduced into California during the 1950s, probably through shipping in a manner similar to the introduction of the yellowfin goby. Currently, there are two isolated chameleon goby populations known to the West Coast of the United States. One is in the San Francisco Bay, including Lake Merritt (Ruth 1964, Brittan *et al.* 1970, Miller and Lea 1972, Moyle 1976), and the other is in Los Angeles Harbor (Hubbs and Miller 1965, Miller and Lea 1972, Haaker 1979). In this study the chameleon goby was observed in the South Bay, at Aquatic Park, and near the Oleum Powerplant on San Pablo Bay. This species has not been reported in California's freshwater systems (Shapovalov *et al.* 1981).

In Japan, spawning of the chameleon goby occurs from April through September in oyster beds (Dotsu 1958). In the Los Angeles Harbor area, mature eggs of this species were observed in May and September (Haaker 1979). In this study area, judging from when the chameleon goby larvae were taken, the spawning period is from May through September. Chameleon goby use old oyster or clam shells as their nesting sites. Eggs are deposited on the inner surface of the shell in a single layer by one or more female fish. The male guards the nest, and eggs hatch in 8½ days at 20˚C (Dotsu 1958). Dotsu also noticed two different sizes of eggs in the ovary, so the female may spawn more than once in a season. There are no oyster beds in the South Bay or Aquatic Park, and the chameleon goby must use cans and bottles as spawning substrates (Haaker 1979), or they may use crevices in jetties or rocks.

Chameleon goby larvae are planktonic or pelagic (Dotsu 1958). Small numbers were found in entrainment samples at the Hunters Point Powerplant and in beach seine samples from Aquatic Park. The bulk of the larval population is in the open water of the South Bay, particularly in the vicinity of the San Mateo and Dumbarton Bridges. Newly hatched chameleon goby larvae can be easily separated from other gobies the their tiny size (ca. 2.2 mm TL) and later by their stubby appearance, which is reflected in their low vertebra counts (24–26).

As juveniles, at about 15 mm TL, they gradually descend to the bottom (Dotsu 1958). In this study, field observations, made mostly at Aquatic Park, indicated that juvenile chameleon goby prefer to rest on the algae, or near the entrances of crevices and tunnels. The population appears to fluctuate, since both juveniles and adults were commonly observed in 1978–1979, but failed to appear at the same collecting sites in 1980–1981. Stomach samples from juveniles collected from Aquatic Park contained copepods, small amphipods, benthic organisms, and detritus.

Chameleon goby mature at 1 year of age, and some individuals may live up to 3 years (Dotsu 1958). This species has no commercial or sport value because of their small size (mostly less than 50 mm TL). The ecological status of the chameleon goby after its introduction in the San Francisco Bay is little known.

References

Brittan *et al.* 1970; Dotsu 1958; Fowler 1961; Haaker 1979; Hubbs and Miller 1965; Lavenberg 1980, personal communication; Ruth 1964; Miller and Lea 1972; Moyle 1976, Shapovalov *et al.* 1981; Tomiyama 1936.

Characteristic Comparison: Gobies

Characteristics	**Yellowfin Goby**	**Arrow Goby**
Eggs		
Shape	Teardrop or club-shaped	Elliptical or club-shaped with blunt distal end
Spawning site	Intertidal, burrow	Intertidal, burrow
Larvae		
Size at hatch (mm)	4.4–5.0	2.75–3.20
Total myomeres	31–33	34–36
Preanal myomeres	13–14	16–18
Postanal myomeres	18–19	16–19
Pigmentation	Light in prolarvae and postlarva;, stellate melanophores on thoracic area, dorsal area of anus, and postanal region; single large melanophore on dorsum of postanal region, diffused in late postlarvae	Light in prolarvae and postlarvae; stellate melanophores on midventral area, dorsal area of anus and postanal region; single large melanophore on dorsum of postanal region, diffused in late postlarvae; very similar to that of yellowfin goby larvae
Juveniles		
Dorsal fin	VIII, 14	IV–VI; O–I, 14–17
Anal fin	I, 11–12	O–I, 14–17
Pectoral fin	20–22	18–21
Vertebrae	32–34	35–37
Distribution	Early juveniles pelagic, juveniles benthic; euryhaline	Early juveniles pelagic, juveniles benthic; seawater-oligohaline
Distinguishing characters	Head and mouth large; eyes near top of head	Ca. 12 dark bands on dorsum, ca. 12 concentrated melanophores on lateral line

Characteristic Comparison: Gobies

Characteristics	**Blackeye Goby**	**Tidewater Goby**
Eggs		
Shape	Spindle-shaped, pointed at both ends	Oval or elliptical in mature eggs
Spawning site	Intertidal, holes on rock reef	Non-tidal coastal lagoons, burrow
Larvae		
Size at hatch (mm)	2.5–3.0	4.0 (or less)
Total myomeres	25–26	32–34
Preanal myomeres	9–10	16–17
Postanal myomeres	14–17	15–17
Pigmentation	Light in prolarvae and postlarvae; sparse stellate melanophores on dorsal surface of gut; 10–15 melanophores along postanal region; short series of melanophores on dorsal surface near caudal peduncle	Heavy in prolarvae and postlarvae; stellate melanophores on dorsal surface of gut and postanal region; dashed to dotted melanophores on midventral region; then, large stellate melanophores on snout, head, and middorsal region; a single black spot at distal end of mandible
Juveniles		
Dorsal fin	V–VI; I–II, 9–15	VI–VIII; I, 9–12
Anal fin	O–I; 11–14	I, 8–11
Pectoral fin	21–24	18–22
Vertebrae	26	
Distribution	Early juveniles pelagic, juveniles on rock reefs; seawater-oligohaline	Early juveniles pelagic, juveniles benthic
Distinguishing characters	Large black eye; three dark blotches on dorsum	Two pores on top of head between eyes.

Characteristic Comparison: Gobies

Characteristics	**Longjaw Mudsucker**	**Cheekspot Goby**
Eggs		
Shape	Club-shaped, with gelatinous threads	Club-shaped
Spawning site	Intertidal (except in Salton Sea), burrow	Intertidal, burrow
Larvae		
Size at hatch (mm)	3.0–4.0	3.1
Total myomeres	29–32	32–34
Preanal myomeres	14–17	16–18
Postanal myomeres	14–16	15–17
Pigmentation	Heavy in prolarvae and postlarvae; very large stellate melanophores on middorsal and midventral, dorsal surface of gut, and postanal regions; few melanophores on the lateral line near caudal region	Light in prolarvae and postlarvae; stellate melanophores on midventral region and dorsal surface of gut; 4–6 large melanophores in postanal region; single melanophore on dorsum of postanal region; melanophores at distal end of mandible and hypleural regions
Juveniles		
Dorsal fin	IV–VIII; I–III, 9–14	V; O–I, 13–17
Anal fin	I–III, 8–14	O–I, 12–16
Pectoral fin	18–23	21–22
Vertebrae	31–33	32–36
Distribution	Early juveniles, juveniles benthic; hypersaline-oligohaline	Early juveniles pelagic, juveniles benthic; seawater-oligohaline
Distinguishing characters	8–9 very dark vertical bands on side of body	Dark oblique stripe (operculum); series of dark blotches near outer margin of anal fin membrane

Figure 34.—Gobiidae: *Acanthogobius flavimanus*, yellowfin goby.

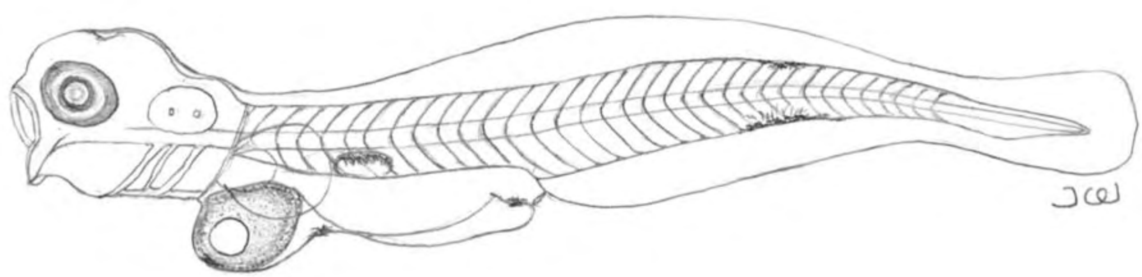


FIGURE 34-1.—Prolarva, 5.5 mm TL.

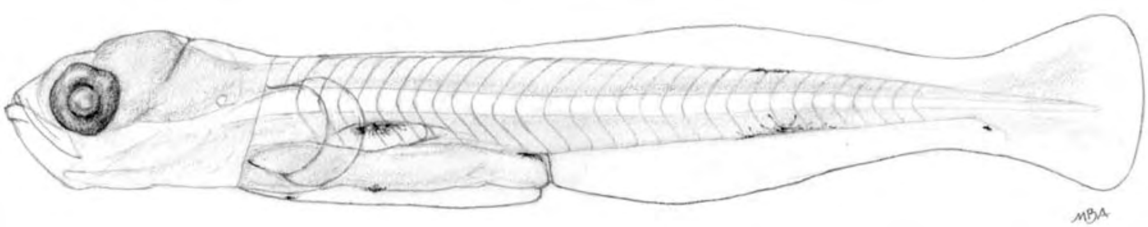


FIGURE 34-2.—Postlarva, 6.8 mm TL.

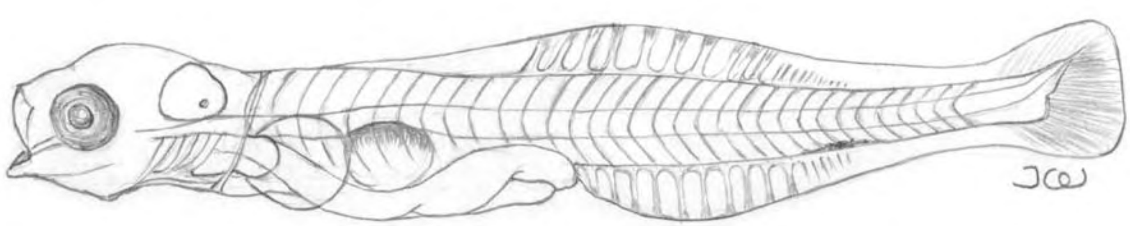


FIGURE 34-3.—Postlarva, 8 mm TL.

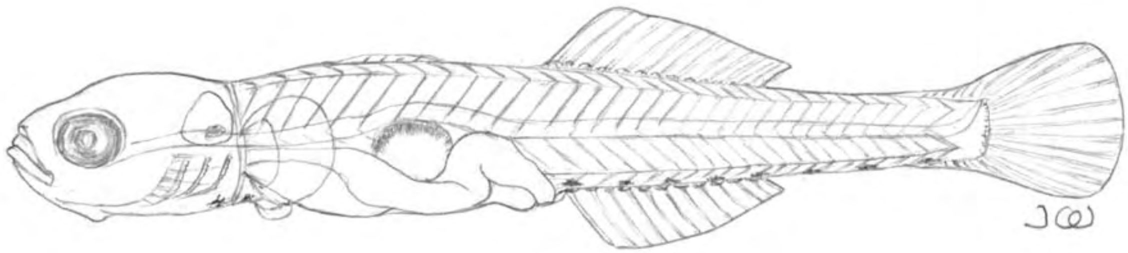


FIGURE 34-4.—Postlarva, 13.2 mm TL.

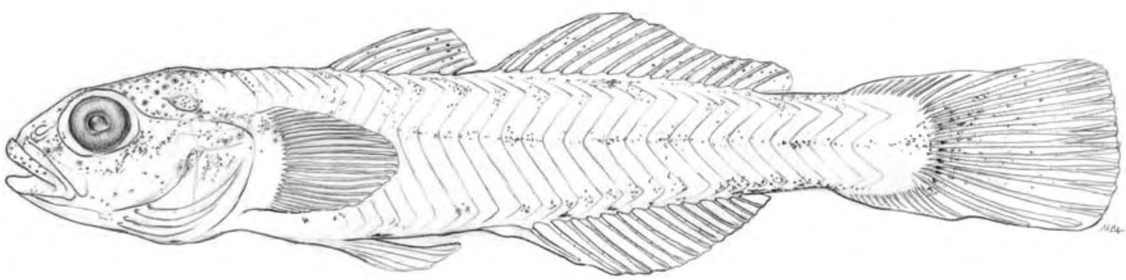


FIGURE 34-5.—Juvenile, 22.3 mm TL.

Gobiidae: *Clevelandia ios*, arrow goby.

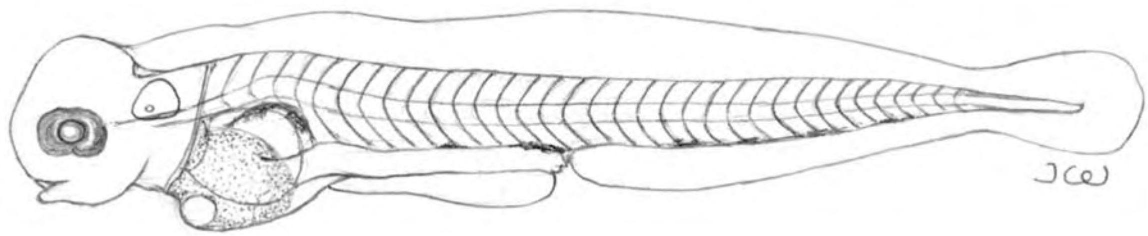


FIGURE 34-6.—Prolarva, 3.1 mm TL.

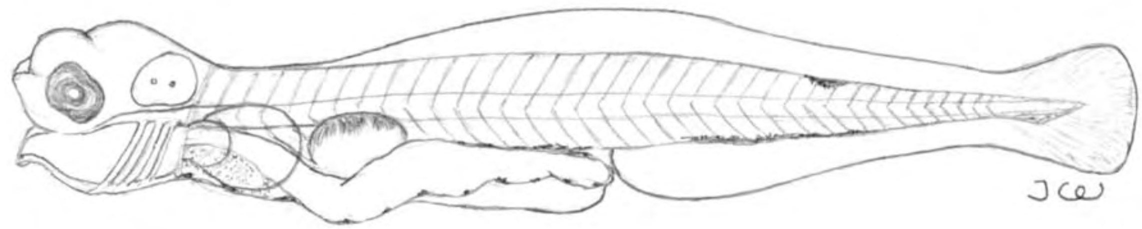


FIGURE 34-7.—Postlarva, 4.8 mm TL.

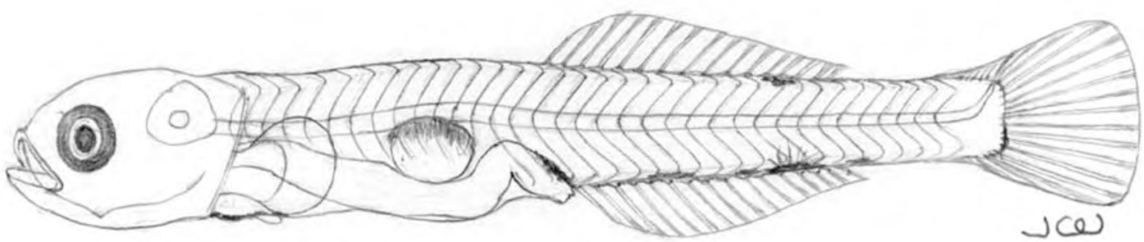


FIGURE 34-8.—Postlarva, 11.5 mm TL.

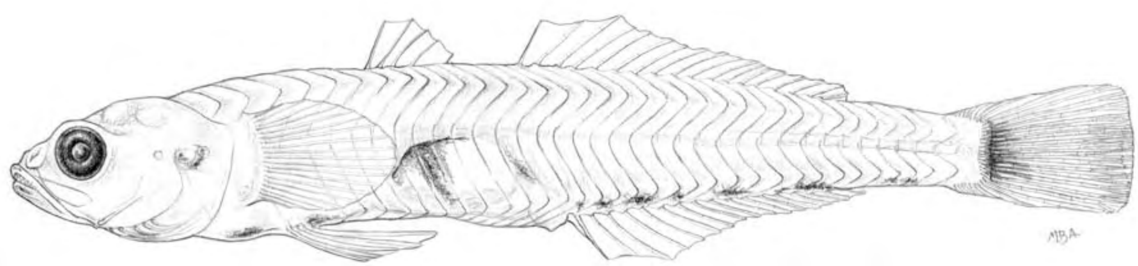


FIGURE 34-9.—Juvenile, 21.5 mm TL.

Gobiidae: *Coryphopterus nicholsi*, blackeye goby.

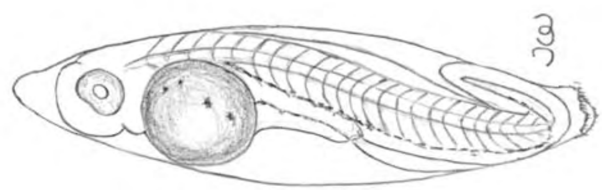


FIGURE 34-10.—Egg, late embryo, 2.2 mm diameter long axis, 1.2 mm short axis.

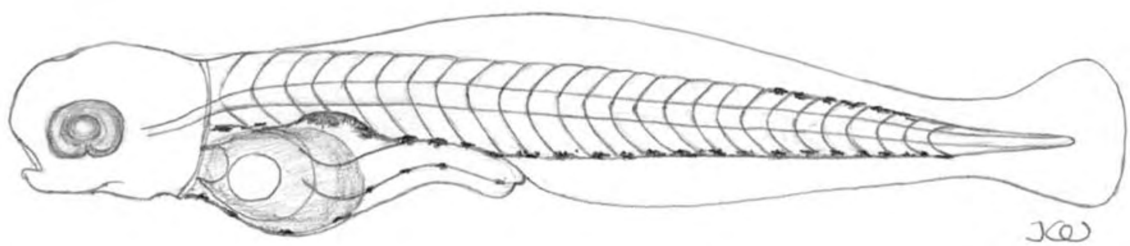


FIGURE 34-11.—Prolarva, 2.2 mm TL.

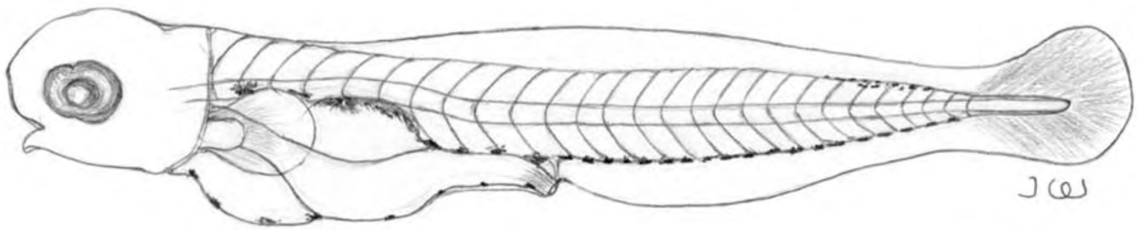


FIGURE 34-12.—Postlarva, 3.4 mm TL.

Gobiidae: *Eucyclogobius newberryi*, tidewater goby.

FIGURE 34-13.—Unfertilized egg. 1.8 mm diameter long axis, 0.8 mm short axis.

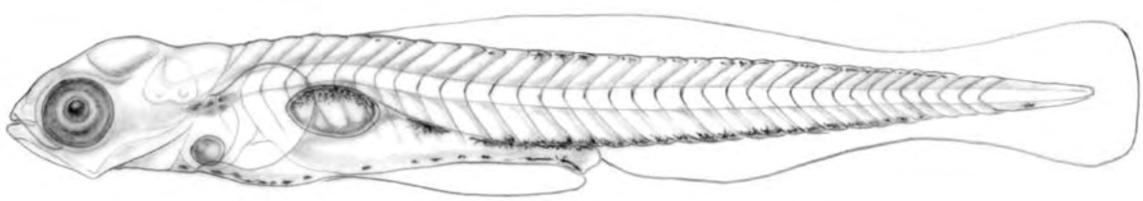


FIGURE 34-14.—Prolarva, 5.1 mm TL.

FIGURE 34-15.—Postlarva, 8.6 mm TL.

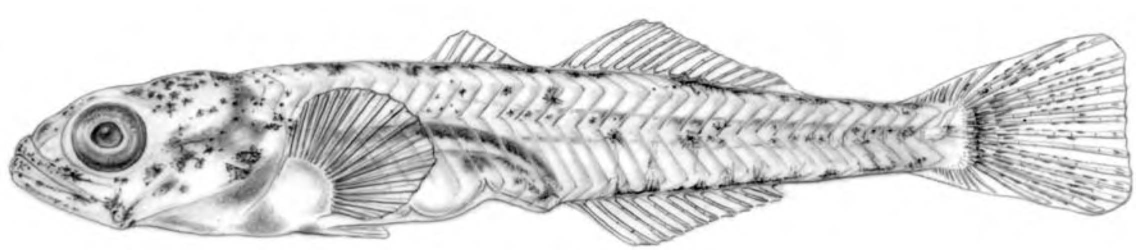


FIGURE 34-16.—Juvenile, 15 mm TL.

Gobiidae: *Gillichthys mirabilis*, longjaw mudsucker.

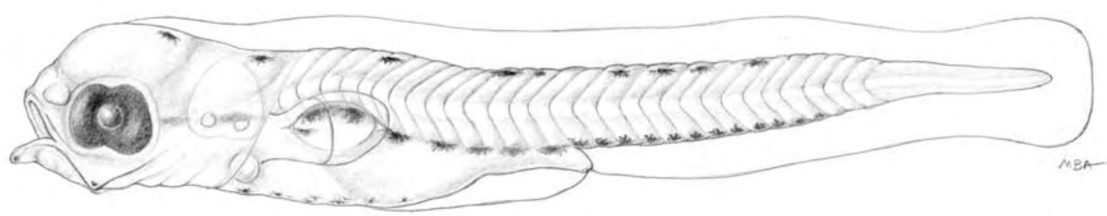


FIGURE 34-17.—Postlarva, 3.5 mm TL.

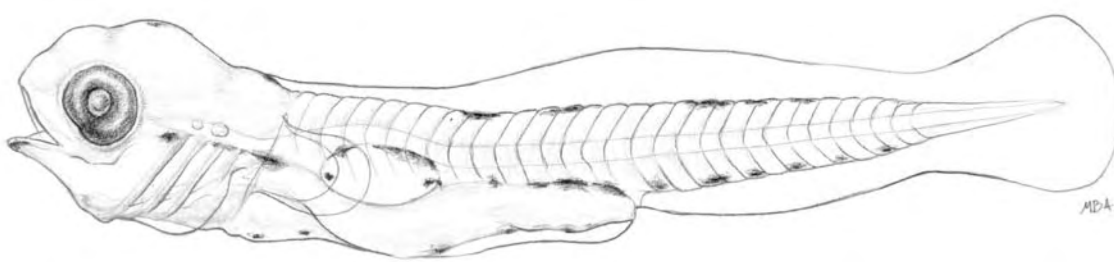


FIGURE 34-18.—Postlarva, 4.5 mm TL.

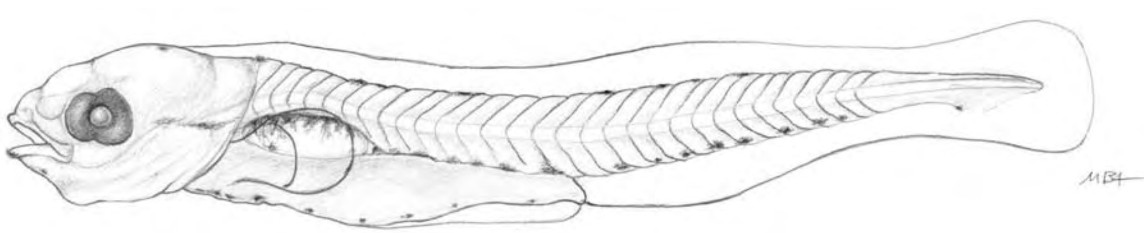


FIGURE 34-19.—Postlarva, 5.2 mm TL.

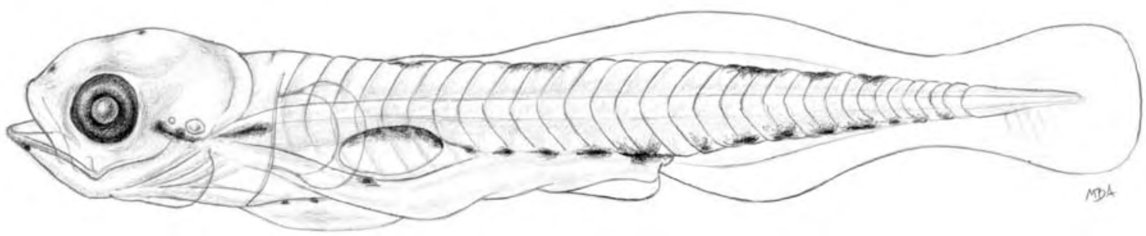


FIGURE 34-20.—Postlarva, 6.2 mm TL.

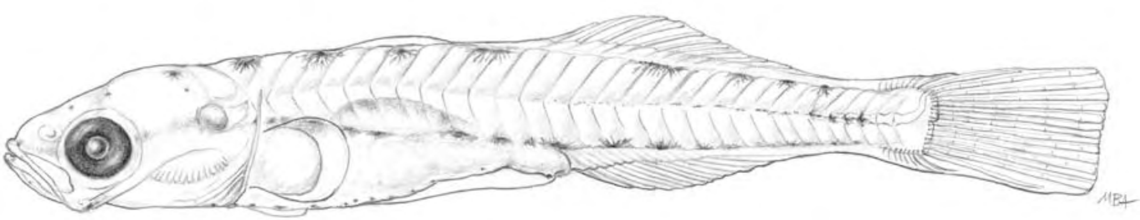


FIGURE 34-21.—Postlarva, 10.5 mm TL.

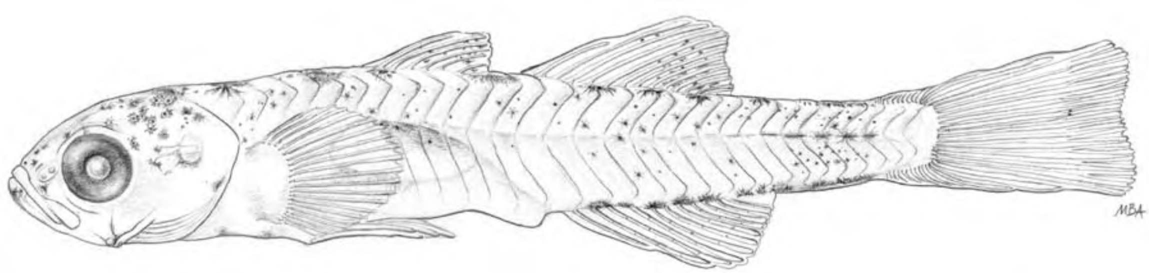


FIGURE 34-22.—Juvenile, 15 mm TL.

Gobiidae: *Ilypnus gilberti*, cheekspot goby.

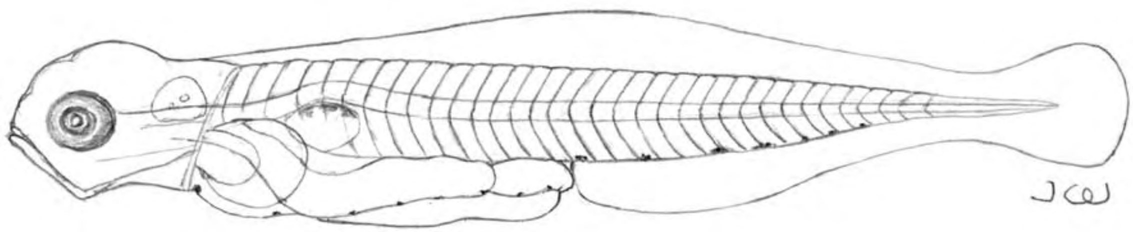


FIGURE 34-23.—Postlarva, 4.9 mm TL.

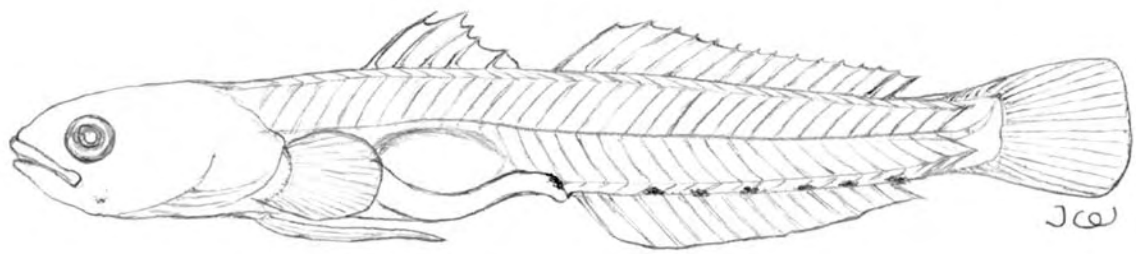


FIGURE 34-24.—Juvenile, 14.8 mm TL.

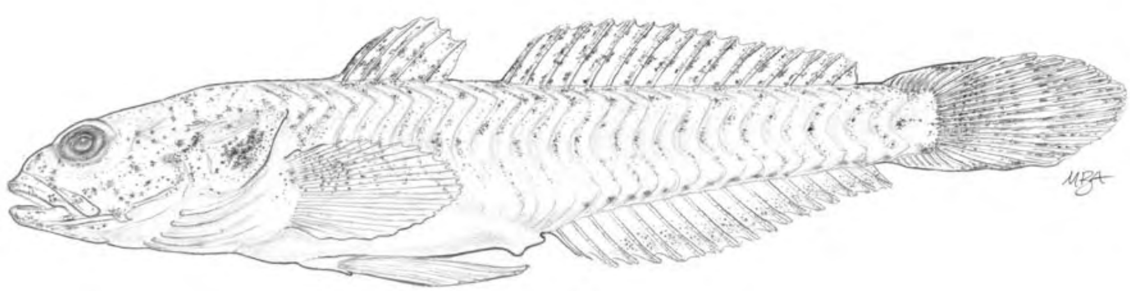


FIGURE 34-25.—Juvenile, 32 mm TL.

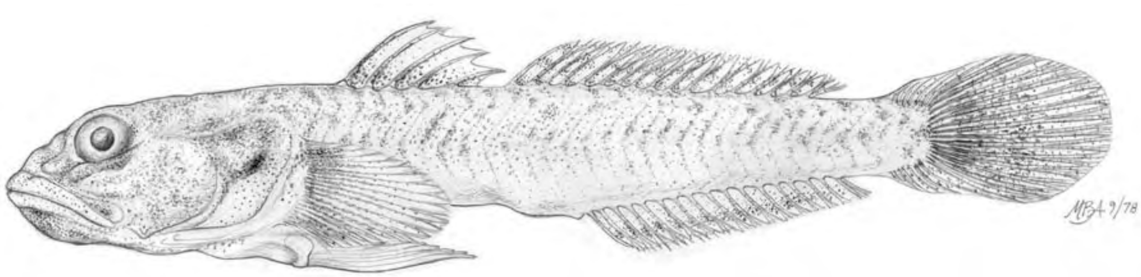


FIGURE 34-26.—Juvenile, 45 mm TL.

Gobiidae: *Lepidogobius lepidus*, bay goby.

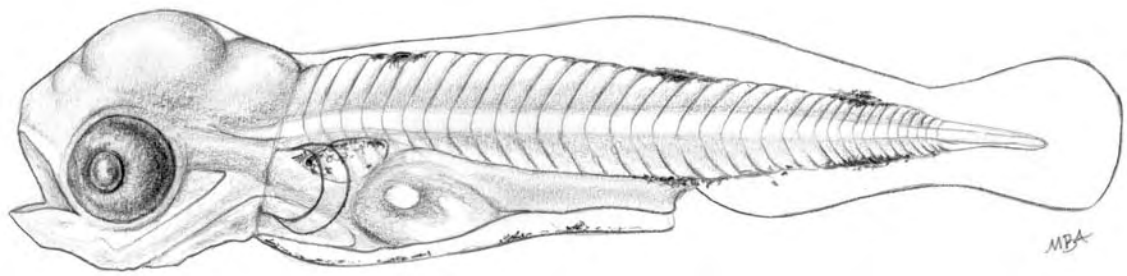


FIGURE 34-27.—Prolarva, 3.2 mm TL.

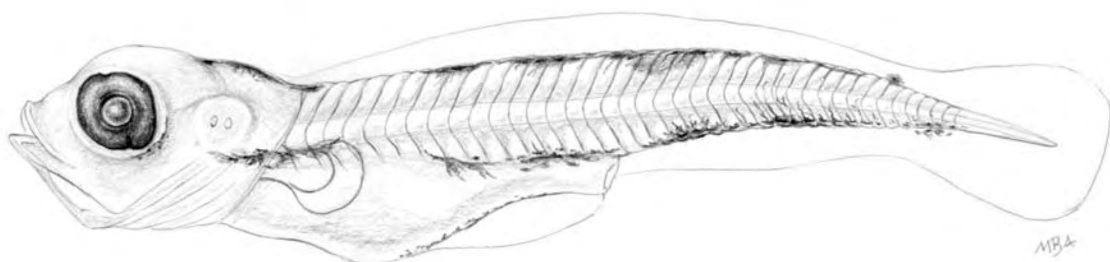


FIGURE 34-28.—Prolarva, 3.6 mm TL.

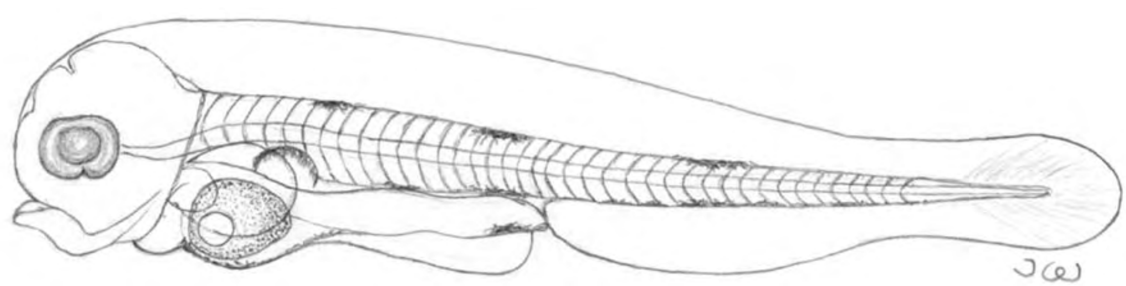


FIGURE 34-29.—Prolarva, 3.7 mm TL.

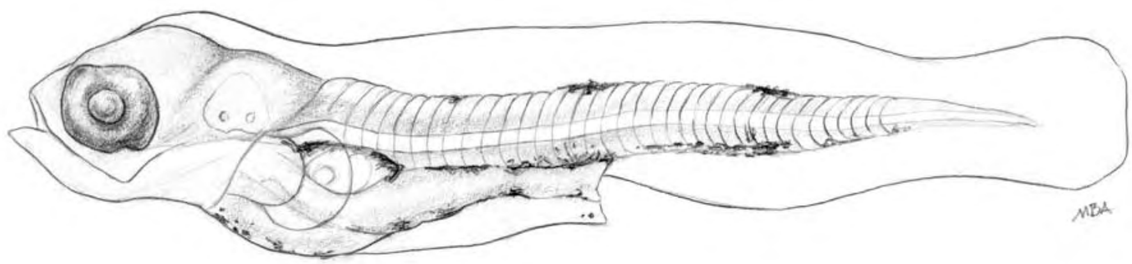


FIGURE 34-30.—Prolarva, 3.7 mm TL.

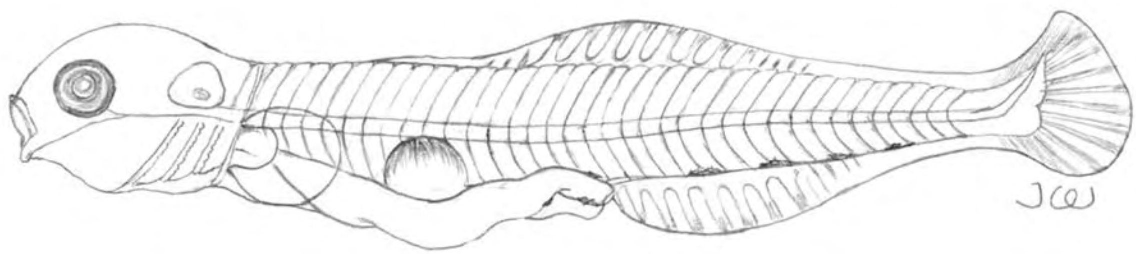


FIGURE 34-31.—Postlarva, 6.9 mm TL.

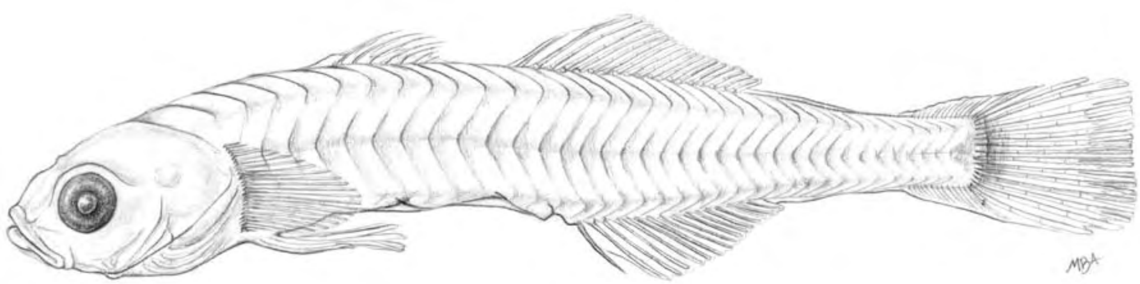


FIGURE 34-32.—Juvenile, 28 mm TL.

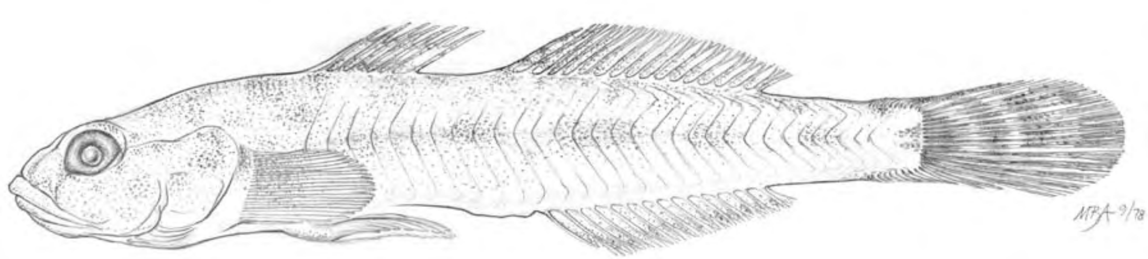


FIGURE 34-33.—Juvenile, 57 mm TL.

Gobiidae: *Tridentiger trigonocephalus*, chameleon goby.

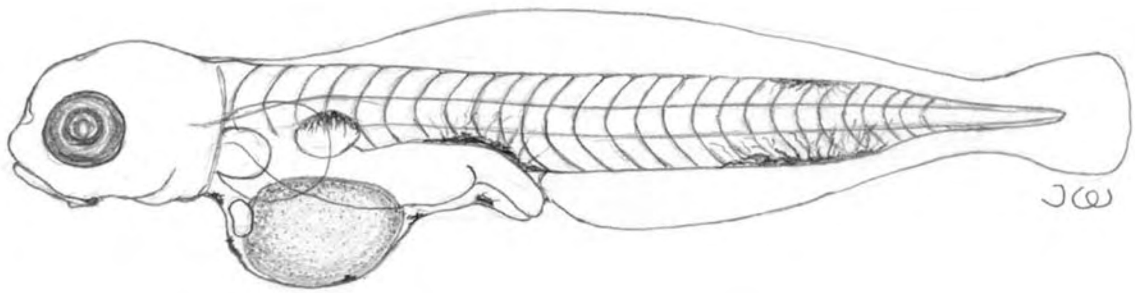


FIGURE 34-34.—Prolarva, 2.5 mm TL.

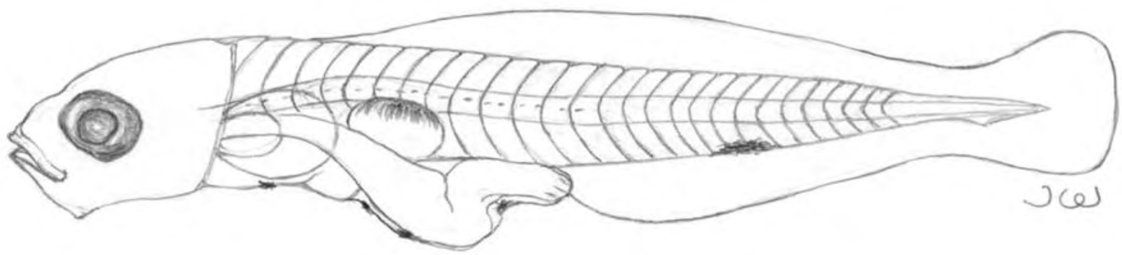


FIGURE 34-35.—Postlarva, 4.2 mm TL.

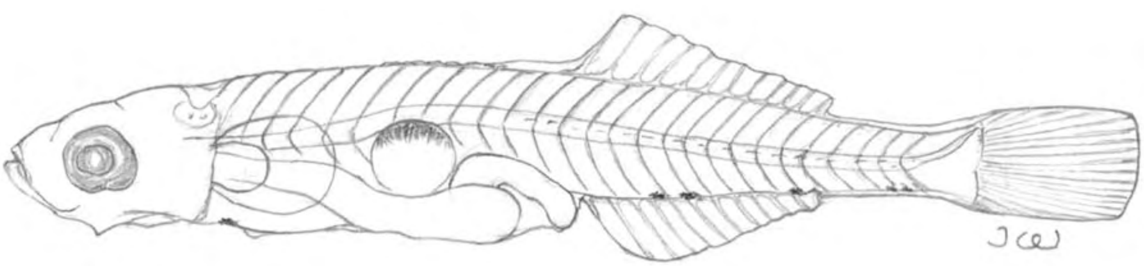


FIGURE 34-36.—Postlarva, 6.8 mm TL.

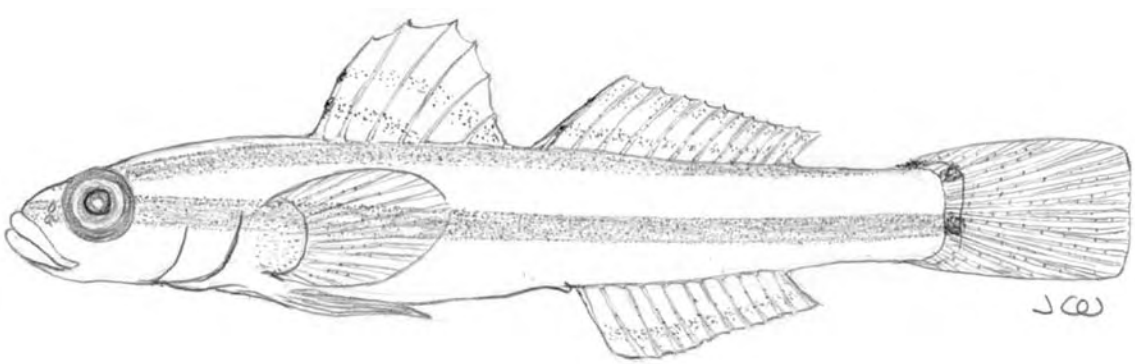


FIGURE 34-37.—Juvenile, 23.2 mm TL.

35. Stromateidae – Butterfishes

Five stromateids are known to the Pacific coast of the United States and Canada (Robins *et al.* 1980). Both the medusafish, *Icichthys lockingtoni*, and the Pacific pompano, *Peprilus simillimus*, are known to the San Francisco Bay area. Medusafish was once placed in the family Centrolophidae by Haedrich (1967), and its early life history has been documented by Ahlstrom and Moser (1976). Only the Pacific pompano is discussed in this manual.

References

Ahlstrom and Moser 1976, Haedrich 1967, Robins *et al.* 1980.

PACIFIC POMPANO, *Peprilus simillimus* (Ayres)

SPAWNING

Location	Mostly offshore along Pacific coast of southern California (Ahlstrom 1965); embayments (Eldridge 1977).
Season	Spring–summer (Fitch and Lavenberg 1975); April–May.
Salinity	Seawater.
Substrates	None, because presumably pelagic (Fitch and Lavenberg 1975).
Fecundity	64,200 to 74,360 for two 195-mm TL specimens.

CHARACTERISTICS

EGGS

Shape	Mature eggs, spherical.
Diameter	Mature eggs, 0.6–0.7 mm in diameter.
Yolk	Yellowish.
Oil globule	Mature egg, several oil globules.
Chorion	Transparent.
Adhesiveness	None.
Buoyancy	Presumably pelagic (Fitch and Lavenberg 1975).

LARVAE (FIGURE 35-1)

Snout to anus length	Ca. 44% of TL of larvae at 2.7 mm TL (this study).
Yolk sac	Spherical, in thoracic region.

Gut	Straight.
Total myomeres	29.
Preanal myomeres	14.
Postanal myomeres	15.
Pigmentation	Scattered melanophores cover head, body, gut, and tail.
Distribution	Pelagic, mostly offshore (Ahlstrom 1965), some embayments (Eldridge 1977).

JUVENILES (FIGURES 35-2)

Dorsal fin	III, 45–47 (Bane and Bane 1971, Hart 1973); II–IV, 41–48 (Miller and Lea 1972).
Anal fin	III, 40–44 (Bane and Bane 1971); II–III, 35–44 (Miller and Lea 1972); III, 39–44 (Hart 1973).
Pectoral fin	19–23 (Miller and Lea 1972); 20–22 (Hart 1973).
Mouth	Terminal or subterminal, small (Bane and Bane 1971).
Vertebrae	29–31 (Miller and Lea 1972); 29 (Hart 1973).
Distribution	San Francisco Bay (Herald and Simpson 1955, Aplin 1967, Green 1975) up to San Pablo Bay (Ganssle 1966).

LIFE HISTORY

The distribution of the Pacific pompano ranges from Cedros Island, Baja California (Roedel 1953), to Queen Charlotte Sound, British Columbia (Hart 1973). In the Sacramento-San Joaquin Estuary Pacific pompano have been observed in San Francisco Bay, but not in great numbers (Aplin 1967). Adults have been found in San Pablo Bay (Ganssle 1966) and Richardson Bay (Green 1975). Larvae were collected in Richardson Bay (Eldridge 1977). They have also been reported impinged on the traveling screens of the Potrero Powerplant (Herald and Simpson 1955) and the Hunters Point Powerplant. This species has been reported in Tomales Bay (Bane and Bane) and in Moss Landing Harbor-Elkhorn Slough (Kukowski 1972b, Nybakken *et al.* 1977, this study).

Fitch and Lavenberg (1975) stated that spawning apparently takes place in the spring and extends to July. They also believe that the eggs of the Pacific pompano are pelagic, but this has not been verified.

Inshore ichthyoplankton surveys at Diablo Canyon (Icanberry and Warrick 1978), Moss Landing Harbor-Elkhorn Slough (Nybakken *et al.* 1977), and San Francisco Bay (this study) did not capture any pompano larvae, but one larva was found in Richardson Bay in October 1972 (Eldridge 1977).

Fitch and Lavenberg (1975) reported that Pacific pompano feed on small crustaceans. In this study, crustaceans, marine invertebrates and unidentified detritus were observed in the gust of juvenile pompano which were mostly collected on the traveling screens of the Moss Landing Powerplant.

The age of maturity of the Pacific pompano is unclear in the literature. Pacific pompano is a valuable commercial species and is sold fresh (Hart 1973). They are very popular in San Francisco's Chinatown. In Tomales Bay, fish of this species were frequently captured by seine nets (Bane and Bane 1971).

References

Ahlstrom 1965; Aplin 1967; Bane and Bane 1971; Eldridge 1977; Fitch and Lavenberg 1975; Ganssle 1966; Green 1975; Hart 1973; Herald and Simpson 1955; Icanberry and Warrick 1978; Kukowski 1972b; Miller and Lea 1972; Nybakken *et al*. 1977; Roedel 1953.

Figure 35.—Stromateidae: *Peprilus simillimus*, Pacific pompano.

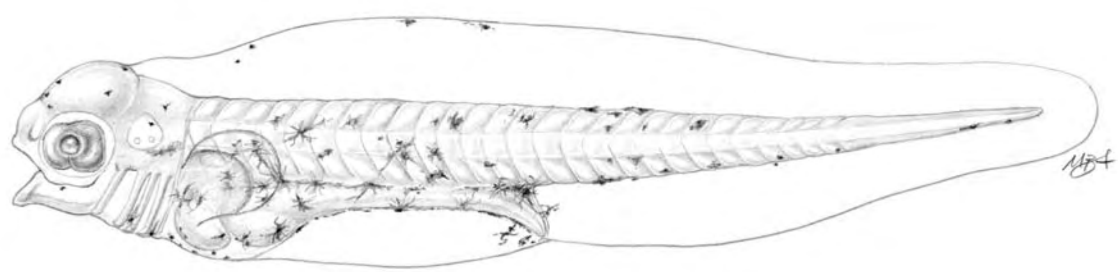


FIGURE 35-1.—Prolarva, 2.5 mm TL.

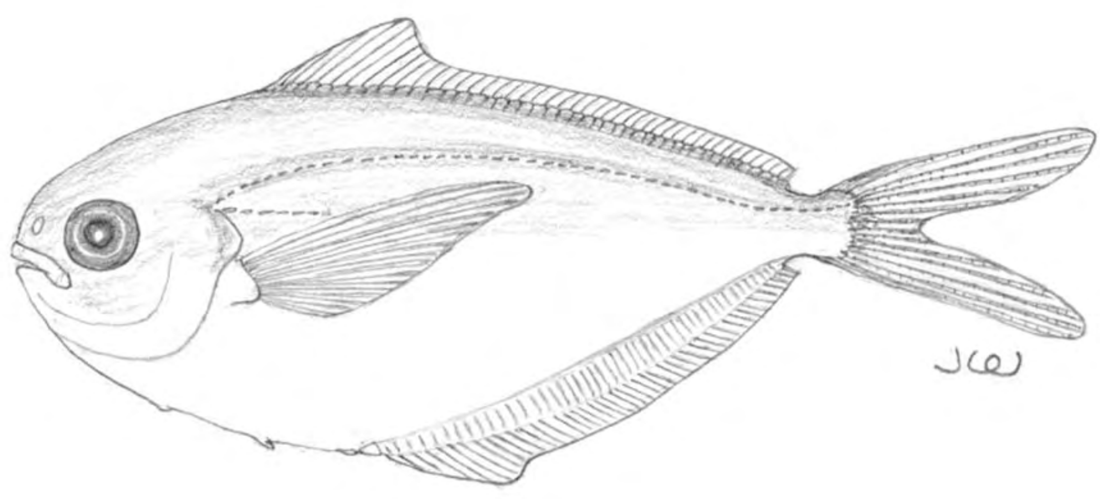


FIGURE 35-2.—Juvenile, 107 mm TL.

36. Scorpaenidae – Scorpionfishes

The scorpaenids comprise four genera and over 60 species along the Pacific coast of California (Miller and Lea 1972). Identification of each species, particularly the juvenile life stages, has been a challenging task for fisheries biologists. Early life histories of all or some of the rockfishes are discussed by Wales (1952), Morris (1956),Delacy and Dryfoos (1962), Delacy *et al*. (1964), Phillips (1964), Moser (1967), Westrheim *et al.* 1968, Westrheim 1975, Moser *et al.* (1977), and Richardson and Laroche (1979). The systematics of the ovoviviparous genus *Sebastes* has been reviewed by Chen (1971).

In this study, 7 species of rockfish were collected in San Francisco Bay and nearby coastal waters, and 13 species were found in Moss Landing Harbor-Elkhorn Slough:

Species	**San Francisco Bay and Nearby Coastal Waters**	**Moss Landing Harbor-Elkhorn Slough**
Kelp rockfish, *Sebastes atrovirens*	x	x
Brown rockfish, *Sebastes auriculatus*	x	x
Copper rockfish. *Sebastes caurinus*		x
Greenspotted rockfish, *Sebastes chlorostictus*	x	
Greenstriped rockfish, *Sebastes elongatus*	x	
Yellowtail rockfish, *Sebastes flavidus*		x
Chilipepper, *Sebastes goodie*		x
Shortbelly rockfish, *Sebastes jordani*		x
Quillback rockfish, *Sebastes maliger*	x	
Black rockfish, *Sebastes melanops*	x	x
Vermilion rockfish, *Sebastes miniatus*		x
Blue rockfish, *Sebastes mystinus*		x
Bocaccio, *Sebastes paucispinis*	x	x
Grass rockfish, *Sebastes rastrelliger*		x
Stripetail rockfish, *Sebastes saxicola*		x
Olive rockfish, *Sebastes serranoides*	x	x

The brown rockfish is the most common species found in San Francisco Bay (T. Echeverria 1980, personal communication). Eggs and larvae of the greenspotted rockfish, greenstriped rockfish, and quillback rockfish were collected from adults in the vicinity of the Farallon Islands by S. Hatfield, CDFG, in April and May 1979.

More than 20 types of larval *Sebastes* spp. were collected in San Francisco Bay and Moss Landing Harbor-Elkhorn Slough in this study, but they were not positively identified to species level.

The early life stages of the brown, greenspotted, greenstriped, and quillback rockfish are discussed in this chapter.

References

Chen 1971; Delacy and Dryfoos 1962; Delacy *et al.* 1964; Echeverria 1980, personal communication; Miller and Lea 1972; Morris 1956; Moser 1967; Moser *et al.* 1977; Phillips 1964; Richardson and Laroche 1979; Wales 1952; Westrheim *et al*. 1968; Westrheim 1975.

BROWN ROCKFISH, *Sebastes auriculatus* Girard

SPAWNING

Location	Along Pacific coastal waters adjacent to San Francisco Bay; some individuals may give birth in the Bay.
Season	Mating season unknown; larvae are born mostly in winter and early spring; in June in Puget Sound (Delacy and Dryfoos 1962); in May and June in Port Orchard, Washington (Delacy *et al.* 1964).
Salinity	Seawater.
Fecundity	52,000–340,000 (Delacy *et al.* 1964).

CHARACTERISTICS

EGGS (Figure 36-1)

Shape	Spherical to oval prior to hatching.
Diameter	Ca. 1.3 mm in short axis and ca. 1.5 mm in long axis.
Yolk	Yellowish, clear to opaque (Hitz and Delacy 1965).
Oil globule	Single, large, ca. 0.5 mm in diameter.
Chorion	Transparent, smooth.
Perivitelline space	Very narrow in late embryo stage.

LARVAE (Figures 36-2, 36-3, 36-4)

Length at hatching	4.70–6.65 mm TL (Delacy *et al.* 1964).
Snout to anus length	Ca. 42–45% of TL of larvae at 4.0–5.0 mm TL.
Yolk sac	Large, spherical to oval, extends from thoracic to abdominal region.
Oil globule	Single, large, ca. 0.3–0.4 mm in diameter, occasionally it will divide into several small oil globules.
Gut	Straight.

Air bladder	Small, oval, near pectoral fin.
Teeth	Sharp, apparent in postlarvae.
Size at completion of yolk-sac stage	Ca. 5.0–6.0 mm TL.
Total myomeres	25–27.
Preanal myomeres	10–11.
Postanal myomeres	15–16.
Last fin(s) to complete development	Spinal dorsal fin.
Pigmentation	Melanophores along postanal region and a few scattered on lateral and dorsal regions anterior to tail in prolarvae; pigmentation variable and unstable prior to extrusion (Westrheim 1975); large stellate melanophores on head, dorsum, dorsal surface of gut, and anus, small melanophores along postanal region in postlarvae.
Distribution	Pelagic, in coastal waters, also found in San Francisco Bay and Moss Landing Harbor-Elkhorn Slough.

JUVENILES (Figure 36-5)

Dorsal fin	XIII, 12–15 (Bane and Bane 1971, Miller and Lea 1972, Hart 1973).
Anal fin	III, 6–8 (Bane and Bane 1971, Hart 1973); III, 5–8 (Miller and Lea 1972).
Pectoral fin	15–19 (Miller and Lea 1972).
Mouth	Terminal, large, upper jaw extends beyond posterior margin of eye (Hart 1973).
Vertebrae	26 (Miller and Lea 1972).
Distribution	Early juveniles are pelagic, gradually settling on the bottom in association with rocks, jetties, pilings, and seaweed in San Francisco Bay, San Pablo Bay, and Moss Landing Harbor-Elkhorn Slough.

LIFE HISTORY

The brown rockfish ranges from Mipolito Bay, Baja California, to southeastern Alaska (Wilimovsky 1954, Phillips 1957). In the study area, the brown rockfish is the most common rockfish in San Francisco Bay and San Pablo Bay (Aplin 1967, this study), but they are uncommon in less saline waters (Ganssle 1966, Messersmith 1966). This species is also common in Tomales Bay (Bane and Bane 1971), Bodega Bay (Standing *et* *al.* 1975), and Moss Landing Harbor-Elkhorn Slough (Kukowski 1972b, Nybakken *et al.* 1977).

Brown rockfish are ovoviviparous: fertilization is internal, and in general, the larvae of *Sebastes* spp. develop in the egg capsule within the ovarian cavity. The egg capsule ruptures upon contact with seawater (Frey 1971). In this study, eggs and larvae were collected from ripe female brown rockfish. Some of the larvae had large yolk sacs, while others had absorbed their yolk sacs. It appears that some hatching occurs within the ovarian cavity. In Puget Sound, the majority of gravid females were found in May (Delacy *et al.* 1964). In the study area, mature females were observed in winter and spring. Pelagic larvae were collected in San Francisco Bay, San Pablo Bay, and Moss Landing Harbor-Elkhorn Slough. Other, unidentified larvae of Sebastes spp. were collected at similar periods as those of brown rockfish larvae. Larvae were captured in winter and spring and juveniles in summer and fall.

Few brown rockfish larvae or early juveniles (ca. 10 mm TL) were observed in this study. Their habitat and behavior are poorly known. Feder *et al.* (1974) have reported that juvenile rockfish prefer depths of 10–30 m, and are found near the bottom. In the study area, juveniles were often observed at the intake screens of the Potrero, Hunters Point, and Oleum Powerplants in summer and fall. The diet of juvenile brown rockfish consists mainly of small crustaceans and small fish (Bane and Bane 1971, Feder *et al.* 1974).

The age of maturity is unclear in the literature. Brown rockfish are often captured by sport fishermen along rocky shores of the bays and the ocean (Miller and Gotshall 1965, this study).

References

Aplin 1967, Bane and Bane 1971, Delacy and Dryfoos 1962, Delacy *et al.* 1964, Feder *et al.* 1974, Frey 1971, Ganssle 1966, Hart 1973, Hitz and Delacy 1965, Kukowski 1972b, Messersmith 1966, Miller and Gotshall 1965, Miller and Lea 1972, Nybakken *et al.* 1977, Phillips 1957, Standing *et al.* 1975, Westrheim 1975, Wilimovsky 1954.

GREENSPOTTED ROCKFISH, *Sebastes chlorostictus* (Jordan and Gilbert)

SPAWNING

Location	In the vicinity of Cordell Bank, outside of San Francisco Bay.
Season	Eggs and larvae were observed in May.

CHARACTERISTICS

EGGS (Figure 36-6)

Shape	Oval prior to hatching.

Diameter	Short axis, 0.8–1.0 mm, long axis, 1.2–1.3 mm.
Yolk	Golden yellow, clear.
Oil globule	Single, large, 0.25–0.3 mm in diameter.
Chorion	Transparent, elastic, smooth.
Perivitelline space	Narrow prior to hatching.
Adhesiveness	None.

LARVAE (Figure 36-7)

Length at hatching	Ca. 3.4–4.0 mm TL.
Snout to anus length	Ca. 34–38% of TL of larvae (dissected from adult) at 3.2–3.4 mm TL.
Yolk sac	In thoracic region; initially large, spherical, becoming small, oval prior to birth.
Oil globule	Single, ca. 0.2 mm in diameter, at various locations in yolk sac.
Gut	Straight, bending ventrally in anal region.
Total myomeres	26–27.
Preanal myomeres	8–9.
Postanal myomeres	18.
Pigmentation	At 3.2–3.4 mm TL, scattered melanophores are found in the posterior portion of the yolk-sac region.
Distribution	Assumed to be coastal waters outside of San Francisco Bay.

JUVENILES

Dorsal fin	XIII, 11–15 (Chen 1971, Miller and Lea 1972).
Anal fin	III, 5–7 (Chen 1971, Miller and Lea 1972).
Pectoral fin	16–18 (Chen 1971, Miller and Lea 1972).
Mouth	Terminal, large, maxillary reaching to the posterior edge of pupil or further (Chen 1971).
Vertebrae	26–27 (Chen 1971, Miller and Lea 1972).
Distribution	Deep waters in Monterey Bay and Morro Bay areas (Miller and Gotshall 1965); assumed to be in the vicinity of Cordell Bank.

LIFE HISTORY

The greenspotted rockfish is commonly found from Cedros Island, Baja California, to San Francisco (Phillips 1975), however Hoover (1964), reported a single specimen from Copalis Island, Washington. Kukowski (1972b) has reported this species in Monterey

Bay. In the study area, the greenspotted rockfish was taken to the northeast of Cordell Bank near the Farallon Islands. This species was not recorded in San Francisco Bay.

Judging from the gravid adult fish taken in this study, spawning occurs in the spring months. Larvae, in the ovary prior to birth, have sparse melanophores on the yolk sac; otherwise, the larvae have little pigmentation.

This species is distributed to depths of at least 100 m (Chen 1971). They are rarely found in shallow reef areas (Miller and Gotshall 1965). The largest reported specimens collected were 347 mm (Chen 1971) and 375 mm (Moser 1966). Age, growth, and maturity are unclear in the literature, although the systematics of the greenspotted rockfish have been reviewed by Chen (1971).

The greenspotted rockfish is of some sport value in the Monterey Bay and Morro Bay areas (Miller and Gotshall 1965).

References

Chen 1971, Hoover 1964, Miller and Gotshall 1965, Kukowski 1972b,Miller and Lea 1972, Moser 1966, Phillips 1957.

Specimen Credits

Larvae were obtained from S. Hatfield, CDFG, Stockton Office.

GREENSTRIPED ROCKFISH, *Sebastes elongatus* Ayres

SPAWNING

Location	Near Farallon Islands off San Francisco Bay.
Season	Young are born in late spring or early summer off the Oregon coast (Hitz 1962); gravid adults were observed in June near the Farallon Islands.

CHARACTERISTICS

EGGS (Figure 36-8)

Shape	Oval prior to hatching.
Diameter	Short axis, 0.9–1.2 mm; long axis, 1.3–1.6 mm.
Yolk	Golden yellow, clear.
Oil globule	Single, 0.3 mm in diameter.
Chorion	Transparent, thin.
Perivitelline space	Very narrow.
Adhesiveness	None.

LARVAE (Figure 36-9)

Length at hatching	Ca. 5 mm. (Delacy *et al.* 1964, Westrheim *et al.* 1968).
Snout to anus length	Ca. 34–36% of TL of larvae (dissected from adult) at 4.1–4.5 mm TL.
Yolk sac	Oval to flat, extends from thoracic to abdominal region.
Oil globule	Golden yellow, single, ca. 0.25–0.33 mm in diameter, located mostly in anterior portion of yolk sac.
Gut	Straight.
Total myomeres	27–29.
Preanal myomeres	6–8.
Postanal myomeres	20–22.
Pigmentation	Prolarvae, ca. 14–22 melanophores along postanal region; scattered melanophores are also found along dorsal surface of the body cavity, gut, and midventral regions.
Distribution	Assumed in the vicinity of Farallon Islands.

JUVENILES

Dorsal fin	XIII, 12–14 (Miller and Lea 1972, Hart 1973).
Anal fin	III, 6–7 (Miller and Lea 1972); III, 6 (Hart 1973).
Pectoral fin	16–18 (Miller and Lea 1972).
Mouth	Terminal, moderate, lower jaw slightly projecting; maxillary reaching about to posterior edge of pupil of eye (Hart 1973).
Distribution	In both inshore and offshore waters of the Pacific (Alverson *et al.* 1964); in the vicinity of Farallon Islands.

LIFE HISTORY

The greenstriped rockfish has been found from Cedros Island, Baja California, to Montague Island, Alaska (Miller and Lea 1972). This species has been reported in Monterey Bay (Kukowski 1972b). In this study, greenstriped rockfish were collected near the Farallon Islands by the CDFG in June 1979, and they apparently inhabit deep water (Miller and Gotshall 1965).

Greenstriped rockfish give birth to their young in late spring or early summer off the Oregon coast (Hitz 1962), the Washington coast (Smith 1936), and British Columbia (Westrheim *et al.* 1968).

Larvae, in the late developmental stages, were dissected from female fish in June 1979. Those larvae had 27–29 myomeres and a series of melanophores along the postanal and gut regions.

Alverson *et al.* (1964) found the greenstriped rockfish to be common in depths of 91–366 m. The maximum length is 38 cm, the maximum weight, 0.3 kg.

The greenstriped rockfish is of some sport value (Miller and Gotshall 1965).

References

Alverson *et al.* 1964, Delacy *et al.* 1964, Hart 1973, Hitz 1962, Kukowski 1972b, Miller and Gotshall 1965, Miller and Lea 1972, Smith 1936, Westrheim *et al.* 1968.

Specimen Credits

Eggs and larvae were obtained from S. Hatfield, CDFG (Stockton Office).

QUILLBACK ROCKFISH, *Sebastes maliger* (Jordan and Gilbert)

SPAWNING

Location	In the vicinity of the Farallon Islands.
Season	Eggs and larvae were observed in May.

CHARACTERISTICS

EGGS (FIgure 36-10)

Shape	Oval or slightly irregular prior to hatching.
Diameter	Short axis, 1.0–1.3 mm; long axis, 1.4–1.6 mm.
Yolk	Golden yellow, clear.
Oil globule	Single, ca. 0.25–0.3 mm in diameter.
Perivitelline space	Narrow prior to hatching.
Adhesiveness	None.

LARVAE (Figure 36-11)

Length at hatching	Ca. 4.1 mm TL or larger.
Snout to anus length	Ca. 36–39% of prolarvae (dissected from adult at 3.9–4.1 mm TL).
Yolk sac	Golden yellow, from large spherical to small oval shapes, becoming translucent prior to hatching.
Oil globule	Golden yellow, single, ca. 0.2–0.3 mm in diameter, located most often in anterior portion of yolk sac.

Gut	Straight.
Total myomeres	28–30.
Preanal myomeres	9–10.
Postanal myomeres	18–20.
Pigmentation	In prolarvae, a series of very dense melanophores along postanal region up to caudal peduncle; less numerous melanophores along middorsal region near tail, sparse melanophores are also found in yolk-sac region.
Distribution	Assumed in the vicinity of Farallon Islands.

JUVENILES

Dorsal fin	XIII, 12–14 (Miller and Lea 1972, Hart 1973).
Anal fin	III, 6–7 (Miller and Lea 1972, Hart 1973).
Pectoral fin	16–18 (Miller and Lea 1972, Hart 1973).
Mouth	Terminal, large, maxillary reaching about midorbit, upper jaw slightly projecting (Hart 1973).
Vertebrae	29–33 (Miller and Lea 1972).
Distribution	Shallow inlets to depths or 275 m. (Alverson *et al*. 1964, Grinols 1965, Miller and Gotshall 1965).

LIFE HISTORY

The quillback rockfish is found from Point Sur, central California, to the Gulf of Alaska (Phillips 1957, Hart 1973). Locally, they have been recorded in both shallow and deep water from Bodega Bay to the Farallon Islands and Monterey Bay (Miller and Gotshall 1965). In this study, quillback rockfish were captured near the southwest end of the Farallon Islands by CDFG biologists in May 1979. This species was not reported in San Francisco Bay.

Judging from the gravid female and developmental conditions of the ovary, this species is estimated to spawn in the spring. As in other *Sebastes* spp., the eggs become oval in the late embryonic stages. Larvae with large golden yolk sacs or with small yolk sacs were found in the ovaries of gravid females.

The maximum length of the quillback has been recorded as 61 cm and its weight as 0.7 kg (Phillips 1957). In California the quillback rockfish has some sport value (Miller and Gotshall 1965), in Canada this species is an important sport and commercial fish (Hart 1973).

References

Alverson *et al.* 1964, Grinols 1965, Hart 1973, Miller and Gotshall 1965; Miller and Lea 1972, Phillips 1957.

Characteristic Comparison: Rockfishes

Characteristic	**Brown Rockfish**	**Greenspotted Rockfish**	**Greenstriped Rockfish**	**Quillback Rockfish**
Eggs				
Shape	Spherical to oval	Oval	—	—
Diameter (mm)	Long axis: ca. 1.5	Long axis: 1.2–1.3	—	—
	Short axis: ca. 1.3	Short axis: 0.8–1.0	—	—
Larvae				
Total myomeres	25–27	26–27	27–29	28–30
Preanal myomeres	10–11	8–9	6–8	9–10
Postanal myomeres	15–16	18	20–22	18–20
Pigmentation	Prolarvae: melanophores along postanal region; a few scattered on lateral and dorsal regions anterior to tail	Prolarvae: scattered melanophores in posterior portion of yolk-sac region	Prolarvae: ca. 14–22 melanophores along postanal region; scattered melanophores also along dorsal surface of body cavity, gut, and midventral region	Prolarvae: a series of dense melanophores along postanal region to caudal peduncle; less numerous melanophores along middorsal region near tail; sparse melanophores in yolk-sac region
Juveniles				
Dorsal fin	XIII, 12–15	XIII, 11–15	XIII, 12–14	XIII, 12–14
Anal fin	III, 5–8	III, 5–7	III, 6–7	III, 6–7
Pectoral fin	15–19	16–18	16–18	16–18
Vertebrae	26	26–27	26–27	29–33

Figure 36.—Scorpaenidae: *Sebastes auriculatus*, brown rockfish.

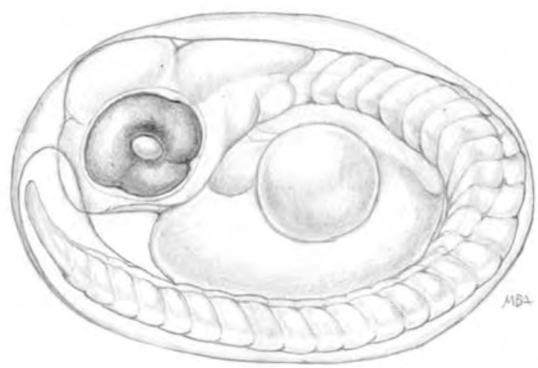


FIGURE 36-1.—Late embryo dissected from adult, 1.8 mm diameter long axis, 1.1 mm short axis.

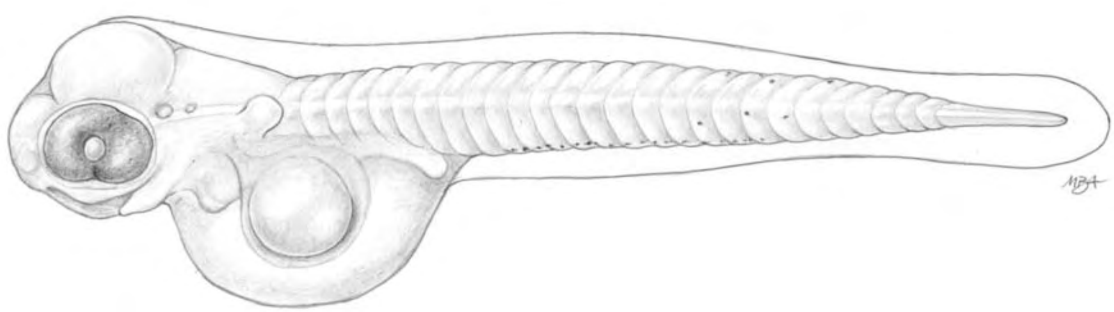


FIGURE 36-2.—Prolarva dissected from adult, 4.5 mm TL.

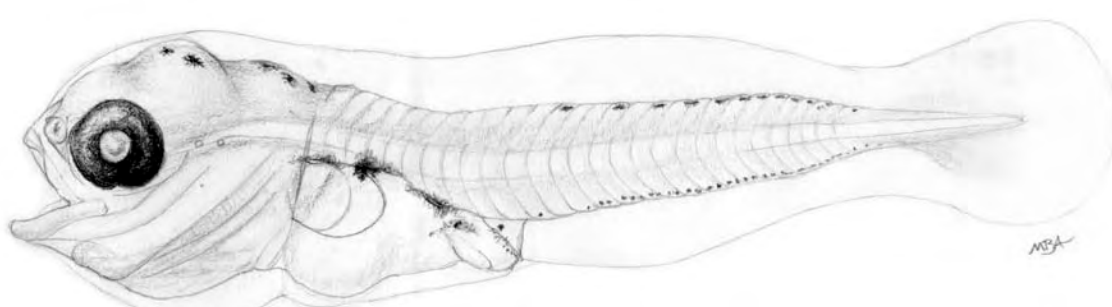


FIGURE 36-3.—Postlarva, 5.3 mm TL.

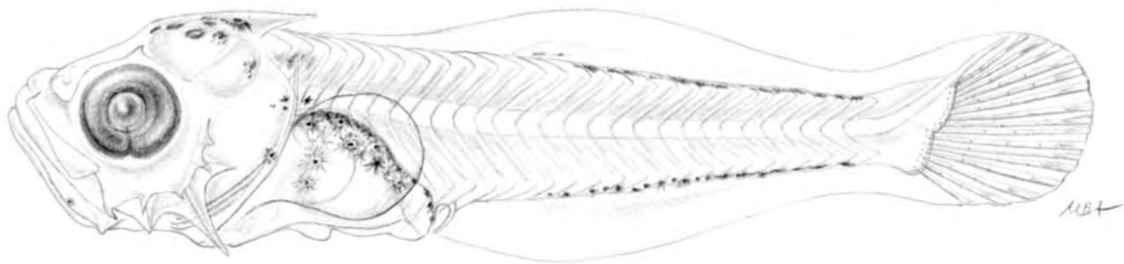


FIGURE 36-4.—Postlarva, 10.1 mm TL.

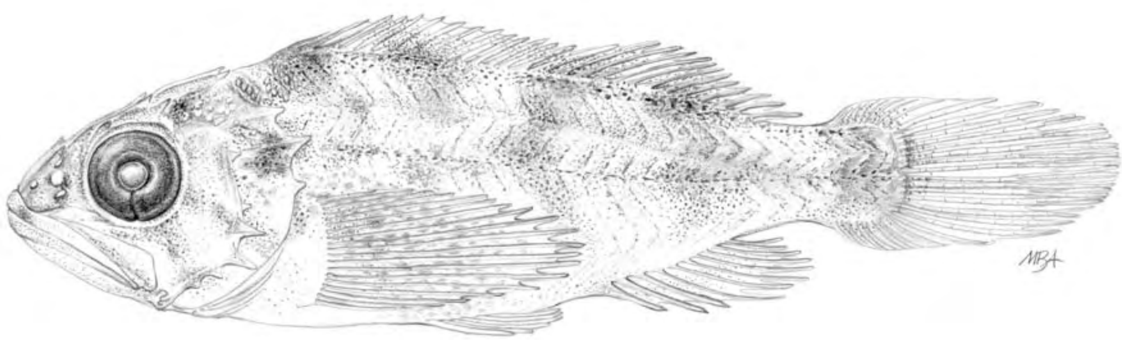


FIGURE 36-5.—Juvenile, 36.8 mm TL.

Scorpaenidae: *Sebastes chlorostictus*, greenspotted rockfish.

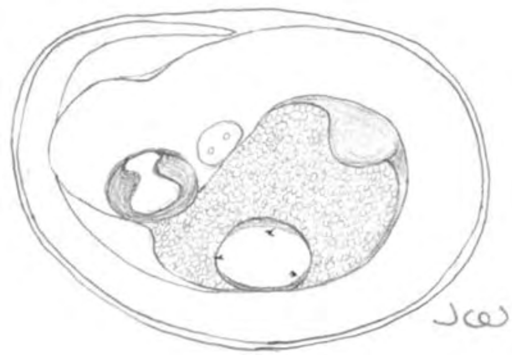


FIGURE 36-6.—Late embryo dissected from adult, 1.7 mm long axis, 1.2 mm short axis diameter.

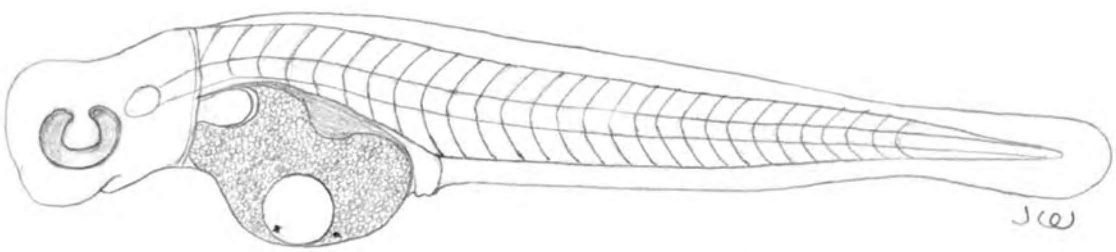


FIGURE 36-7.— Prolarva dissected from adult, 3.4 mm TL.

Scorpaenidae: *Sebastes elongates*, greenstriped rockfish.

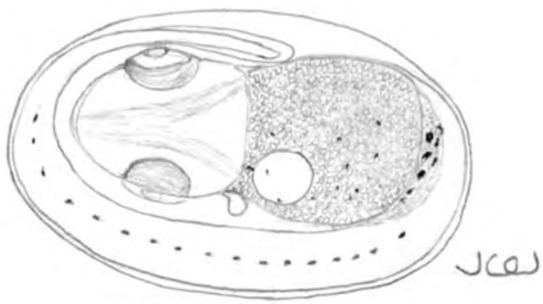


FIGURE 36-8.—Late embryo dissected from adult, 1.6 mm long axis, 0.9 mm short axis diameter.

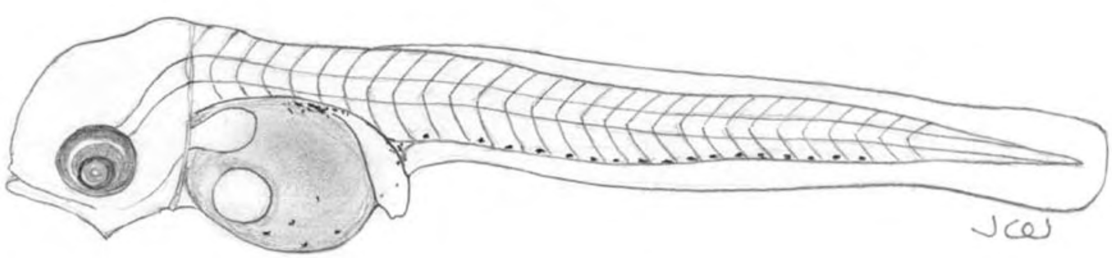


FIGURE 36-9.—Prolarva dissected from adult, 4.0 mm TL.

Scorpaenidae: *Sebastes maliger*, quillback rockfish.

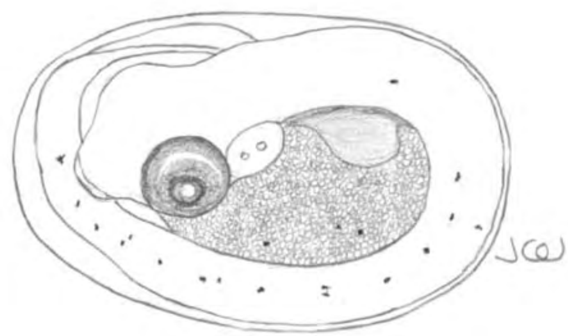


FIGURE 36-10.—Late embryo dissected from adult, 1.5 mm long axis, 1.1 mm short axis diameter.

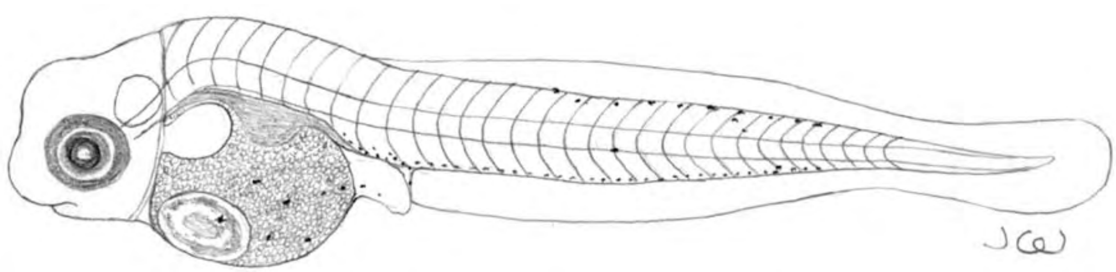


FIGURE 36-11.—Prolarva dissected from adult, 4.1 mm TL.

37. Hexagrammidae – Greenlings

Nine species of greenlings are known to the Pacific coast of the United States and Canada (Robins *et al.* 1980). Four of the nine species have been found in the study area: they are kelp greenling, *Hexagrammos decagrammus*, rock greenling, *Hexagrammos logocephalus*, lingcod, *Ophiodon elongatus*, and painted greenling, *Oxylebius pictus*. The kelp greenling, lingcod, and painted greenling are discussed in this chapter.

References

Robins *et al.* 1980.

KELP GREENLING, *Hexagrammos decagrammus* (Pallas)

SPAWNING

Location	Kelp zone of inlets (Marliave 1975) coastal inshore waters; may occur in embayments.
Season	Fall and early winter (Fitch and Lavenberg 1971); October and November (Hart 1973, Baxter 1966); winter (Feder *et al.* 1974) November and December (Marliave 1975); December–March.
Temperature	Ca. 10–12°C.
Salinity	Seawater.
Substrates	On rocky substrates (Fitch and Lavenberg 1971).

CHARACTERISTICS

EGGS (Figure 37-1)

Shape	Spherical.
Diameter	2.2–2.4 mm.
Yolk	Pale blue (Clemens and Wilby 1946, Fitch and Lavenberg 1971, Hart 1973, Baxter 1974); brown (Marliave 1975); yellowish to green to blue, with granular structure.
Oil globule	Several oil globules in early embryo stage, which consolidate into one oil globule prior to hatching.
Chorion	Transparent, thick.
Perivitelline space	Very narrow, particularly at the stage prior to hatching.
Egg mass	Form large cluster (Hart 1973).

Adhesiveness	Strongly adhesive to each other, at one or more than one spot, some eggs have fibrous filaments.
Buoyancy	Demersal.

LARVAE (Figure 37-2)

Length at hatching	Ca. 7.0–8.0 mm TL.
Snout to anus length	Ca. 33% of TL (Marliave 1975); ca. 32–34% of larvae at 8.4–10.0 mm TL.
Yolk sac	Large, spherical, extending from jugular to abdominal region (Marliave 1975, this study).
Oil globule	Single large oil globule located in anterior of yolk sac (Marliave 1975); many small oil globules scattered in yolk sac.
Gut	Straight, thick, curved, bending ventrally in anal region.
Air bladder	None.
Teeth	Small, pointed, apparent in postlarval stage.
Size at completion of yolk-sac stage	Ca. 9.5–10.0 mm TL.
Total myomeres	52–56.
Preanal myomeres	15–17.
Postanal myomeres	36–40.
Last fin(s) to complete development	Pelvic.
Pigmentation	Stellate melanophores on head, dorsal surface of gut and inner lining of body cavity; single row of large stellate melanophores on middorsum; no postanal pigmentation in prolarvae; some melanophores along postanal region in postlarval stage; 2 rows of melanophores run longitudinally along side of the body.
Distribution	Deeper coastal waters (Follett 1952); high seas or pelagic (Gorbunova 1962).

JUVENILES (Figure 37-3)

Dorsal fin	XXII, 24 (Follett 1952); XXI, 24 (Bane and Bane 1971); XX–XXIII, 22–26 (Miller and Lea 1972); XXI–XXII, 24 (Hart 1973).
Anal fin	I, 22 (Follett 1952); I, 23 (Bane and Bane 1971); O–I, 21–25 (Miller and Lea 1972); I, 23–24 (Hart 1973).

Pectoral fin	19–20 (Follett 1952); 18–20 (Miller and Lea 1972); 19 (Hart 1973).
Mouth	Terminal, small, directed forward (Hart 1975).
Vertebrae	55 (Follett 1952); 54–56 (Miller and Lea 1972).
Distribution	High seas (Gorbunova 1962); coastal waters as well (Hart 1973).

LIFE HISTORY

The kelp greenling ranges from San Pablo, Los Angeles Harbor, to Alaska and both sides of the Aleutian Islands (Roedel 1953, Gorbunova 1962, Wilimovsky 1964). In the study area, larvae of the kelp greenling were collected in Richardson Bay (S. Goodwin 1980, personal communication with M. Eldridge), various life stages of this species were found in deeper water off San Francisco Bay (Follett 1953). The species was also reported in Tomales Bay (Bane and Bane 1971). The egg through adult stages of the kelp greenling were observed in San Francisco Bay and Moss Landing Harbor.

Spawning takes place in fall and winter months (Fitch and Lavenberg 1975), mostly in winter (this study). Adults choose rocky coastal areas for spawning (Marliave 1975), although some spawning may occur in harbors or bays.

Eggs, in clustered form, were collected at the intake screens of the Moss Landing Powerplant, Moss Landing Harbor, in December 1979. Eggs embedded in the center of the cluster have a slower development rate than those on periphery (this study).

Newly hatched larvae are pelagic and are widely distributed. Eldridge and Bryan (1972) collected larvae in Humboldt Bay, Icanberry *et al.* (1978) collected them in surface coastal waters. Marliave (1975) observed kelp greenling larvae in the shallow coastal waters of British Columbia. Larvae of this species were also found in the deeper coastal waters (Follett 1952) to pelagic off both sides of the Aleutian Islands (Gorbunova 1962).

Juveniles feed on copepods, amphipods, and other small crustaceans and small fish (Barraclough 1967, Fitch and Lavenberg 1971) also noted polychaete worms and clam siphons in stomach samples. In addition, small invertebrates (Frey 1971) and algae (Bane and Bane 1971) have been reported in the stomachs of juvenile kelp greenling.

There have been few life history studies on the kelp greenling. The age of maturity is unknown. The largest specimen was recorded as 21 inches (53 cm) TL, adults usually range from 12 to 18 inches (30–46 cm) TL (Frey 1971). Kelp greenling are an important sport fish on the rocky shoreline north of the Golden Gate (Frey 1971), although the commercial catch is insignificant or small. Those taken commercially are sold fresh (Frey 1971, Bane and Bane 1971).

References

Bane and Bane 1971, Barraclough 1967, Baxter 1966,1974, Clemens and Wilby 1946, Eldridge and Bryan 1972, Feder *et al.* 1974, Fitch and Lavenberg 1971, Follett 1952, Frey 1971, Goodwin 1980, personal communication; Gorbunova 1962, Hart 1973, Icanberry *et al.* 1978, Marliave 1975, Miller and Lea 1972, Roedel 1953; Wilimorsky 1964.

LINGCOD, Ophiodon elongatus Girard

SPAWNING

Location	Subtidal rocky areas at 3.3–10 m depth (Wilby 1937); rocky crevices (Phillips 1958); subtidal rocks (Bane and Bane 1971; subtidal rocky areas (Frey 1971); sometimes in intertidal reefs (Hart 1973); rocky crevices on subtidal reefs (Feder *et al.* 1974); lower intertidal to the area below low tide, about 19 m (Miller and Geibel 1973).
Season	December–March in British Columbia (Wilby 1937) and along the California coast (Phillips 1958); winter months (Clemens and Wilby 1946). In Monterey Bay, November through March (Miller and Geibel 1973).
Salinity	Seawater.
Substrates	Rocky reefs (Wilby 1937).
Fecundity	6,000–520,000 (Wilby 1937).

CHARACTERISTICS

EGGS

Shape	Spherical (Wilby 1937).
Diameter	Newly fertilized egg, 2.8 mm; at water hardening, 3.5 mm (Wilby 1937), 2.5–3.0 mm (Marliave 1975).
Yolk	Progresses from pinkish to opaque white, to light yellow to greenish brown (Wilby 1937); pinkish white first and becomes gray with maturation (Marliave 1975).
Oil globule	Single large oil globule (judging by the description of newly hatched larvae) (Wilby 1937).
Chorion	Transparent, thick (Wilby 1937).
Egg mass	Very large clusters on substrate, up to 76 cm across and 13.6 kg in weight.
Adhesiveness	Strongly adhesive and cohesive (Wilby 1937).

Buoyancy	Demersal.

LARVAE (FIGURES 37-4, 37-5, 37-6, 37-7)

Length at hatching	Ca. 10 mm TL (Wilby 1937); 7–10 mm TL (Hart 1973), 9.5–11.0 mm TL (Marliave 1975).
Snout to anus length	Ca. 41–44% of TL of larvae at 9.8–10.0 mm TL.
Yolk sac	Spherical in thoracic region (Marliave 1975); yellowish, spherical to oval in thoracic region.
Oil globule	Single large yellow oil globule (Wilby 1937).
Gut	Straight or waved, thick, bending ventrally in anal region.
Air bladder	None.
Teeth	Sharp, pointed, apparent in postlarval stage.
Size at completion of yolk-sac stage	Ca. 10–12 mm TL.
Total myomeres	56–58.
Preanal myomeres	18–19.
Postanal myomeres	39–40.
Last fin(s) to complete development	Pelvic.
Pigmentation	Stellate melanophores on snout and cephalic regions; a double row of melanophores on middorsum; melanophores on dorsal surface of gut and portion of the body cavity; melanophores along postanal region and the area just above postanal region.
Distribution	In the aquarium, larvae stay on bottom (Wilby 1937); pelagic (Frey 1971); estuarine (Hart 1973); coastal waters (Richardson and Pearcy 1977).

JUVENILES (Figure 37-8)

Dorsal fin	XXV–XXVIII, 19–21 (Clothier 1950); XXV–XXVIII, 19–24 (Miller and Lea 1972); XXIV–XXVII, 21–24 (Bane and Bane 1971, Hart 1973).
Anal fin	III, 21–24 (Bane and Bane 1971, Miller and Lea 1972, Hart 1973).
Pectoral fin	17.
Mouth	Terminal, large, directed slightly upward, maxillary reaches to mid-eye in small juveniles (this study) and extends beyond posterior part of eye in adult (Hart 1973).

Vertebrae	56–58 (Clothier 1950, Miller and Lea 1972); 55–57 (Hart 1973).
Distribution	On bottom of eel grass beds and in rocky areas (Wilby 1937); San Pablo Bay and Carquinez Strait (Ganssle 1966, Messersmith 1966); sandy or mud bottom from shallow harbor to deep offshore shelf (Frey 1971); lower-salinity estuaries (Hart 1973).

LIFE HISTORY

The lingcod ranges from Pt. San Carlos, Baja California, to Kodiak Island, Alaska (Roedel 1948, Fitch 1949, Frey 1971, Miller and Lea 1972, Hart 1973). Lingcod are widely distributed in coastal waters, and have been recorded as deep as 421 m (Grinols 1965). In the study area, lingcod larvae were observed in Richardson Bay (Eldridge 1977); juveniles and adults were collected in San Francisco Bay (Aplin 1967, Green 1975), San Pablo Bay (Ganssle 1966), and Carquinez Strait (Messersmith 1966). This species was also reported in Tomales Bay (Bane and Bane 1971), Bodega Bay (Standing *et al.* 1975), Monterey Bay (Kukowski 1972b), and Moss Landing-Elkhorn Slough (Nybakken *et al.* 1977).

In this study, most larvae were collected in San Francisco Bay, in the vicinity of the Golden Gate Bridge in particular, juveniles were collected from the intake screens at the Potrero and Hunters Point Powerplants of San Francisco Bay and the Moss Landing Powerplant on Moss Landing Harbor.

Like the kelp greenling, the lingcod is a winter spawner (Phillips 1958). Life history and the spawning behavior of this species have been described for the British Columbia region by Wilby (1937). He reported that lingcod deposited large clusters of eggs in the subtidal zone. The egg mass was up to 76 cm across and 13.6 kg in weight. The male fish guards and fans the eggs until hatching (about 6–7 weeks).

Newly hatched larvae are about 7–10 mm TL (Hart 1973) or 9.5–11.0 mm TL (Marliave 1975). The larvae are pelagic and extend their ranges from estuaries to coastal waters to deep offshore shelves (Frey 1971, Eldridge 1977, Eldridge and Bryan 1972, Richardson and Pearcy 1977).

Small juveniles, up to 70 mm TL, are mainly epipelagic (Miller and Geibel 1973), thereafter they become demersal and mostly concentrate near rocky inshore areas (Frey 1971) and eel grass beds (Wilby 1937). Juvenile lingcod were captured in San Pablo Bay (Ganssle 1966) and in Carquinez Strait in spring, and are also common in Tomales Bay and Bodega Bay (Bane and Bane 1971). The diet of juvenile lingcod may consist largely of copepods and other small crustaceans (Bane and Bane 1971), shrimp and other crustaceans (Frey 1971), or entirely copepods (Hart 1973).

In Canadian waters the male fish reaches maturity at a smaller size, ca. 52 cm, than the female, ca. 76.8 cm (Wilby 1937); in Monterey Bay, the range is about 31–96 cm for both sexes (Miller and Geibel 1973). Those sizes correspond to 2-year-old males and 3-year-old females (Frey 1971). According to Phillips (1958), both sexes become partially mature at 58 cm and completely mature at 68 cm. A 58-cm female lingcod is 3 years old, a 68-cm female fish is about 4 years old (Chatwin 1956). Lingcod are one of the most important sport as well as commercial fish from the northern California coast to Canada (Bane and Bane 1971, Frey 1971, Hart 1973). The lingcod has an excellent flavor and is marketed as fresh fish in the San Francisco Bay area (Bane and Bane 1971).

References

Aplin 1967, Bane and Bane 1971, Chatwin 1956, Clemens and Wilby 1946, Clothier 1950, Eldridge 1977, Eldridge and Bryan 1972, Feder *et al.* 1974, Fitch 1949, Frey 1971, Ganssle 1966, Green 1975, Grinols 1965, Hart 1973, Kukowski 1972b, Miller and Geibel 1973, Marliave 1975, Messersmith 1966, Miller and Lea 1972, Nybakken *et al.* 1977, Phillips 1958, Richardson and Pearcy 1977, Roedel 1948, Standing *et al.* 1975, Wilby 1937.

PAINTED GREENLING, *Oxylebius pictus* Gill

SPAWNING

Location	Tidal pools and subtidal rocky areas along the Pacific coast (Frey 1971, Fitch and Lavenberg 1973).
Season	February through November (Fitch and Lavenberg 1973); March, August and November (Feder *et al.* 1974, Fitch and Lavenberg 1975) larvae were collected in January and February and the spawning was estimated to have occurred during the winter months.
Temperature	The larvae were collected at water temperatures between 11.5 and 11.8°C.
Salinity	Seawater.
Substrates	Low growing algae on rocky substrates (Fitch and Lavenberg 1975); rocks (Feder *et al.* 1974).

CHARACTERISTICS

EGGS

Egg mass	Clusters, eggs orange in color (Fitch and Lavenberg 1975).
Adhesiveness	Adhesive (Fitch and Lavenberg 1975, Feder *et al.* 1974).

LARVAE

Snout to anus length	Ca. 32–35% of TL of larvae at 6.2–6.3 mm TL.
Yolk sac	Spherical to moderately oval, located in the thoracic region.
Oil globule	Single, in anterior portion of the yolk sac, ca. 0.22 mm in diameter.
Gut	Thick, coiled.
Air bladder	None.
Size at completion of yolk-sac stage	Ca. 6.3 mm TL.
Total myomeres	35–39.
Preanal myomeres	12–13.
Postanal myomeres	23–26.
Last fin(s) to complete development	Pelvic.
Pigmentation	Two or more rows of large stellate melanophores on snout and cephalic and trunk regions, which merge into a single row of melanophores in the caudal penducle area; single row of heavy melanophores along postanal region terminating at the caudal peduncle; the end portion of the notochord is free from pigmentation; melanophores are also found at the base of pectoral and dorsal fins and the lateral surface of the gut.
Distribution	Pelagic, near shore and in open waters of San Francisco Bay.

JUVENILES (Figure 37-9)

Dorsal fin	XV–XVII, 14–16 (Miller and Lea 1972); XVI, 14–16 (Hart 1973).
Anal fin	III–IV, 12–13 (Miller and Lea 1972).
Pectoral fin	15 (Hart 1973).
Mouth	Terminal, small, directed forward (Hart 1973).
Vertebrae	36–39 (Miller and Lea 1972).
Distribution	Mostly in coastal tidal and subtidal zones (Fitch and Lavenberg 1975); they are also found in harbors, such as Moss Landing Harbor and San Francisco Bay.

LIFE HISTORY

The painted greenling has been found from Pt. San Carlos, Baja California, to Queen Charlotte Island, British Columbia (Miller and Lea 1972). This species was observed in Moss Landing Harbor and Elkhorn Slough (Nybakken *et al.* 1977, this study), but it had not been reported in San Francisco Bay and Tomales Bay until this study.

Fitch and Lavenberg (1975) described some of the painted greenling's spawning behavior, but incubation and early life stage development have not been described.

The larvae are generally pelagic, although they have been collected in the shallow intertidal zone as well as the open waters of San Francisco Bay. Larvae of this species, but with much heavier pigmentation than found in this study, were reported on the high seas in the northeastern Pacific by Gorbunova (1962).

Juveniles are common along the southern California coast in fall and winter (Feder *et al.* 1974); they were taken at Moss Landing Harbor in the fall during this study. Stomach contents are reported to include crustaceans and polychaete worms (Fitch and Lavenberg 1975).

Adults inhabit rocky intertidal and subtidal zones and are strictly demersal (Fitch and Lavenberg 1975). Adults sometimes live on and among rocks below kelp beds (Feder *et al*. 1974). Age of maturity is unknown. The sport value as food fish is probably insignificant, because they rarely exceed 6 inches (15 cm) TL (Frey 1971).

References

Feder *et al.* 1974, Fitch and Lavenberg 1975, Frey 1971, Gorbunova 1962, Hart 1973, Nybakken et al. 1973, Miller and Lea 1972.

Characteristic Comparison: Greenlings

Characteristic	**Kelp Greenling**	**Lingcod**	**Painted Greenling**
Eggs			
Shape	Spherical	Spherical	—
Diameter (mm)	2.2-2.4	2.8-3.5	—
Color	Yellow/green/blue	Pink/white/yellow/green/brown	Orange
Larvae			
Total myomeres	52–56	56–58	35–39
Preanal myomeres	15–17	18–19	12–13
Postanal myomeres	36–40	39–40	23–26
Pigmentation	One row of large stellate melanophores on middorsum, no postanal melanophores in prolarvae; two rows of melanophores longitudinally on side of body	Two rows of smaller stellate melanophores on middorsum; postanal melanophores in prolarvae; two rows (or none) of scattered melanophores on side of body	Two or more rows of large stellate melanophores on snout, head, and trunk, merging into one row to caudal peduncle; row of heavy melanophores in postanal region, ending at caudal peduncle; unpigmented tip of notochord; melanophores at base of pectoral, dorsal fins and lateral surface of gut region
Juveniles			
Dorsal fin	XX–XXIII, 22–26	XXIV–XXVIII, 19–24	XV–XVII, 14–16
Anal fin	O–I, 21–25	III, 21–24	III–IV, 12–13
Pectoral fin	18–20	17	15
Lateral lines	4	1	1
Vertebrae	54–56	55–58	36–39
Snout	Short, blunt	Elongate, pointed	Elongate, pointed
Mouth	Small, maxillary to front of pupil	Large, maxillary to middle of pupil	Small, directed forward

Figure 37.—Hexagrammidae: *Hexagrammos decagrammus*, kelp greenling.

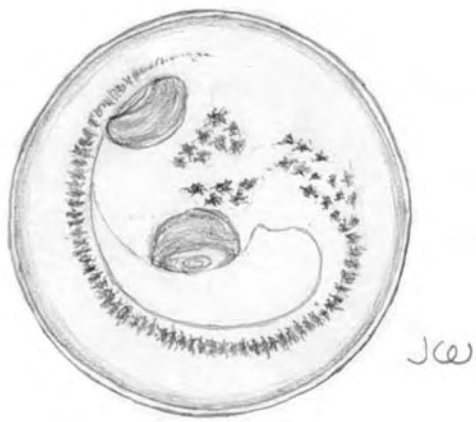


FIGURE 37-1.—Egg, late embryo, 2.3 mm diameter.

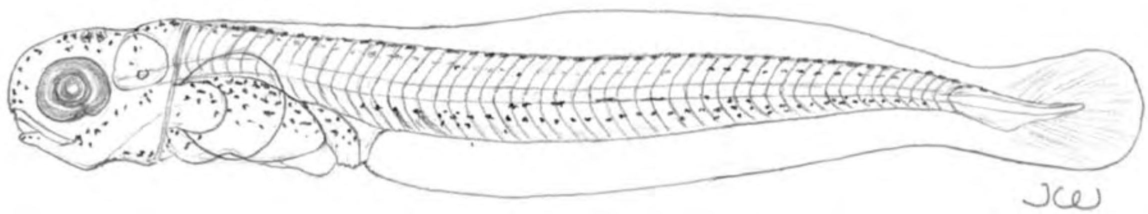


FIGURE 37-2.—Postlarva, 11 mm TL.

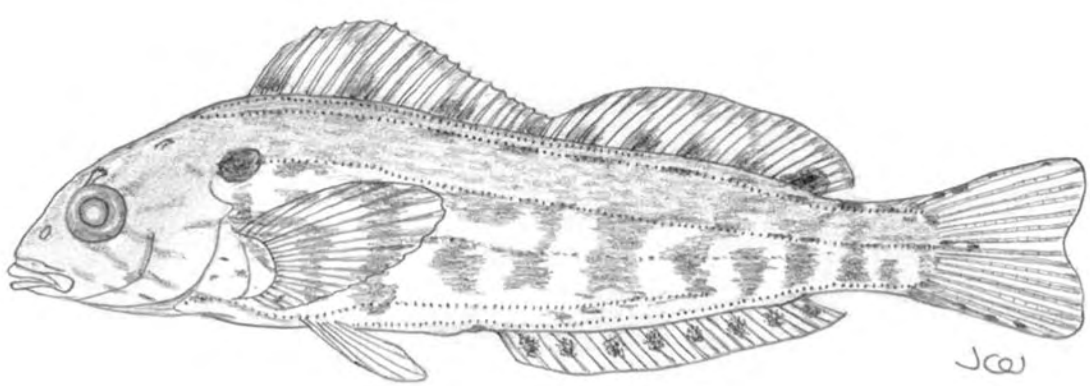


FIGURE 37-3.—Juvenile, 71.5 mm TL.

Hexagrammidae: *Ophiodon elongates*, lingcod.

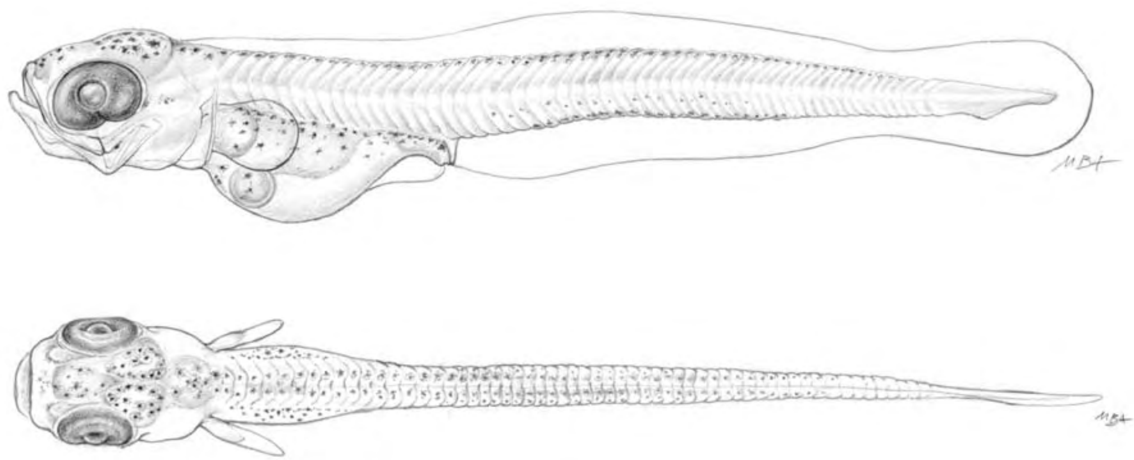


FIGURE 37-4, 37-5.—Postlarva lateral and dorsal views, 9 mm TL.

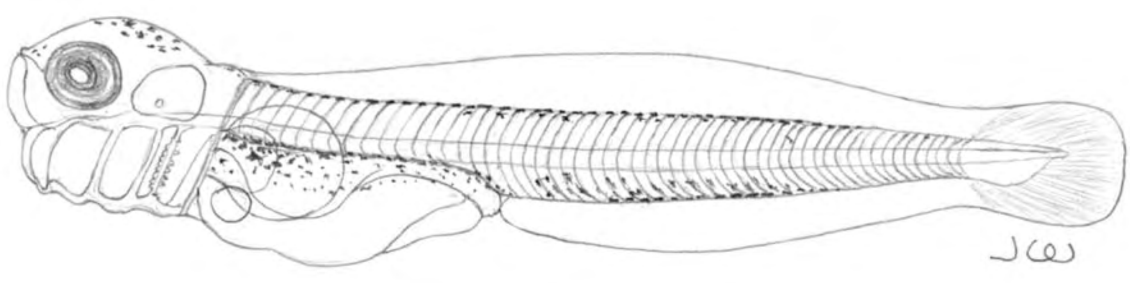


FIGURE 37-6.—Postlarva, 10 mm TL.

Hexagrammidae: *Ophiodon elongates*, lingcod.

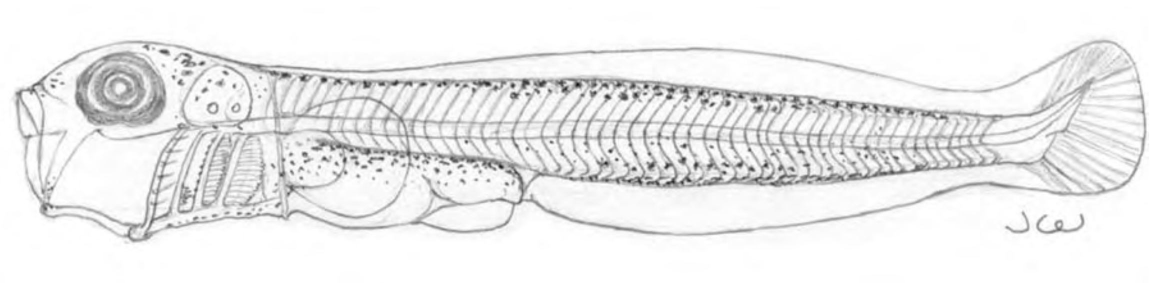


FIGURE 37-7.—Postlarva, 14.9 mm TL.

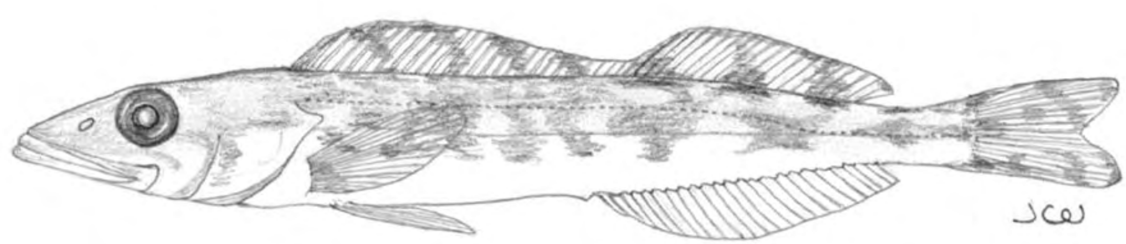


FIGURE 37-8.—Juvenile, 97 mm TL.

Hexagrammidae: *Oxylebius pictus*, painted greenling.

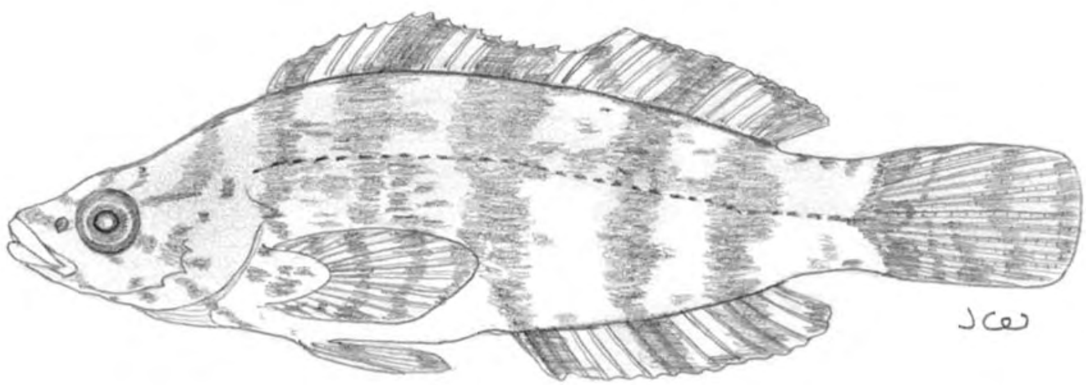


FIGURE 37-9.—Juvenile, 85 mm TL.

38. Cottidae – Sculpins

The cottid family contains numerous species which have successfully adapted to a wide range of salinities and environments. Approximately 300 species of cottids have been reported from the northern hemisphere waters of the Pacific and Atlantic oceans (Bolin 1944). Most species inhabit coastal waters, some are found only in freshwater, and others migrate between areas of high and low salinity, depending upon their life stages.

At least 20 species of sculpins have been reported in the Sacramento-San Joaquin Estuary and adjacent waters:

	Habitat	
Species	**Marine and Estuarine**	**Freshwater**
Scalyhead sculpin, *Artedius harringtoni*	x	
Smoothhead sculpin, *Artedius lateralis*	x	
Bonyhead sculpin, *Artedius notospilotus*	x	
Sharpnose sculpin, *Clinocottus acuticeps*	x	
Woolly sculpin, *Clinocottus analis*	x	
Calico sculpin, *Clinocottus embryum*	x	
Mosshead sculpin, *Clinocottus globiceps*	x	
Bald sculpin, *Clinocottus recalvus*	x	
Coastrange sculpin, *Cottus aleuticus*	x	x
Prickly sculpin, *Cottus asper*	x	x
Riffle sculpin, *Cottus gulosus*		x
Buffalo sculpin, *Enophrys bison*	x	
Brown Irish lord, *Hemilepidotus spinosus*	x	
Pacific staghorn sculpin, *Leptocottus armatus*	x	x
Sailfin sculpin, *Nautichthys oculofasciatus*	x	
Tidepool sculpin, *Oligocottus maculosus*	x	
Saddleback sculpin, *Oligocottus rimensis*	x	
Fluffy sculpin, *Oligocottus snyderi*	x	
Cabezon, *Scorpaenichthys marmoratus*	x	

Because of the availability and abundance of all life stages, the following species have been chosen for description in this chapter: prickly sculpin, riffle sculpin, buffalo sculpin, brown Irish lord, Pacific staghorn sculpin, Tidepool sculpin, cabezon, and *Artedius* spp. (possibly the bonyhead sculpin).

References

Bolin 1944.

PRICKLY SCULPIN, *Cottus asper* Richardson

SPAWNING

Location	Freshwater of the Sacramento-San Joaquin River systems (also known into the oligohaline portion of the estuary): American River (below Nimbus Dam), Wilson Slough, vicinity of Pittsburg and Contra Costa Powerplants, Lake Herman, lower reach of Walnut Creek, Alameda Creek, Corte Madera Creek, Rodeo Lagoon, Millerton Lake, upper San Joaquin River, Kerckhoff Reservoir, and O'Neill Forebay.
Season	February through June (Krejsa 1967); mainly in March and April (Moyle 1976); February through May (Millikan 1968); January through September; January through May in Central Valley floor waters; and May through September in foothill creeks.
Temperature	8–13˚C (Krejsa 1967); ca. 9–17 ˚C.
Salinity	Brackish and freshwater (McAllister and Lindsey 1960); up to 12 ppt salinity (Millikan 1968); freshwater to intertidal (Moyle 1976); freshwater to oligohaline.
Substrates	Large cobbles or flat rocks (Krejsa 1967); under surface of rocks, in beer cans, rusting automobile bodies (Millikan 1968); trash (Moyle 1976); under-surfaces or crevices of rocky bottoms and banks, jetties, concrete blocks and other artificial substrates.
Fecundity	336–5,652 eggs in ovary and 700–4,000 per cluster (Krejsa 1967); 584–10,980 eggs in ovary (Bond 1963); 280–7,410 eggs in ovary (Patten 1971); 1,094–5,656 (Millikan 1968).

CHARACTERISTICS

EGGS (Figures 38-1, 38-2, 38-3, 38-4)

Shape	Spherical.
Diameter	Less than 1.0 mm (Krejsa 1967); mature ova 1.1–1.3 mm (Millikan 1968); fertilized eggs 1.4–1.6 mm.
Yolk	Orange (Krejsa 1967); creamy yellow-white (Millikan 1968); yellowish, partially clear and partially granular.

Oil globule	One large oil globule (ca. 0.2–0.3 mm in diameter), with many small oil globules congregating in yolk sac.
Chorion	Transparent, thick, and hard.
Perivitelline space	Ca. 0.1–0.2 mm in width.
Egg mass	Eggs deposited in jelly-enclosed cluster (Krejsa 1967); in small clusters.
Adhesiveness	Very adhesive (Krejsa 1967); very adhesive to one another and less to substrate.
Buoyancy	Demersal.

LARVAE (Figures 38-5, 38-6, 38-7, 38-8, 38-9)

Length at hatching	5–7 mm (Krejsa 1967); 5.5–6.3 mm TL (Stein 1972); 4.5–5.0 mm TL.
Snout to anus length	Ca. 40–45% of TL in prolarval and postlarval stages.
Yolk sac	Large, spherical, in thoracic region.
Oil globule	Single, usually located in anterior yolk sac, with many small oil globules.
Gut	Short, coiled in one loop in prolarvae; becomes twisted 1–2 times in postlarvae.
Air bladder	None.
Teeth	Sharp, pointed.
Size at completion of yolk-sac stage	5.2–6.0 mm TL (Millikan 1968), 5.4–6.0 mm TL.
Total myomeres	32–37.
Preanal myomeres	8–12.
Postanal myomeres	22–26.
Last fin(s) to complete development	Pelvic.
Pigmentation	Large stellate melanophores at base of pectoral fins and mid-ventral and dorsal surface of gut (near anus); a series of melanophores along postanal region.
Distribution	Pelagic (Millikan 1968); planktonic or near surface of water column in shallow inshore and deep open water of freshwater and oligohaline regions (Broadway and Moyle 1978, this study).

JUVENILES (Figures 38-10, 38-11)

Dorsal fin	VII–X, 19–23 (Moyle 1976); VII–XI for first dorsal (McAllister and Lindsey 1960); 19–22 for second dorsal (Scott and Crossman 1973).
Anal fin	15–18, mostly 17–18 (Moyle 1976); 14–18 (Scott and Crossman 1973).
Pectoral fin	15–18 (Moyle 1976, Scott and Crossman 1973).
Mouth	Terminal.
Vertebrae	34–36 (Scott and Crossman 1973); 34–37.
Distribution	Demersal (Broadway and Moyle 1976, this study) widely distributed in Sacramento-San Joaquin River and estuary systems, including foothill areas such as Millerton Lake (Moyle 1976, Lambert 1979), Kerckhoff Reservoir, and below Kerckhoff Dam.

LIFE HISTORY

The prickly sculpin ranges from Seward, Alaska, southward along the Pacific coast and into adjacent inland waters to the Ventura River in southern California (Krejsa 1965, 1967, Scott and Crossman 1973). In this study, the prickly sculpin has been found to be very common in the Sacramento and San Joaquin Rivers and Estuary. Their present range may be much wider than their historical range, because the planktonic larvae can be distributed via the California Aqueduct, Friant-Kern Canal, and other man-made water transport systems to various portions of southern California. Evidence of the transportation of planktonic larvae is the population of prickly sculpin established in O'Neill Forebay.

Prior to the spawning season (December–January), the males move into the spawning zone in freshwater or brackish water and are later joined by the females (Krejsa 1967, McAllister and Lindsey 1960). Krejsa (1967) has reported that spawning migration is limited to the coastal population and does not occur in the inland population. Judging from the location of sculpin larvae taken in this study, both migratory and nonmigratory populations exist. Spawning takes place in winter and spring in the estuary and Central Valley floor, and may extend to summer in foothill creeks.

Egg clusters may be found on the under-surface or crevices of rocks or jetties, or in other hollow submerged objects. The male guards the nest and aerates the eggs by fanning with his large pectoral fins until hatching occurs (Krejsa 1967). In this study, mating activity was observed mostly at night or during darkened conditions. Eggs adhere strongly to one another, but less to other substrates. Incubation is relatively long: 15–16 days at 12˚C (Krejsa 1967), 19–20 days at 10–12˚C (Mason and Machidori 1976), and 14–15 days at 9–13˚C under laboratory conditions. Millikan (1968) noted that hatching rate of prickly sculpin eggs is higher at a salinity of 12 ppt than in freshwater.

Although newly hatched larvae are pelagic and are able to swim immediately (Krejsa 1967, Millikan 1968), the newly hatched prolarva may remain in the nest for a few hours until its body straightens out and it becomes free-swimming. Prickly sculpin do not have air bladders, and the larvae swim just below the surface film. It has been suggested that larval sculpin may use surface tension to maintain their position (Mason and Machidori 1976). Larvae remain planktonic and near the water surface for a period of 30–35 days (Krejsa 1967, Mason and Machidori 1976). Sculpin larvae were among the most abundant fishes collected in plankton tows in Suisun Bay and the Delta from March through May. Turner (1966b) reported that early life stages of prickly sculpin were common in the Delta.

The early life history has been reported by Krejsa (1965, 1967) and the early life stages are described by Stein (1972) and Richardson and Washington (1980).

Juveniles become demersal at approximately 15 mm TL (Broadway and Moyle 1978), and are common in shallow water with various bottom substrates and shelters. They may remain in upper estuary waters until early summer of the following year, subsequently ascending the tributaries and upper river, as was reported for migratory populations in the British Columbia region (Krejsa 1967, Mason and Machidori 1976). This upstream and downstream migration of the prickly sculpin may relate to genetic orientation rather than imprinted behavior (McAllister and Lindsey 1960). Juvenile prickly sculpin feed on planktonic crustaceans, insects, and different kinds of benthic invertebrates (Cook 1964, Millikan 1968, Moyle 1976).

Prickly sculpin mature in their second to fourth year (Millikan 1968, Patten 1971). They have some value as forage for salmon, trout, bass, and birds (Moyle 1976).

References

Bond 1963, Broadway and Moyle 1976, Cook 1964, Krejsa 1965, 1967, Lambert 1979, Mason and Machidori 1976, McAllister and Lindsey 1960, Millikan 1968, Moyle 1976, Patten 1971, Richardson and Washington 1980, Scott and Crossman 1973, Stein 1972, Turner 1966b.

RIFFLE SCULPIN, *Cottus gulosus* (Girard)

SPAWNING

Location	Mostly in small streams with sandy to rocky bottoms. Specific locations where spawning was observed include Olema Creek (near Fire Brook Trail) and Lake Berryessa and its drainages.
Season	February–April (Moyle 1976); February–May (Millikan 1968, Bond 1963, this study).
Temperature	10–12˚C (Millikan 1968); ca. 10–17.5 °C.
Salinity	Freshwater to 12 ppt (Millikan 1968); freshwater.

Substrate	Rotting logs (Millikan 1968); gravel and rocks.
Fecundity	104 to 449 (Bond 1963, Millikan 1968).

CHARACTERISTICS

EGGS

Shape	Spherical.
Diameter	Mature eggs 2.3–2.6 mm in diameter (Millikan 1968); mature eggs 2.0–2.2 mm.
Yolk	Pale yellow to deep orange (Millikan 1968); yellowish.
Oil globule	Single, 0.25–0.4 mm in diameter (this study); also there is a white spot which contains many small oil globules (Millikan 1968).
Chorion	Smooth, except the adhering area.
Egg mass	Deposited in small clusters (Millikan 1968).
Adhesiveness	Adhesive (Millikan 1968, this study).
Buoyancy	Demersal.

LARVAE (Figures 38-12, 38-13)

Length at hatching	Ca. 6.0–6.5 mm TL.
Snout to anus length	Ca. 42–43% of TL of prolarvae and postlarvae.
Yolk sac	Spherical to oval, large, in thoracic region.
Gut	Short, forms a single loop in late prolarvae and postlarvae.
Air bladder	None.
Teeth	Small, pointed in postlarvae.
Size at completion of yolk-sac stage	Ca. 7.0 mm TL.
Total myomeres	31–34.
Preanal myomeres	10–12.
Postanal myomeres	20–22.
Last fin(s) to complete development	Pelvic.
Pigmentation	In prolarvae, a few large stellate melanophores scattered on head, yolk sac, dorsal side of gut, and a series of melanophores along the postanal region; in postlarvae, large and heavy melanophores cover the head and the body; the density of melanophores varies among individuals.

Distribution	Benthic (Millikan 1968); found in shallow, moderate to fast running streams.

JUVENILES (Figure 38-14)

Dorsal fin	VII–VIII, 16–19 (Moyle 1976); V–VIII, 17–18.
Anal fin	14–16 (Moyle 1976, this study).
Pectoral fin	15–16 (Moyle 1976); 14–17 (Bond 1973, this study).
Mouth	Large, maxillary reaches rear edge of eye (Moyle 1976); terminal or slightly subterminal, large.
Vertebrae	32–34.
Distribution	Settle on bottom of streams and lakes, where they are associated with sand, gravel, or rock.

LIFE HISTORY

The riffle sculpin is a freshwater cottid found in the Sacramento-San Joaquin River system and coastal streams of California from Morro Bay to the Noyo River (Moyle 1976). They also occur in coastal streams from Coquille River, Oregon to Puget Sound, Washington (Bond 1973). In this study, the riffle sculpin was not collectd in waters between San Pablo Bay and Delta tributaries, although they are reported in the Sacramento-San Joaquin River system by Moyle (1976). However, they were common in Olema Creek and in Lake Berryessa and its surrounding drainages.

Spawning occurs from February through April (Moyle 1976). In this study, ripe riffle sculpin were observed in May, suggesting that spawning may well extend longer than it does in Oregon and Washington waters (Bond 1963, Millikan 1968). The female deposits eggs in small clusters on the underside of rocks and in blind pockets of rotting logs (Bond 1963, Millikan 1968). The ova are in different sizes in the ovaries, indicating that a female may deposit several batches of eggs during the spawning season. Mature ova were 2.0–2.6 mm in diameter (Millikan 1968, this study), which is large for this small freshwater cottid. Millikan (1968) has hypothesized that this phenomenon is a successful spawning strategy because the food availability in a small stream is often minimal and the larvae could benefit by possessing more stored energy. In Lake Berryessa, the major spawning ground is in the tributaries that have gravel bottoms with swift riffles.

Newly hatched larvae are larger than those of the prickly sculpin (6.0–6.5 mm TL vs. 4.5–5.0 mm TL). Riffle sculpin larvae are benthic after the yolk sac is absorbed (Millikan 1968). In this study, the larvae were collected in the shallow portion of Capell Creek (a tributary to Lake Berryessa) and in Olema Creek. It is unclear whether the riffle sculpin exhibits planktonic behavior in its early life stage.

Both postlarvae and early juveniles were captured by fine-mesh (0.5-µm) beach seine in shallow streams. Field observations indicated that the heavily pigmented juveniles prefer to cling to the top or side of small gravel particles or rest on sandy bottom, seldom moving. Small juvenile riffle sculpin feed on amphipods and other crustaceans, which are their major foods (Millikan 1968). Larger juveniles feed on mayflies, midges, and other insect larvae and fish eggs, as observed in this study.

Maturity in riffle sculpin is reached at the end of the second year (Millikan 1968). The riffle sculpin has no commercial or sport value, because of its small size, but they are probably forage for predatory stream fishes.

References

Bond 1963, 1973; Millikan 1968, Moyle 1976.

BUFFALO SCULPIN, *Enophrys bison* (Girard)

SPAWNING

Location	Coastal Pacific waters (Richardson 1977); intertidal and subtidal coastal waters, often in areas exposed to strong tidal currents (DeMartini 1978).
Season	February–March (Hart 1973); January–March (Pearcy and Myers 1974, Richardson 1977); January–May (Misitano 1978).
Temperature	10–11˚C (Misitano 1978); 5–9˚C (DeMartini 1978).
Salinity	Seawater.
Substrate	Rocks, reef crests (DeMartini 1978).
Fecundity	16,600–43,100 (DeMartini 1978).

CHARACTERISTICS

EGGS

Shape	Spherical.
Diameter	1.74–1.83 mm (Misitano 1978); 1.7–2.0 mm (DeMartini 1978).
Yolk	Beige to maroon to red (Misitano 1978); orange-brown (Hart 1973); varied: purple, pink, yellow, orange, red, and tan (DeMartini 1978).
Oil globule	Single, ca. 0.36 mm in diameter (Misitano 1978).
Perivitelline space	Ca. 0.09 mm in width (Misitano 1978).
Egg mass	Multilayered clusters in roughly circular shape, ca. 7–14 cm in diameter and 1–4 cm thick (DeMartini 1978).

Adhesiveness	Adhesive (Misitano 1978, DeMartini 1978).
Buoyancy	Demersal.

LARVAE (Figure 38-15)

Length at hatching	4.9–5.2 mm TL, with an average of 5.0 mm TL (Misitano 1978).
Snout to anus length	Ca. 40% of TL at 4.7 mm TL.
Yolk sac	Spherical, in thoracic region.
Oil globule	Single, near anterior end of yolk sac (Misitano 1978).
Gut	Short, coiled.
Air bladder	None.
Size at completion of yolk-sac stage	Ca. 5.5 mm TL (Misitano 1978).
Total myomeres	30–31 (Misitano 1978).
Preanal myomeres	8–9 (Misitano 1978).
Postanal myomeres	20–23 (Misitano 1978, this study).
Last fin(s) to complete development	Pelvic.
Pigmentation	Newly hatched larvae have stellate melanophores on nape and thoracic region. A dark band covers dorsal potion of gut, and a few melanophores are located along the postanal region; the numbers of melanophores along the postanal region increase as development proceeds. In late postlarvae, additional melanophores are found on the head and nape, and a dark blotch occurs just behind the anal region (Misitano 1978).
Distribution	Planktonic (Marliave 1975); pelagic, coastal water to offshore area (Richardson 1977); found in San Francisco Bay.

JUVENILES

Dorsal fin	VII–IX, 11–12 (Bolin 1944); VII–IX, 10–13 (Sandercock and Wilimovsky 1964, Hart 1973); VII–IX, 9–13 (Miller and Lea 1972).
Anal fin	8–9 (Bolin 1944, Sandercock and Wilimovsky 1968, Hart 1973); 8–10 (Miller and Lea 1972).
Pectoral fin	16–18 (Sandercock and Wilimovsky 1968, Miller and Lea 1972, Hart 1973).
Mouth	Terminal (Sandercock and Wilimovsky 1968); subterminal.

Vertebrae	29–30 (Sandercock and Wilimovsky 1968); 29–31 (Miller and Lea 1972).
Distribution	Near beach on bottom (Hart 1973); shallow coastal water, frequently enters tidepools (Bane and Bane 1971).

LIFE HISTORY

The buffalo sculpin is known from Monterey Bay, California, to Kodiak Island in the Gulf of Alaska (Bolin 1944, Sandercock and Wilimovsky 1968, Hart 1973). In this study, larval and adult buffalo sculpin were collected in San Francisco Bay. In addition to San Francisco Bay (Bolin 1944), this species has also been reported in Tomales Bay (Bane and Bane 1971) and Bodega Bay (Standing *et al.* 1975).

Spawning takes place in coastal waters during the winter months. Males guard the egg clusters, which can usually be found in rocky regions of 1–10 mm depth (DeMartini 1978, Misitano 1978). Details of spawning of this species have been described by DeMartini (1978). In the laboratory, eggs hatched after 24 days at temperatures of 10–11˚C (Misitano 1978). Apparently, two batches of eggs are spawned per season (DeMartini 1978).

Newly hatched larvae remain on the bottom for about 3 days, and then become active swimmers near the surface (Marliave 1975, Misitano 1978). The larval population is concentrated near the bay and coast, but some larvae have been observed as far as 37 km from the coastline (Richardson 1977). In this study, larval buffalo sculpin were found in San Francisco Bay.

Transformation from larva to juvenile occurred at 7.6–7.8 mm SL (Misitano 1978). Juveniles gradually settle on the bottom along the Pacific coast. Juveniles gradually settle on the bottom along the Pacific coast. Juvenile buffalo sculpin feed on algae, polychaetes, small crabs, and small fish (Bane and Bane 1971, Hart 1973). In addition, shrimps, mussels, and amphipods are known prey items (Clemens and Wilby 1961).

The buffalo sculpin can reach at least 30.5 cm in total length (Hart 1973). It is occasionally taken by anglers, but has little sport or commercial value.

References

Bane and Bane 1971, Bolin 1944, Clemens and Wilby 1961, DeMartini 1978, Hart 1973, Marliave 1975, Miller and Lea 1972, Misitano 1978, Pearcy and Myers 1974, Richardson 1977, Sandercock and Wilimovsky 1968, Standing *et al.* 1975.

BROWN IRISH LORD, *Hemilepidotus spinosus* (Ayres)

SPAWNING

Location	Assumed outside of Moss Landing Harbor and Tomales and Bodega bays.
Season	Larvae taken along the Oregon Coast in February and March (Richardson and Pearcy 1977); in January and February in the study area.
Temperature	Larvae were taken at 12.6–13.2°C.
Salinity	Seawater.

CHARACTERISTICS

LARVAE (Figure 38-16)

Snout to anus length	Ca. 37–38% of TL of larvae at 5.05 to 6.5 mm TL.
Gut	Very thick, twisted in postlarval stage.
Air bladder	None.
Total myomeres	34–36.
Preanal myomeres	10–11.
Postanal myomeres	24–26.
Last fin(s) to complete development	Pelvic (Richardson and Washington 1980).
Pigmentation	Melanophores on head, middorsum to the posteriormost myomere, some melanophores on dorsolateral surface of the gut, a series of melanophores along the postanal region, and a single melanophore near the tip of notochord (Richardson and Washington 1980). In addition, a few melanophores also appear on the thoracic region.
Distribution	Neustonic (Richardson and Pearcy 1977); Strait of Georgia, British Columbia (Barraclough 1967); planktonic, mostly offshore (Richardson and Washington 1980), found in Moss Landing Harbor and Tomales and Bodega bays.

JUVENILES

Dorsal fin	XI, 18–20 (Miller and Lea 1972, Hart 1973); X–XI, 18–20 (Richardson and Washington 1980).
Anal fin	14–16 (Miller and Lea 1972, Hart 1973); 14–17 (Richardson and Washington 1980).

Pectoral fin	14–16 (Miller and Lea 1972, Hart 1973, Richardson and Washington 1980).
Mouth	Terminal, moderate in size, directed forward (Hart 1973).
Vertebrae	35 (Peden 1964), 35–37 (Miller and Lea 1972).
Distribution	Coastal and offshore of Oregon (Richardson and Washington 1980), Strait of Georgia, British Columbia (Barraclough 1967).

LIFE HISTORY

The distributional range of the brown Irish lord is from near Santa Barbara Island (Ventura County, California, on mainland), to Puffin Bay, Alaska (Barraclough 1967). In the study area, this species has been reported in Bodega Bay (Standing *et al.* 1975) and Monterey Bay (Kukowski 1972b), but it has not been recorded in San Francisco Bay.

Larvae were collected in February and March along the Oregon coast (Richardson and Pearcy 1977), the spawn might start in January. In the study area, spawning is estimated occur in January and February. Mating behavior is unreported in the literature, but spawning is believed to occur within 28 km of the coast (Richardson and Pearcy 1977).

Larvae are planktonic (Richardson and Washington 1980), preferring the Neustonic region (Richardson and Pearcy 1977). The offshore flow of surface water during upwelling provides a dispersal mechanism (Richardson and Pearcy 1977). However, the postlarve have appeared in the entrance of Queen Charlotte Sound, British Columbia (Peden 1964), and they were found inside of the bays (this study). Gorbunova (1964) has described the related members of *Hemilepidotus* from inshore to farther offshore in the north Pacific.

The distribution of juvenile brown Irish lord is similar to that of their larval stages. Richardson and Washington (1980) stated that offshore is important as a nursery area, and Barraclough (1967) has reported that the late postlarvae and early juveniles (8–12 mm TL) were common in the waters of the Strait of Georgia, where they feed on bryozoan larvae, amphipods, and copepods.

Adults are common in coastal water (Hart 1973). Age of maturity is not known, nor is their economic or ecological value.

References

Barraclough 1967, Gorbunova 1964, Hart 1973, Kukowski 1972b, Miller and Lea 1972, Peden 1964, Richardson and Pearcy 1977, Richardson and Washington 1980, Standing *et al.* 1975.

PACIFIC STAGHORN SCULPIN, *Leptocottus armatus* Girard

SPAWNING

Location	Shallow coastal waters, bay, inlet, sound, and slough (Jones 1962). Specific locations in this study include San Francisco Bay, San Pablo Bay, Tomales Bay, Moss Landing Harbor-Elkhorn Slough and the outer coastline.
Season	October–March, with a peak in January and February (Jones 1962); February (Hart 1973); October–April.
Temperature	Ca. 15˚C (Jones 1962); ca. 9–15.2˚C.
Salinity	Optimum 27–28.3 ppt (Sumner *et al.* 1914); oligohaline-seawater (Jones 1962); mesohaline to polyhaline.
Substrate	Various; from soft muddy slough to firm substrates to rock areas.
Fecundity	Ca. 2,000–11,000, with an average of 5,000 per year (Jones 1962).

CHARACTERISTICS

EGGS (Figure 38-17)

Shape	Spherical, slightly flattened at the adhering area (Jones 1962).
Diameter	Mature eggs, 1.36–1.50 mm (Jones 1962); fertilized eggs, 1.2–1.45 mm.
Yolk	Creamy white through yellow or orange to deep orange, containing a mass of flocculent material (Jones 1962); yellowish with granular deposits.
Oil globule	1–7 oil globules (Jones 1962); single large oil globule, ca. 0.3 mm in diameter.
Chorion	Transparent, smooth except for the adhering area.
Perivitelline space	Prominent (Jones 1962); ca. 0.1–0.2 mm in width.
Egg mass	Deposited in clusters (Jones 1962).
Adhesiveness	Adhesive (Jones 1962).
Buoyancy	Demersal (Jones 1962).

LARVAE (Figures 38-18, 38-19)

Length at hatching	3.8–4.9 mm TL (Jones 1962); ca. 4.5 mm.
Snout to anus length	Ca. 37–40% of TL of prolarvae and postlarvae.

Yolk sac	Spherical, large (Jones 1962); spherical to oval, large, in thoracic region.
Oil globule	Single oil globule, located in anterior yolk sac, ca. 0.3 mm in diameter (Jones 1962, this study).
Gut	Short, straight in prolarvae, and coiled and twisted in late prolarvae and early postlarvae.
Air bladder	None.
Teeth	Small, less pointed in postlarvae.
Size at completion of yolk-sac stage	Ca. 5.5–6.0 mm TL.
Total myomeres	32–37.
Preanal myomeres	8–12.
Postanal myomeres	23–28.
Last fin(s) to complete development	Pelvic.
Pigmentation	In prolarvae, 5–8 pairs of dark lobed bands shade the dorsal portion of the body cavity; several large stellate melanophores on cephalic region. A horizontal bar is in front of nasals or snout; small melanophores in thoracic and postanal regions in postlarvae, and more pigment on the entire head region. At least three distinctive dark blotches on the middorsal region and many irregular blotches on side of body.
Distribution	Swimming near the water surface (Jones 1962); planktonic, mostly in polyhaline and mesohaline ranges of this estuary.

JUVENILES (Figure 38-20)

Dorsal fin	VI–VII, 15–20 (Bolin 1944, Miller and Lea 1972, Hart 1973); VII, 17 (Moyle 1976).
Anal fin	15–20 (Bolin 1944, Hart 1973); 14–20 (Miller and Lea 1972); ca. 19 (Hart 1973).
Pectoral fin	17–20 (Bolin 1944, Miller and Lea 1972); ca. 19 (Hart 1973).
Mouth	Large, maxillary reaching to anterior or middle margin of pupil (Bolin 1944); the maxillary passing the eye (Moyle 1976).
Vertebrae	35–38 (Miller and Lea 1972).

Distribution	Bottom dwelling throughout the estuary (Jones 1962); including tidal freshwater of the Sacramento-San Joaquin River system.

LIFE HISTORY

The Pacific staghorn sculpin is found from San Quintin Bay, Baja California, to Karluk (on Kodiak Island), Alaska (Bolin 1944, Jones 1962). Pacific staghorn sculpin is a euryhaline species (Jones 1952), but it appears to be more common in freshwater in the southern half of its distribution (Moyle 1976). This species is abundant locally in San Francisco Bay and San Pablo Bay (Aplin 1967, Ganssle 1966, this study). They are also common in Tomales Bay (Jones 1962, this study) and in Moss Landing Harbor and Elkhorn Slough (Nybakken *et al.* 1977, this study).

Spawning behavior of the Pacific staghorn sculpin has not been fully described in the literature (Jones 1962, Marliave 1975), but the early development and early life history have been well documented by Jones (1962). Judging from the eggs and larvae collected in this study, spawning takes place from October through early April in polyhaline and mesohaline waters of the estuary. Clustered eggs were observed on muddy or sandy bottoms or firm rocky substrates. Jones (1962) has stated that Pacific staghorn sculpin probably spawn only once during a breeding season. Observations made during this study agree with Jones's observation, in that the eggs in the gravid female are of similar size and developmental stage. Jones (1962) reported that eggs hatched in 9–14 days at 15˚C under laboratory conditions.

Newly hatched larvae immediately swim to the surface (Jones 1962). However, newly hatched larvae were seldom found in the plankton samples in this study, suggesting that they may remain on the bottom for a short time before becoming planktonic swimmers.

The majority of staghorn sculpin larvae were taken in the higher-salinity portion of the estuary. Their presence in oligohaline-mesohaline waters in Suisun Bay probably resulted from drifting during the high tides.

Few juveniles larger than 10–15 mm TL were caught in plankton samples, suggesting that they become demersal at this size. Moyle (1976) reported movement by juveniles up the estuary. Juveniles prefer shallow inshore water and sloughs. Their major prey include amphipods (genus *Corophium*), nereid worms, and small anchovy (Jones 1962).

Sexual maturity occurs at 1 year (Jones 1962) or near the end of their first year of life (Tasto 1975). Adults leave the shallow spawning ground to inhabit deep offshore water after spawning (Tasto 1975). The planktonic stages of this species may have value as forage fish, and large staghorn sculpin are used as bait by sport fishermen.

The Pacific staghorn sculpin occurs together with gobies and other sculpins. Brittan *et al.* (1970) has described interspecific competition between yellowfin goby and Pacific staghorn sculpin in Palo Alto Yacht Harbor, San Francisco Bay. The ecological status of the Pacific staghorn sculpin as related to yellowfin goby and other species in the entire Sacramento-San Joaquin Estuary is not well understood.

References

Aplin 1967, Bolin 1944, Brittan *et al.* 1970, Ganssle 1966, Hart 1973, Jones 1962, Marliave 1975, Miller and Lea 1972, Moyle 1976, Nybakken *et al.* 1977, Sumner *et al.* 1914, Tasto 1975.

TIDEPOOL SCULPIN, *Oligocottus maculosus* Girard

SPAWNING

Location	Shallow coastal tidal pools, in bays near rocky areas or jetties. Specific locations observed in this study include Richardson Bay, Tomales Bay, and Bodega Bay.
Season	November–December at Trinidad Head near Humboldt Bay (Stein 1973); April–July in Tomales Bay, October–February.
Temperature	Ca. 11–13°C.
Salinity	Seawater, may occur in polyhaline.
Substrate	On rocks (Bane and Bane 1971, Hart 1973), jetties, and abandoned mussel shells.
Fecundity	Ca. 250–400 (Stein 1973); counts of 84–309 in females 50–62 mm TL.

CHARACTERISTICS

EGGS

Diameter	1.081–1.549 mm with an average of 1.221 mm (Atkinson 1939); mature eggs 1.1–1.3 mm.
Yolk	Eggs deep red (Atkinson 1939); pale green (Bane and Bane 1971); pale apple green to pale brown (Stein 1973); mature eggs pale green to brown.
Oil globule	Numerous at first, tend to unite (Atkinson 1939); 1–3 large oil globules surrounded by numerous small oil globules (Stein 1973); one large oil globule (0.2–0.3 mm in diameter) surrounded by a few smaller oil globules scattered in the yolk.
Chorion	Transparent, thick.
Perivitelline space	0.05 mm in width (Atkinson 1939, Stein 1973).
Egg mass	Deposited in clusters (Atkinson 1939, Stein 1973).

Adhesiveness	Clusters cohesive, but do not adhere to substrate (Atkinson 1939, Stein 1973).
Buoyancy	Demersal.

LARVAE (Figures 38-21, 38-22, 38-23)

Length at hatching	4.6–5.2 mm TL (Stein 1973).
Snout to anus length	Ca. 39–43% of TL of larvae at 6.5–10.3 mm TL.
Yolk sac	Spherical to oval, large, extending from thoracic to abdominal region.
Oil globule	Consolidated into one.
Gut	Short in prolarvae, coiled and twisted in late prolarvae and postlarvae.
Air bladder	None.
Teeth	Sharp, pointed in postlarvae.
Size at completion of yolk-sac stage	Ca. 6.0 mm TL (Stein 1973).
Total myomeres	31–34.
Preanal myomeres	7–8 for prolarvae (Stein 1973); 8–12 for prolarvae and postlarvae.
Postanal myomeres	26–27 for prolarvae (Stein 1973); 21–27 for prolarvae and postlarvae.
Last fin(s) to complete development	Pelvic.
Pigmentation	Large stellate melanophores on head and nape; melanophores also covering dorsal portion of body cavity and part of the gut; a series of melanophores along postanal region. Additional large melanophores are found on head, opercles, and jugular region on larger larvae and early juveniles.
Distribution	Pelagic, shallow intertidal zones, tidal pools, and rocky jetty areas.

JUVENILES (Figure 38-24)

Dorsal fin	VIII–IX, 16–18 (Bolin 1944, Hart 1973); VII–IX, 1 5–18 (Miller and Lea 1972).
Anal fin	12–14 (Bolin 1944); 11–14 (Miller and Lea 1972).
Pectoral fin	13–15 (Bolin 1944, Miller and Lea 1972).
Mouth	Moderate, maxillary extends to under pupil (Bolin 1944); mouth small (Bane and Bane 1971, this study).

Vertebrae	33–34 (Clothier 1950).
Distribution	Bottom-dwelling, shallow intertidal areas, rock areas and jetties.

LIFE HISTORY

The tidepool sculpin has been reported from various Pacific Ocean locations from White Point and Portugese Bend, in southern California, to the Sea of Okhotsk, USSR (Miller and Lea 1972). In the study area, tidepool sculpin have been reported in Richardson Bay (Green 1975, Eldridge 1977), Tomales Bay (Bane and Bane 1971), and Bodega Bay (Standing *et al.* 1975). In this study, tidepool sculpin were taken in Richardson and Tomales bays.

The spawning of tidepool sculpin occurs from December through February, judging by the time when females are gravid, when egg masses can be located, and when larval fish were collected (Eldridge 1977, this study). Egg color ranged from pale green to brown. Eggs are deposited on rocks and in intertidal regions (Bane and Bane 1971, Stein 1973). It may be that several batches of eggs are deposited during a single season, since ova of different sizes were found in the ovary (Atkinson 1939, this study). Laboratory spawning of this species has been reported by Atkinson (1939).

The larvae are pelagic, and have been collected near the main channel of the Golden Gate, in San Francisco Bay, and in inshore waters of Marconi Cove. Eldridge (1977) has collected tidepool sculpin larvae during flood tide in an anchored channel net installed in Richardson Bay. The tidal currents may facilitate the movement of larvae. The laboratory rearing of larvae of this species, taken from Trinidad Head, Humboldt County, has been described by Stein (1972, 1973).

Juvenile tidepool sculpin were collected mainly in the same general area occupied by the larvae of the species. Eastman (1962) has interpreted similar findings as evidence of homing behavior. The function of homing behavior is to stabilize the spatial distribution of the species (Green 1971). Few specimens were observed in San Francisco Bay and Richardson Bay, while many were captured along the eastern shore of Tomales Bay. Juveniles are located in very shallow pools and pockets of water behind rocks during an ebbing tide. The stomach contents of juvenile tidepool sculpin were dominated by small amphipods.

Maturity is reached at about 1 year (Atkinson 1939). Tidepool sculpin grow only to 8.9 cm (Hart 1973). They are very attractive, particularly the juveniles; the body is olive, the abdomen yellow-greenish, and the fins rusty red. This species is probably forage for predators.

References

Atkinson 1939; Bane and Bane 1971; Bolin 1944; Clothier 1950; Eastman 1962; Eldridge 1977; Green 1971, 1975; Hart 1973; Miller and Lea 1972; Standing *et al.* 1975, Stein 1972, 1973.

CABEZON, *Scorpaenichthys marmoratus* (Ayres)

SPAWNING

Location	Subtidal and intertidal regions of the coastal Pacific Ocean (O'Connell 1953).
Season	October–March (O'Connell 1953, this study); October–April (Frey 1971).
Temperature	Ca. 11–13°C.
Salinity	Seawater.
Substrate	In coastal rocky area (O'Connell 1953, Hart 1973).
Fecundity	48,700–97,600 per batch (O'Connell 1953); 37,000–100,000 (Bane and Bane 1971).

CHARACTERISTICS

EGGS

Shape	Spherical.
Diameter	Mature eggs 1.4–1.7 mm (O'Connell 1953); 1.5 mm (Bane and Bane 1971); 1.4–1.6 mm.
Yolk	Amber color, clear (O'Connell 1953); white, pink, blue-green, and olive (Feder *et al.* 1974); greenish (Hart 1973).
Oil globule	Single, 0.27 mm in diameter (O'Connell 1953); also occasionally surrounded by smaller oil globules.
Chorion	Transparent and smooth (O'Connell 1953); thick and hard.
Perivitelline space	Ca. 0.1–0.3 mm in width.
Egg mass	Eggs formed hard and compact mass (O'Connell 1953); in large mass (Hart 1973, Feder *et al.* 1974).
Adhesiveness	Sticky and adhered to each other (O'Connell 1953).
Buoyancy	Demersal.

LARVAE (Figures 38-25, 38-26, 38-27, 38-28, 38-29, 38-30)

Length at hatching	5.85 mm TL (O'Connell 1953); 3.6–4.8 mm TL (Bane and Bane 1971); ca. 3.0–4.0 mm TL.
Snout to anus length	Ca. 45–50% of TL of prolarvae at 4.1–5.8 mm TL; increasing to ca. 55% of TL of larvae at 10.0 mm TL.
Yolk sac	Elongate (O'Connell 1953); spherical to oval.
Oil globule	Single, located mostly in anterior yolk sac (O'Connell 1953).

Gut	Formed in one loop in prolarvae (O'Connell 1953); coiled and twisted in late prolarvae and postlarvae.
Air bladder	None.
Teeth	Pointed in postlarvae.
Size at completion of yolk-sac stage	Ca. 6.0–6.5 mm TL (O'Connell 1953, this study).
Total myomeres	34–36.
Preanal myomeres	14.
Postanal myomeres	20–22.
Last fin(s) to complete development	Pelvic.
Pigmentation	Larvae covered with melanophores and tinted with orange-yellow coloration (O'Connell 1953); body greenish with large stellate melanophores on snout and head, 2 rows of melanophores along nape and middorsal regions; heavy melanophores cover dorsal portion of body cavity, dorsal surface of gut and postanal region; scattered melanophores on side of body, but the entire caudal region is free of pigmentation.
Distribution	Pelagic (O'Connell 1953, Feder *et al.* 1974); found in Richardson Bay (Eldridge 1977); Moss Landing Harbor and Elkhorn Slough (Nybakken *et al.* 1977, this study); San Francisco Bay and Tomales Bay.

JUVENILES (Figures 38-31, 38-32)

Dorsal fin	X–XII, 15–18 (Bolin 1944); VIII–XII, 15–18 (Miller and Lea 1972, Hart 1973).
Anal fin	11–13 (Bolin 1944, Hart 1973); 11–14 (Miller and Lea 1972).
Pectoral fin	14–16 (Bolin 1944, Miller and Lea 1972); 15 (Hart 1973).
Mouth	Large, maxillary extending to posterior margin of pupil (Bolin 1944); terminal to subterminal, large.
Vertebrae	35–36 (Miller and Lea 1972); ca. 35 (Hart 1973).
Distribution	Young are pelagic (O'Connell 1953, Feder *et al.* 1974) and then settle into bottom along shallow coast. Some move into tidal pools (Feder *et al.* 1974); some enter bay and estuary (this study).

LIFE HISTORY

The range of the cabezon extends from Turtle Bay, Baja California, northward to Samsing Cove, near Sitka, Alaska (Hart 1973). They are abundant in shallow inshore coastal water and also offshore to moderate depths (O'Connell 1953). In this study, cabezon were observed in San Francisco Bay, San Pablo Bay, Tomales Bay, and Moss Landing-Elkhorn Slough.

Judging from the size of the larvae (3.1–5.8 mm TL) collected during the study, spawning probably occurs along the coast adjacent to San Francisco Bay from October through March. O'Connell (1953), Hart (1973), and Feder *et al.* (1974) have reported that amber to greenish cabezon eggs are deposited in rocky areas from the subtidal to the intertidal zone. The male protects the nest, according to Feder *et al.* (1974), but Jones (1962) has reported that the cabezon provides no parental care. Hart (1973) noted that the toxicity of their eggs reduces the risk of predation by beach foraging mammals and birds. Incubation of eggs takes from 2–3 weeks at unspecified temperature ranges (Frey 1971).

Both larvae and early juveniles are pelagic (O'Connell 1953, Feder *et al.* 1974). The bulk of the larval population remains in coastal waters, although some drift offshore (O'Connell 1953) and others enter bays (Eldridge 1977, Nybakken *et al.* 1977). In this study, cabezon larvae were observed in both shallow and deep waters of San Francisco Bay, Tomales Bay, Moss Landing Harbor, and Elkhorn Slough (up to the end of the slough).

Early juveniles are silver and blue and gradually develop mottling. They become bottom-dwelling at ca. 33–45 mm TL (Bane and Bane 1971, Feder *et al.* 1974). They are common in shallow coastal water. The diet of demersal juvenile cabezon includes mainly crustaceans (amphipods, shrimps, small crabs) and small tidepool fishes (O'Connell 1953, Bane and Bane 1971).

Cabezon reach maturity at 2–3 years for males, females mature at slightly greater ages (O'Connell 1953). This species is considered to be an excellent food fish, however, the roe is toxic (Feder *et al.* 1974). Commercial landings of cabezon occur mainly in Monterey during winter months, sportfishing ranges from Santa Barbara to San Francisco Bay, mostly in the warmer summer months (O'Connell 1953, Frey 1971).

O'Connell (1953) provides an excellent description of the early life history of cabezon, which has been summarized in this report. Other important investigations include those of Marliave (1975) and Richardson and Washington (1980).

References

Bane and Bane 1971, Bolin 1944, Eldridge 1977, Feder *et al.* 1974, Frey 1971, Hart 1973;Marliave 1975, Miller and Lea 1972, Nybakken *et al.* 1977, O'Connell 1953, Richardson and Washington 1980.

ARTEDIUS spp. (*Artedius notospilotus* Girard?)

SPAWNING

Location	In the vicinity of San Mateo and Dumbarton Bridges of south San Francisco Bay.
Season	Larvae were collected in March and April; spawning was estimated from March through April.
Temperature	Larvae collected at 11.8°C.
Salinity	Polyhaline to seawater.

CHARACTERISTICS

LARVAE

Length at hatching	Ca. 2.5–3.0 mm TL.
Snout to anus length	Ca. 38–40% of TL of larvae at 3.0–3.5 mm TL.
Yolk sac	Spherical, in thoracic region, extending to abdominal region.
Oil globule	Single.
Gut	Twisted or coiled in late prolarvae and early postlarvae; anus protruding to the edge of the finfold.
Air bladder	None.
Size at completion of yolk-sac stage	Ca. 3.0–3.5 mm TL.
Total myomeres	31–33.
Preanal myomeres	10–13.
Postanal myomeres	20–22.
Pigmentation	A series of melanophores (ca. 10–20) along postanal region; a dark blotch covering from anus to the dorsal portion of body cavity and a pair of “hollowed-horn” structures which stand behind dorsal base of pectoral fin; a few large stellate melanophores located between the two “hollowed horns”.
Distribution	Pelagic, found in south San Francisco Bay.

LIFE HISTORY

In the genus *Artedius*, there are three species known to San Francisco Bay: the padded sculpin, *A. fenestralis*, the Smoothhead sculpin, *A. lateralis*, and the bonyhead sculpin, *A. notospilotus* (Aplin 1967, Ruth 1969). (The roughcheek sculpin, *A. creaseri*, and Scalyhead sculpin, *A. harringtoni*, were collected in Moss Landing-Elkhorn Slough in this study.)

Budd (1940) described the early life stages of smoothhead sculpin, Marliave (1975) the padded sculpin, and Richardson and Washington (1980) the scalyhead sculpin. The specimens of *Artedius* collected in south San Francisco Bay in this study fit into *Artedius* larvae Type 2 as described by Richardson and Washington (1980). The distinguishing characteristic of this type of larva is having a pair of “water wings” or “horn-like” or “diverticulum from gut” structures behind and above the base of the pectorals.

Bonyhead sculpin were more often observed in San Francisco Bay than padded sculpin and smoothhead sculpin. Therefore, these *Artedius* larvae may be assumed to be bonyhead sculpin.

References

Aplin 1967, Budd 1940, Marliave 1975, Richardson and Washington 1980, Ruth 1969.

Characteristic Comparison: Sculpins

Characteristic	Prickly Sculpin	Riffle Sculpin	Buffalo Sculpin	Brown Irish Lord
Larvae				
Total myomeres	32–37	31–34	29–31	34–36
Preanal myomeres	8–12	10–12	10–11	10–11
Postanal myomeres	22–26	20–22	19–20	24–26
Pigmentation	Series of stellate melanophores along postanal region; melanophores in thoracic area, dorsal gut, and base of pectoral fins	Prolarvae: a few large stellate melanophores scattered on head, yolk sac, and dorsal side of gut and a series of melanophores in postanal region, postlarvae: large and heavy melanophores covering head and throughout the body, the density varying among individuals	Stellate melanophores on nape, thoracic region, dorsal body cavity, and postanal region, late postlarvae: melanophores on head, caudal, and anterior to caudal regions (the last forming a blotch)	Melanophores on head, middorsum to the posterior-most myomere, some melanophores on dorsolateral surface of gut, a series of melanophores in postanal region, and a single melanophore near tip of notochord, a few melanophores also in the thoracic region
Juveniles				
Dorsal fin	VII–X, 13–19	V–VIII, 16–19	VII–IX, 9–13	X–XI, 18–20
Anal fin	15–18	14–16	8–10	14–17
Pectoral fin	15–18	14–17	16–18	14–16
Distribution	Freshwater to estuarine	Freshwater	Coastal marine	Coastal marine, offshore
Distinguishing characters	Elongated base of anal fin	Large pigmented blotch on spiny dorsal fin	End of spiny dorsal with cirri, first (upper) preopercular spine elongate	Anterior nostril with flap

Characteristic Comparison: Sculpins

Characteristic	**Pacific Staghorn Sculpin**	**Tidepool Sculpin**	**Cabezon**	**Bonehead Sculpin**
Larvae				
Total myomeres	31–37	31–34	34–36	31–33
Preanal myomeres	8–14	7–12	14	10–13
Postanal myomeres	23–28	21–27	20–22	20–22
Pigmentation	Ca. 7 dark bands shade dorsal portion of body cavity; stellate melanophores on cephalic, thoracic, and postanal regions; a bar in front of snout, pigmentation on head and 3 distinctive dark blotches on middorsal region in postlarvae	Large stellate melanophores on head and nape areas; melanophores also covering dorsal portion of body cavity and part of the gut; a series of melanophores along postanal region, large melanophores on head, opercles, and jugular region	Large stellate melanophores on snout and on cephalic, middorsal, dorsal, and postanal regions; melanophores on sides of body in postlarvae; caudal region free of pigmentation	Series (10–20) of melanophores along postanal region; a dark blotch from anus to dorsal portion of body cavity and a pair of hollowed-horn structures which stand behind dorsal base of pectoral fin; a few large stellate melanophores between two hollowed horns
Juveniles				
Dorsal fin	VI–VIII, 15–20	VII–IX, 16–18	VII–XII, 15–18	IX, 14–16
Anal fin	14–20	11–14	11–14	11–13
Pectoral fin	17–20	13–15	14–16	15–17
Distribution	Euryhaline	Coastal marine	Coastal marine	Coastal marine
Distinguishing characters	Prominent stag's horn or antler-like first (upper) preopercular spine	Anal papilla long, usually curved forward	Spine behind nasal area directed backward toward eyes; cirrus at tip of snout	No scales under anterior portion of orbit

Figure 38.—Cottidae: *Cottus asper*, prickly sculpin.

FIGURE 38-1.—Newly fertilized egg, 1.4 mm diameter.

FIGURE 38-2.—Egg, morula, 1.4 mm diameter.

FIGURE 38-3.—Egg, early embryo, 1.5 mm diameter.

FIGURE 38-4.—Egg, late embryo, 1.5 mm diameter.

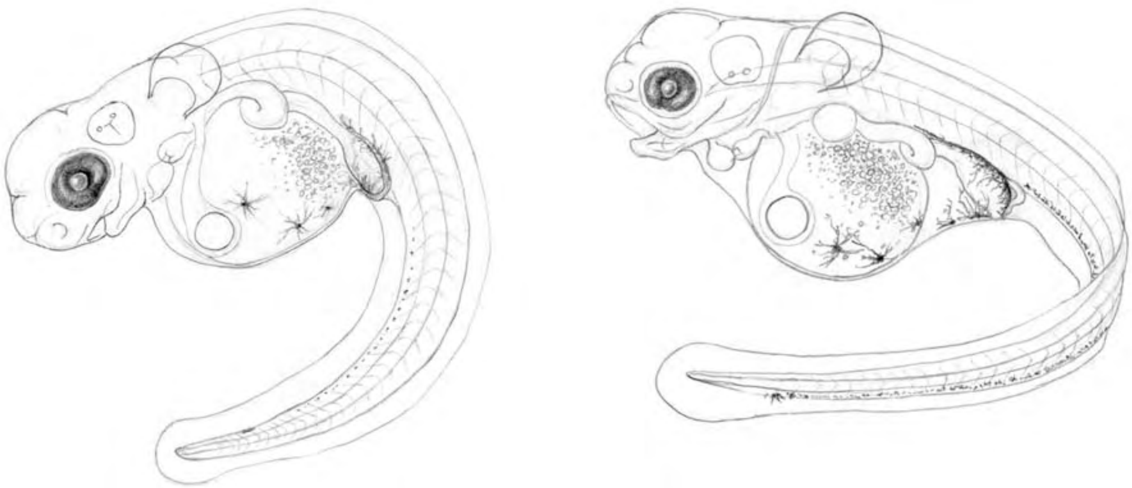


FIGURE 38-5, 38-6.—Newly hatched prolarvae, 4.5 mm TL.

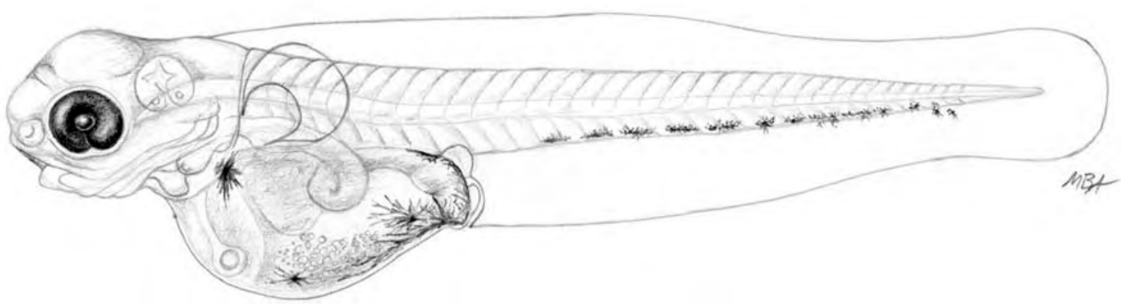


FIGURE 38-7.—Prolarva, 5.5 mm TL.

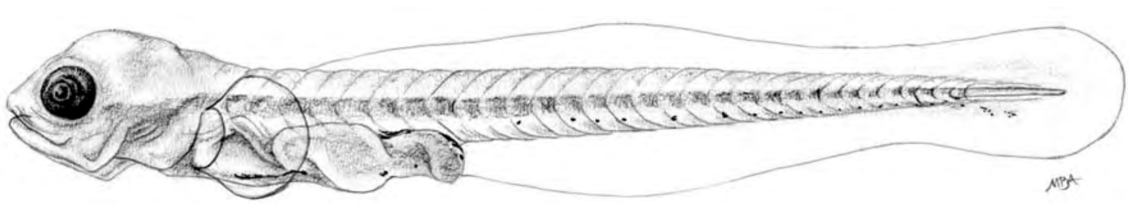


FIGURE 38-8.—Postlarva, 6 mm TL.

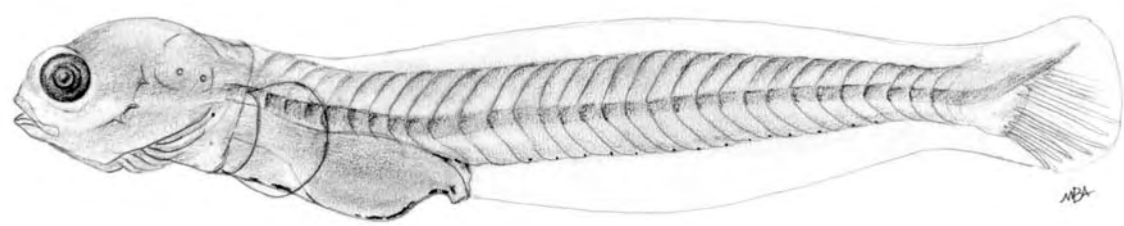


FIGURE 38-9.—Postlarva, 7.4 mm TL.

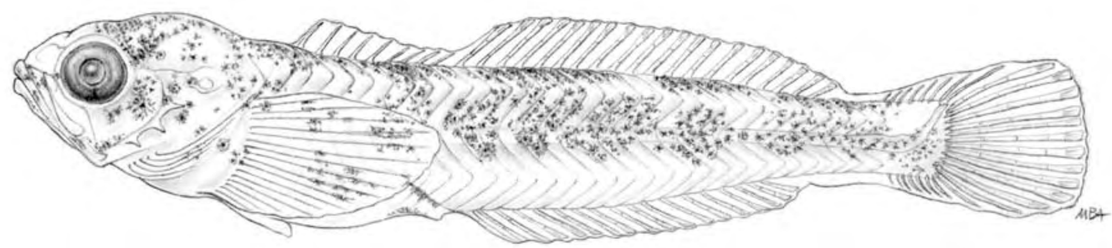


FIGURE 38-10.—Juvenile, 11.4 mm TL.

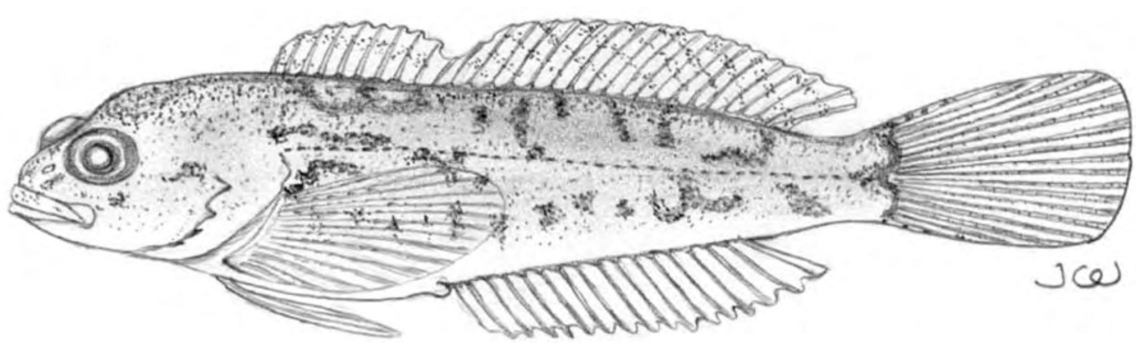


FIGURE 38-11.—Juvenile, 34.5 mm TL.

Cottidae: *Cottus gulosus*, riffle sculpin

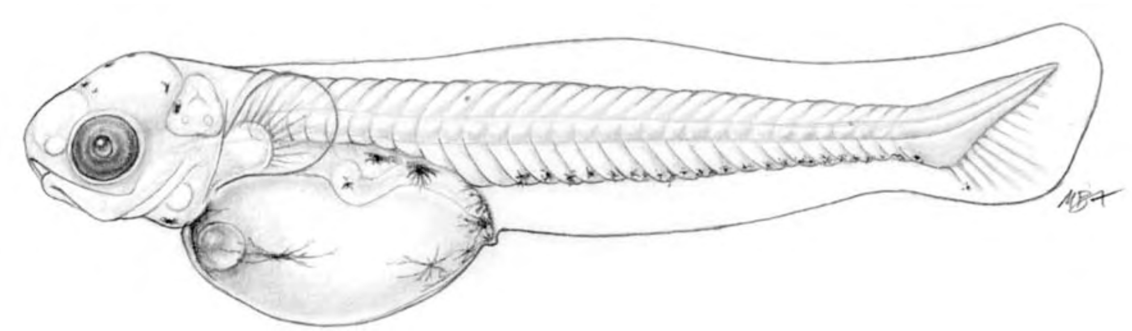


FIGURE 38-12.—Prolarva, 6.5 mm TL.

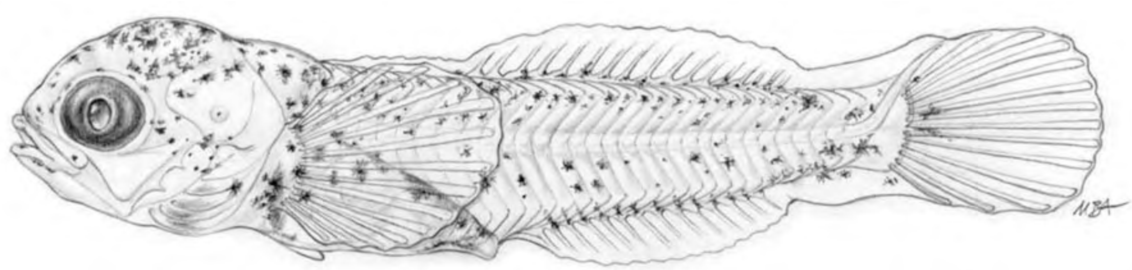


FIGURE 38-13.—Postlarva, 7.2 mm TL.

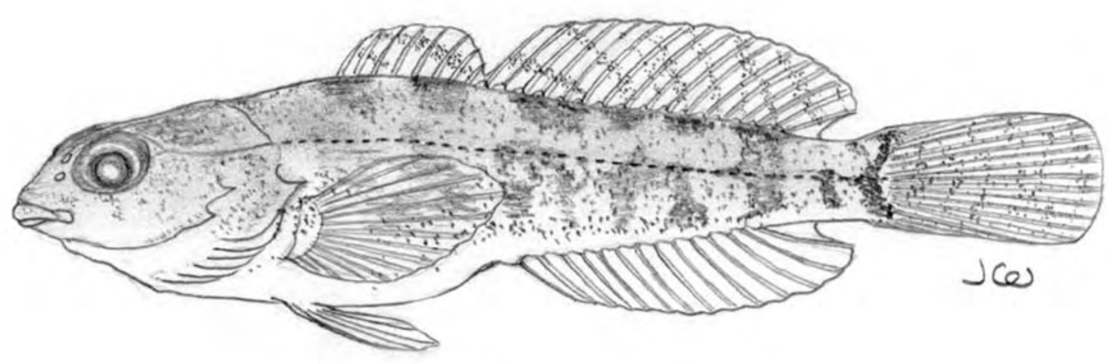


FIGURE 38-14.—Juvenile, 22.7 mm TL.

Cottidae: Sculpins.

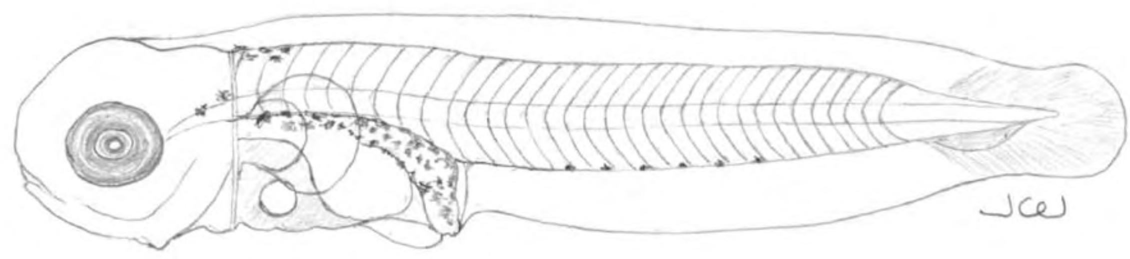


FIGURE 38-15.—*Enophrys bison*, buffalo sculpin prolarva, 4.6 mm TL.

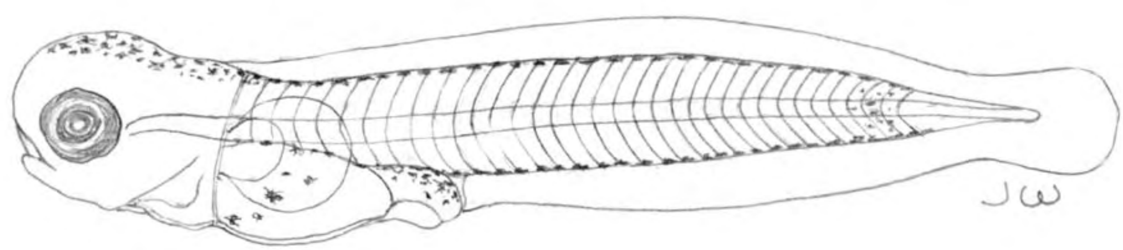


FIGURE 38-16.—*Hemilepidotus spinosus*, brown Irish lord postlarva, 5.1 mm TL.

Cottidae: *Leptocottus armatus*, Pacific staghorn sculpin.

FIGURE 38-17.—Egg, late embryo, 1.4 mm diameter.

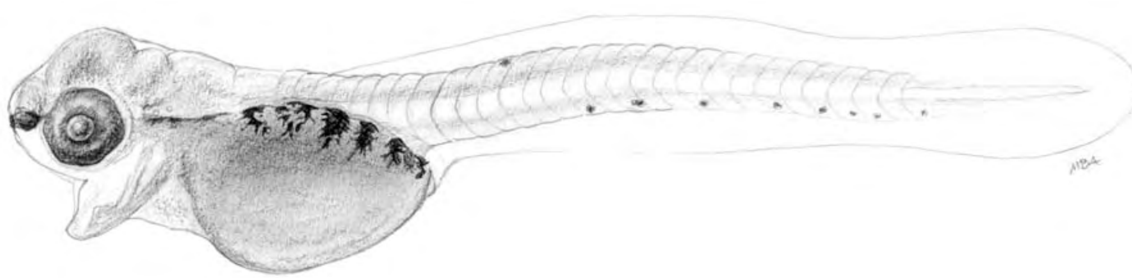


FIGURE 38-18.—Prolarva, 5 mm TL.

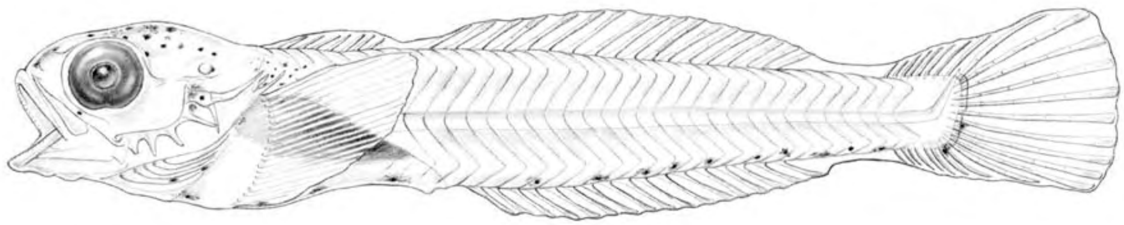


FIGURE 38-19.—Postlarva, 12 mm TL.

FIGURE 38-20.—Juvenile, 43 mm TL.

Cottidae: *Oligocottus maculosus*, tidepool sculpin.

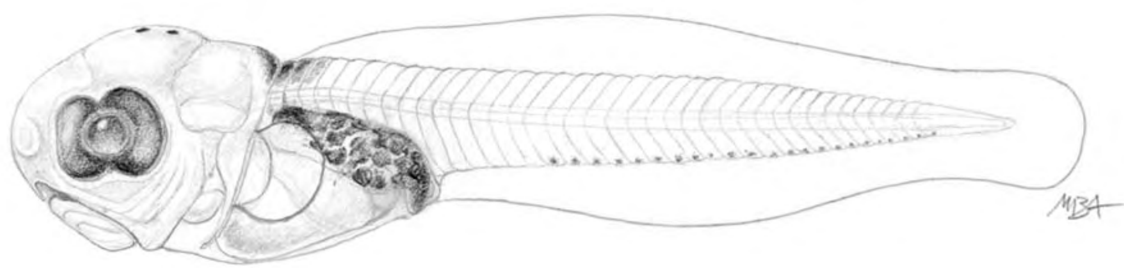


FIGURE 38-21.—Prolarva, 3.5 mm TL.

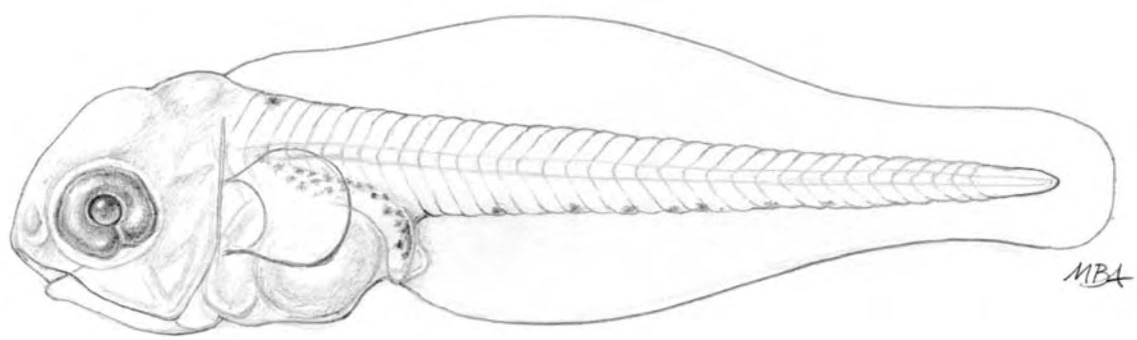


FIGURE 38-22.—Prolarva, 4.5 mm TL.

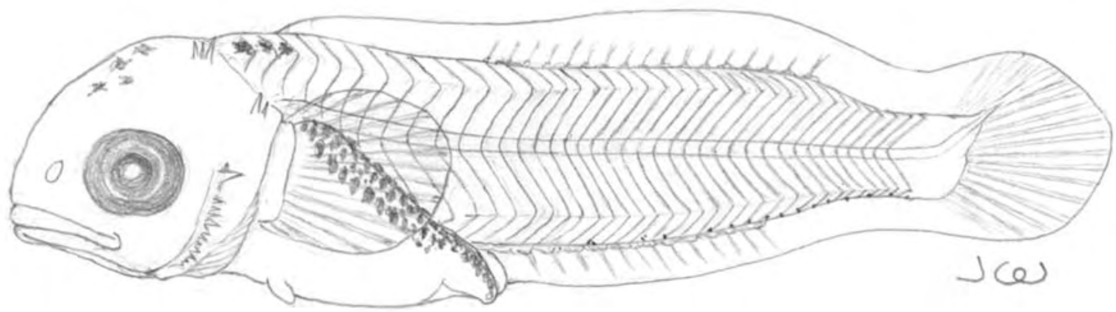


FIGURE 38-23.—Postlarva, 8.4 mm TL.

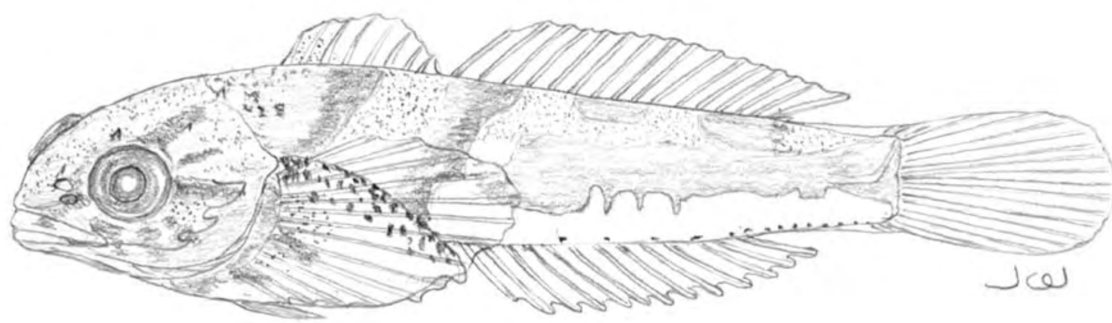


FIGURE 38-24.—Juvenile, 13 mm TL.

Cottidae: *Scorpaenichthys marmoratus*, cabezon.

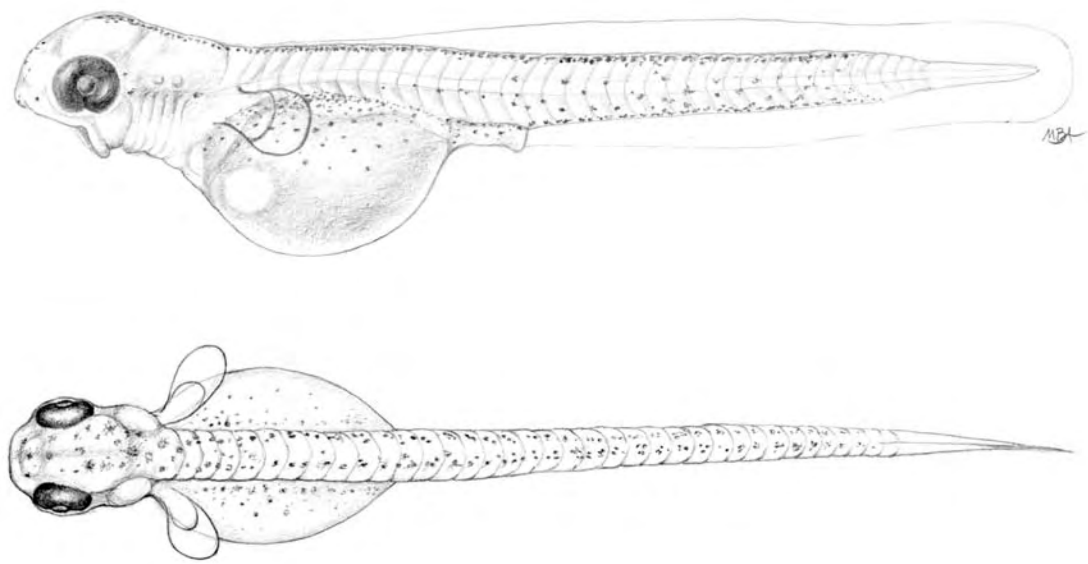


FIGURE 38-25, 38-26.—Prolarva, lateral and dorsal views, 4.8 mm TL.

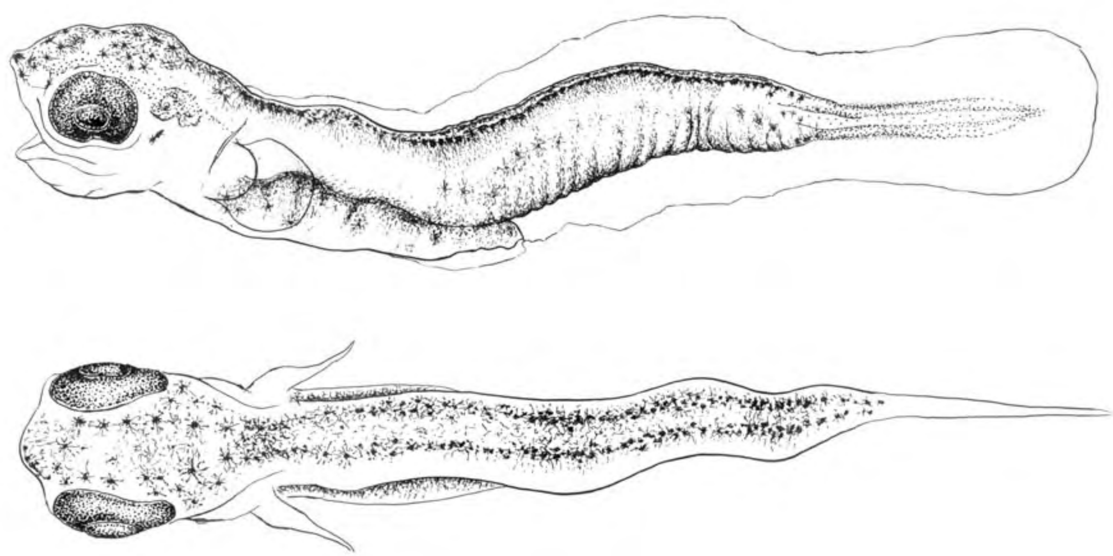


FIGURE 38-27, 38-28.—Postlarva, lateral and dorsal views, 5 mm TL.

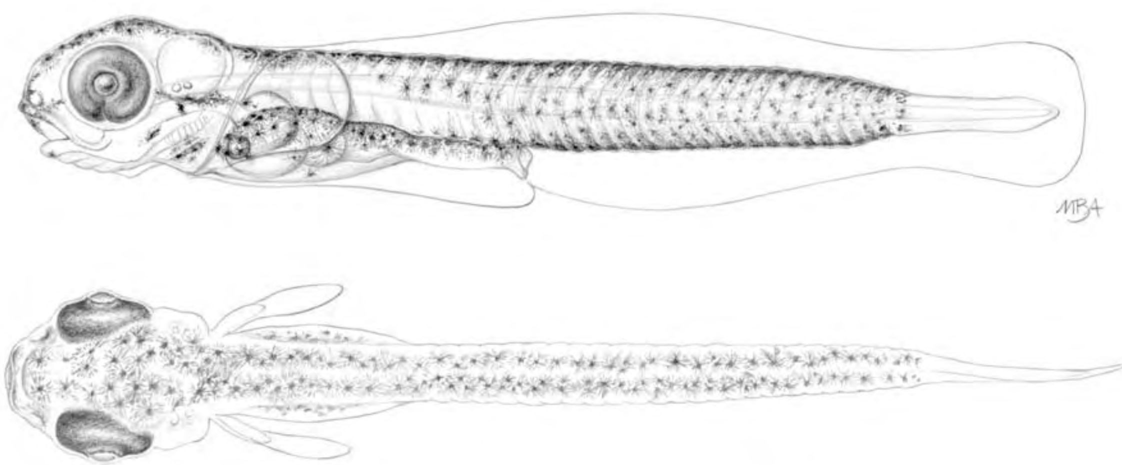
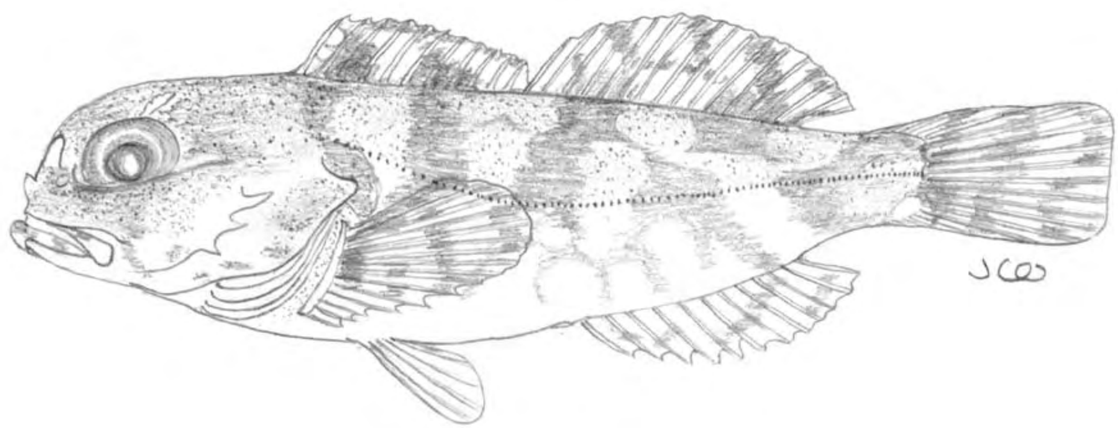


FIGURE 38-29, 38-30.—Postlarva, lateral and dorsal views, 6.3 mm TL.



FIGURES 38-31.—Juvenile, 50 mm TL.

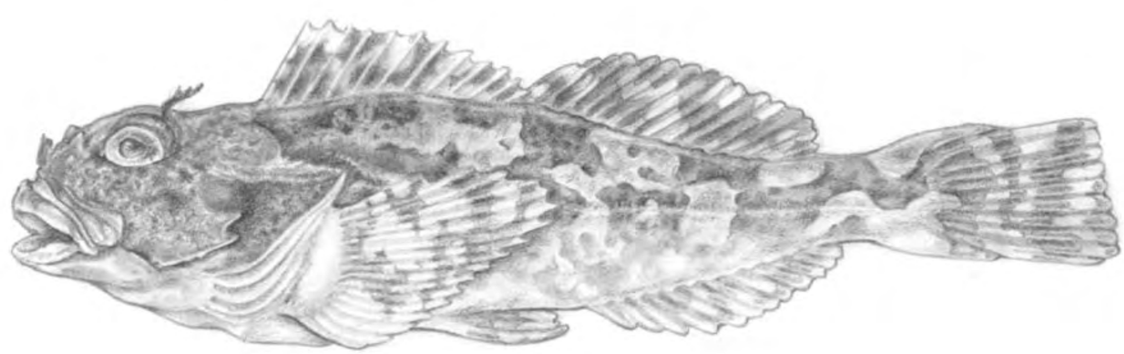


FIGURE 38-32.—Juvenile, 83 mm TL.

Cottidae: Sculpins.

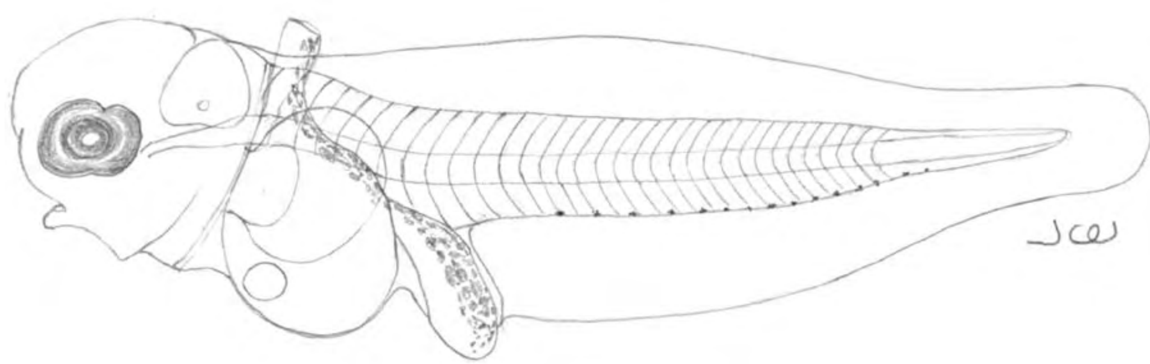


FIGURE 38-33.—*Artedius* spp. prolarva, 3.2 mm TL (may be *Artedius notospilotus*, bonehead sculpin).

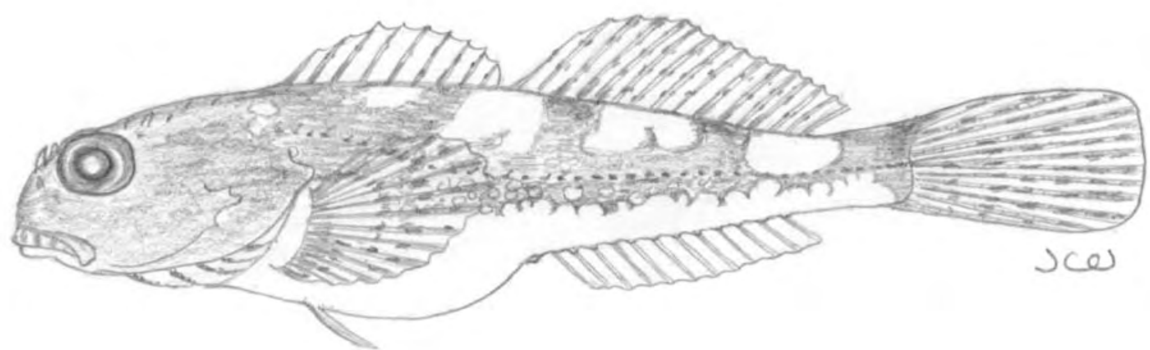


FIGURE 38-34.—*Artedius notospilotus*, bonehead sculpin juvenile, 58 mm TL.

39. Agonidae – Poachers

Twenty-five species of poachers are recorded on the Pacific coast of the United States and Canada (Robins *et al.* 1980). Both the pricklebreast poacher, *Stellerina xyosterna*, and the pygmy poacher, *Odontopyxis trispinosa*, are found in the San Francisco Bay (Aplin 1967) and Bodega-Tomales Bay areas (Bane and Bane 1971). Only the pricklebreast poacher is discussed in this chapter. The body of a poacher is completely covered with bony plates, so it superficially resembles an alligator.

References

Aplin 1967, Bane and Bane 1971, Robins *et al.* 1980.

PRICKLEBREAST POACHER, *Stellerina xyosterna* (Jordan and Gilbert)

SPAWNING

Location	Coastal waters and possibly lower portions of estuaries (Richardson and Pearcy 1977, Misitano 1977).
Season	Fall to winter months.
Temperature	12–14.
Salinity	Seawater.
Fecundity	1,100 mature eggs observed from a 128-mm TL specimen.

CHARACTERISTICS

EGGS

Shape	Spherical.
Diameter	Mature unfertilized eggs: 1.3–1.4 mm.
Yolk	Unfertilized eggs, yellowish clear.
Oil globule	Unfertilized eggs, numerous oil globules.
Chorion	Unfertilized eggs, transparent, very thick.

LARVAE (Figure 39-1)

Snout to anus length	Ca. 40% of TL of larvae at 4.9 mm TL; 46–47% of TL of larvae at 5.8–9.6 mm TL.
Yolk sac	Spherical to oval, in thoracic region.
Oil globule	Single oil globule.

Gut	Short, twisted, and thick. The rectum and anus protrude in prolarval and postlarval stages.
Air bladder	None.
Teeth	Small, pointed, apparent in postlarval stage.
Total myomeres	33–36.
Preanal myomeres	11–13.
Postanal myomeres	21–23.
Last fin(s) to complete development	Pelvic.
Pigmentation	In prolarvae, little or no pigment on head and nape, but the rest of the body is covered with large melanophores. Melanophores are also found on finfolds in three distinct regions: just above the anal, behind the anal, and the caudal. After the pectoral fins develop, three distinctive blotches appear on pectoral fins, in the thoracic area, and a band crossing mid-second dorsal and anal fin regions.
Distribution	Pelagic in coastal waters and lower estuaries (Richardson and Pearcy 1977, Misitano 1977, this study).

JUVENILES (Figure 39-2)

Dorsal fin	VI–VII, 6 (Bane and Bane 1971); VI–VIII, 5–7 (Miller and Lea 1972).
Anal fin	8–9 (Bane and Bane 1971, Miller and Lea 1972).
Pectoral fin	17–19 (Miller and Lea 1972).
Mouth	Mouth oblique, lower jaw projecting (Bane and Bane 1971); superior.
Vertebrae	34–37 (Miller and Lea 1972).
Distribution	Early juveniles are pelagic in coastal waters and bays (Richardson and Pearcy 1977, Misitano 1977), large juveniles probably settle on bottom.

LIFE HISTORY

The pricklebreast poacher is found from San Carlos Bay, Baja California, to the Strait of Juan De Fuca, British Columbia (Fitch and Lavenberg 1968, Miller and Lea 1972). In the study area this species has been reported in San Francisco Bay (Aplin 1967), but it is apparently more common in Bodega and Tomales Bays (Bane and Bane 1971). Specimens used for the description here were mostly collected from Moss Landing Harbor-Elkhorn Slough.

Information on the spawning season and location of the pricklebreast poacher is unclear in the literature. A related species, the blacktip poacher, *Xeneretmus latifrons*, is known to spawn in deeper water (10–218 fathoms) along the California coast in spring (Fitch and Lavenberg 1968). Ehrenbaum (1904) reported that *Agonus cataphractus*, a British coastal species, spawns from January to April. The chorion of the eggs is very thick to protect them from changes in temperature during the 10–12 months of incubation. In this study, mature eggs of the pricklebreast poacher stripped from adult fish in late summer and early fall had the very thick chorion. Pelagic larvae and early juveniles have been taken in coastal waters and estuarine embayments by plankton samplers along the Oregon coast (Richardson and Pearcy 1977, Misitano 1977). In this study the larvae of the pricklebreast poacher were not collected in San Francisco Bay, but they were captured in plankton nets in the Moss Landing Harbor-Elkhorn Slough area between December and March.

Small juveniles are strong swimmers, their pectoral fins are about one-third of the total body length. They use their large pectoral fins to reach the deeper waters, where they possibly feed on plankton (Bane and Bane 1971). The size of the pectoral fins decreases to about 25% the total body length in the adult. Juvenile and adult poachers were often captured by bottom trawls (D. Watts, Ecological Analysts, Inc. personal communication, 1980).

The age of maturity of the pricklebreast poacher is unknown. The smallest mature fish observed in this study area was 108 mm TL. The pricklebreast poacher is of no value for sport or commercial fishing.

References

Aplin 1967; Bane and Bane 1971; Ehrenbaum 1904; Fitch and Lavenberg 1968; Miller and Lea 1972; Misitano 1977; Richardson and Pearcy 1977; Watts 1980, personal communication.

Figure 39.—Agonidae: *Stellerina xyosterna*, pricklebackk poacher.

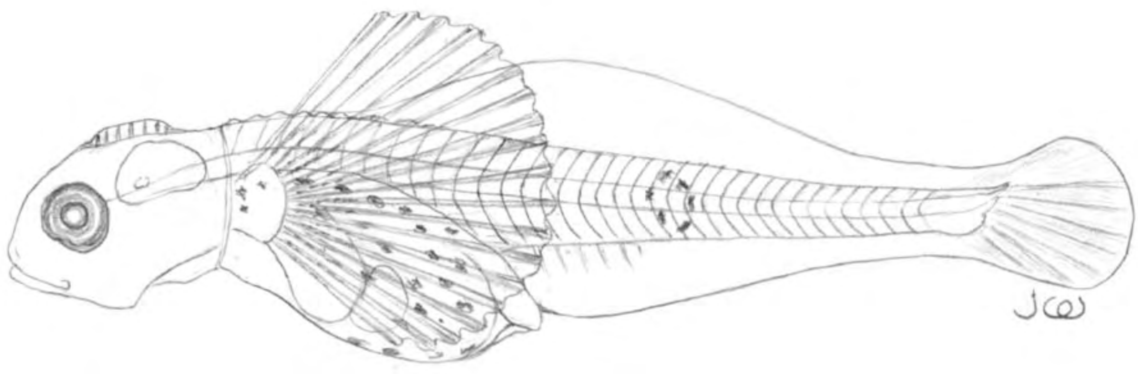


FIGURE 39-1.—Postlarva, 6.1 mm TL.

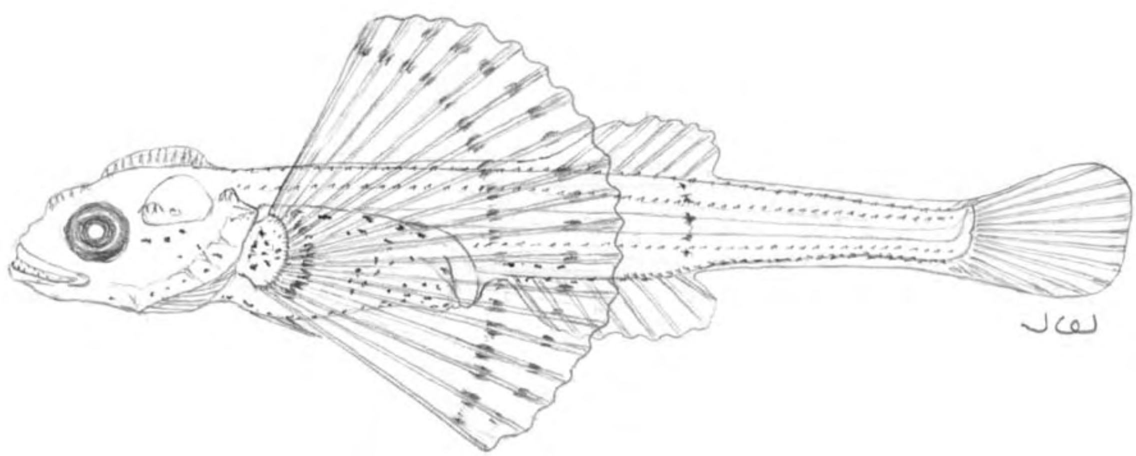


FIGURE 39-2.—Juvenile, 9.4 mm TL.

40. Cyclopteridae – Snailfishes

Six species of snailfish are known to the California coast (Miller and Lea 1972). Three of them were collected in the study area: the showy snailfish, *Liparis pulchellus,* is reported in San Francisco Bay (Aplin 1967), Tomales Bay (Bane and Bane 1971), Bodega Bay (Standing *et al.* 1975), and Moss Landing Harbor-Elkhorn Slough; the tidepool snailfish, *Liparis florae*, is recorded in Tomales Bay (Bane and Bane 1971), and the slipskin snailfish, *Liparis fucensis*, has been taken in Moss Landing Harbor-Elkhorn Slough. Due to the lack of availability of life stage information on the showy and tidepool snailfishes, only the slipskin snailfish is discussed in this chapter.

References

Aplin 1967, Bane and Bane 1971, Miller and Lea 1972, Standing *et al.* 1975.

SLIPSKIN SNAILFISH, *Liparis fucensis* Gilbert

SPAWNING

Location	Coastal area (Marliave 1975, DeMartini 1978).
Season	February in Burrard Inlet (Hart 1973); late May in British Columbia (Marliave 1975); February–September for cyclopteridae along the Oregon coast (Richardson and Pearcy 1977); lengthy spawning season for slipskin snailfish (DeMartini 1978); judging by larvae taken, spawning occurs in May and June.
Salinity	Seawater.
Substrates	Tubes of tubeworms (Marliave 1975); shells (DeMartini 1978).
Fecundity	1,700–4,800 for 62–92 mm SL specimens (DeMartini 1978).

CHARACTERISTICS

EGGS

Shape	Ca. 1.0 mm (Marliave 1975); 0.7–0.9 mm (DeMartini 1978).
Yolk	Light orange, turning silver-grey prior to hatching (Marliave 1975); tan, pink, and orange (DeMartini 1978).
Egg mass	Adhesive and multilayered (DeMartini 1978).

LARVAE (Figure 40-1)

Length at hatching	3.0 mm TL (Marliave 1975, this study).
Snout to anus length	Ca. 37–39% of TL of larvae at 3.0–3.5 mm TL.
Yolk sac	Spherical, large, in thoracic region.
Oil globule	Single (Marliave 1975).
Gut	Twisted.
Air bladder	None.
Size at completion of yolk-sac stage	Ca. 3.5 mm TL or slightly greater.
Total myomeres	38–42.
Preanal myomeres	10–11.
Postanal myomeres	28–31.
Pigmentation	Scattered melanophores on pectoral fins, nape, and yolk sac region; a series of melanophores (ca. 20 or more) along postanal region. Scattered melanophores are also found along both dorsal and ventral finfolds, tip of lower jaw is darkened (Marliave 1975, this study).

JUVENILES (Figure 40-2)

Dorsal fin	33–35 (Miller and Lea 1972, Hart 1973).
Anal fin	27–29 (Miller and Lea 1972, Hart 1973).
Pectoral fin	37–43 (Miller and Lea 1972, Hart 1973).
Mouth	Terminal, small (Hart 1973).
Vertebrae	39–41 (Miller and Lea 1972).
Distribution	Mostly in coastal waters, also found at depth of 385 m (Hart 1973); Moss Landing-Elkhorn Slough.

LIFE HISTORY

The distribution of the slipskin snailfish is from north of San Simeon Point, California, to southeast Alaska (Schultz and DeLacy 1936, Wilimovsky 1954, Miller and Lea 1972). In this study slipskin snailfish were collected from Moss Landing-Elkhorn Slough. None were observed in San Francisco Bay.

Spawning of this species takes place in the subtidal zone along the coast (DeMartini 1978). Egg masses were found in tubes formed by tubeworms (Marliave 1975) and in shells (DeMartini 1978). Spawning has been reported in February (Hart 1973), late May (Marliave 1975), and from May to June (this study). De Martini (1975) predicted a prolonged spawning season, since two distinctive sizes of ova were found in the ovary of the slipskin snailfish. During spawning the nest was attended by the male fish (Marliave 1975, DeMartini 1978). Eggs of slipskin snailfish hatch in 2 weeks at 11˚C (Marliave 1975).

In Oregon, the bulk of the larval slipskin snailfish populations is found along the coast (Richardson and Pearcy 1977). Snailfish larvae have been reported in Humboldt Bay by Eldridge and Bryan (1972). Slipskin snailfish larvae were collected in Moss Landing Harbor-Elkhorn Slough. Larvae of this species are characterized by their oversized and pigmented pectoral fins.

Juvenile slipskin snailfish presumably settle on the bottom after the completion of the development of their sucking disc, as in other cyclopterids. Juveniles feed on small crustaceans, such as shrimp (Hart 1973).

The age of maturity is not clear in the literature. DeMartini (1978) reported capturing a male snailfish in the Straits of Juan de Fuca that was mature although only 55 mm SL. Slipskin snailfish are of no sport or commercial value.

References

DeMartini 1978, Eldridge and Bryan 1972, Hart 1973, Marliave 1975, Miller and Lea 1972, Richardson and Pearcy 1977; Schultz and DeLacy 1936, Wilimovsky 1954.

Figure 40.—Cyclopteridae: *Liparis fucensis*, slipskin snailfish.

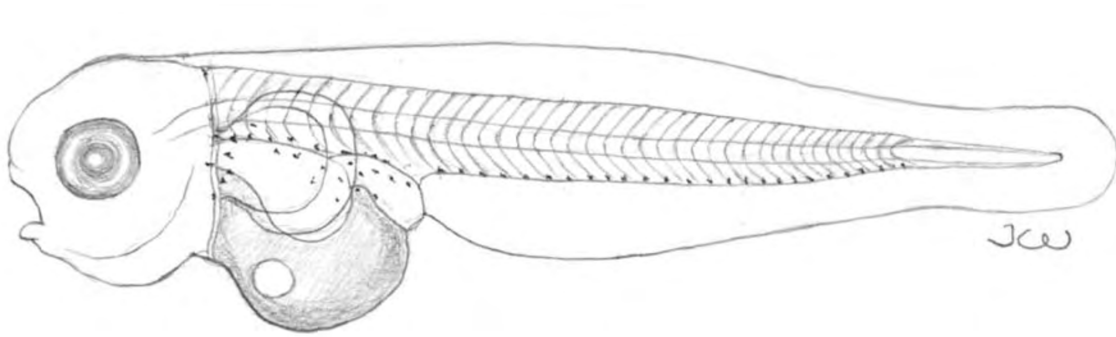


FIGURE 40-1.—Prolarva, 3.2 mm TL.

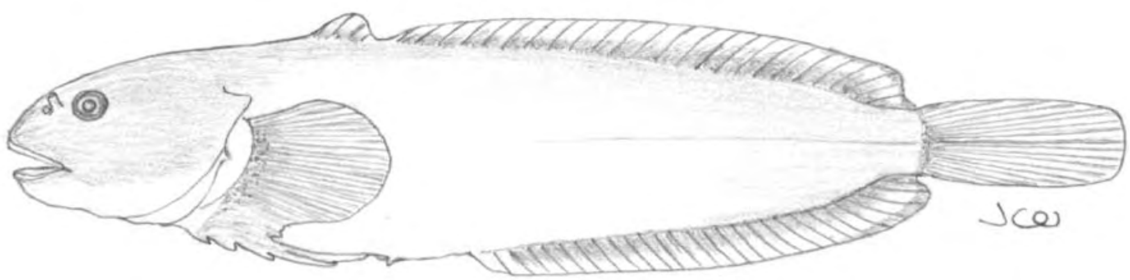


FIGURE 40-2.—Juvenile, 82 mm TL.

41. Bothidae – Lefteye Flounders

Ganssle (1966), Aplin (1967), Ruth (1969), and Green (1975) have reported three species of lefteye flounders inhabiting the Sacramento-San Joaquin Estuary: Pacific sanddab, *Citharichthys sordidus*, speckled sanddab, *Citharichthys stigmaeus*, and California halibut, *Paralichthys californicus*. No larvae of the Pacific sanddab were collected in this study, although it has been reported in Richardson Bay by Green (1975). The early life stages of the speckled sanddab and California halibut are discussed in this chapter.

Bothids have bilaterally symmetrical free-swimming larvae (Bigelow and Schroeder 1953, Ahlstrom and Moser 1975), and they are plankton feeders. As the larvae grow, their bodies become deeper and the right eye migrates to the left side of the head (sinistral movement). Juveniles are asymmetrical and eventually settle and feed mainly on the bottom. Lefteye flounders are generally found in shallow coastal waters, although some can be found in deeper water offshore.

References

Ahlstrom and Moser 1975, Aplin 1967, Bigelow and Schroeder 1953, Ganssle 1966, Green 1975, Ruth 1969.

SPECKLED SANDDAB, *Citharichthys stigmaeus* Jordan and Gilbert

SPAWNING

Location	Probably in coastal waters, since females in spawning condition were taken in 5–45 m deep water (Ford 1965).
Season	April–September (Ford 1965). Judging by time when larvae were collected, spawning occurs in December (Eldridge with Bryan 1972); March–September (Fitch and Lavenberg 1975); all months, with large numbers in June and July (Ahlstrom and Moser 1975). Judging by larval collections, spawning occurred from November through April.
Temperature	10.5–14.0˚C (Ford 1965).
Salinity	Seawater.
Fecundity	(Mature eggs) 1,000–6,200 per batch (Ford 1965).

CHARACTERISTICS

EGGS

Diameter	0.60–0.77 mm, mature eggs (Ford 1965).

LARVAE (Figure 41-1)

Length at hatching	Ca. 2.0 mm TL (judging by the smallest specimens taken in this study).
Snout to anus length	Ca. 36–38% of TL in larvae of 2.1–3.4 mm TL.
Yolk sac	Spherical, in thoracic region.
Gut	Short and straight, bends vertically in anal region, forms a loop in postlarvae at ca. 3.0 mm TL.
Air bladder	Small, spherical or oval, near anus, apparent in postlarvae ca. 6.0 mm TL.
Size at completion of yolk-sac stage	Ca. 3.0 mm TL.
Total myomeres	36–39.
Preanal myomeres	11–14.
Postanal myomeres	24–27.
Last fin(s) to complete development	Pectoral.
Pigmentation	A series of melanophores in thoracic region and dorsal portion of gut region and a single melanophore located in infraorbital region. A few large melanophores in postanal region and around the tip of notochord. Two dark blotches encircle the body between anus and tail, one near caudal peduncle and the other close to anus.
Distribution	Pelagic in coastal waters and offshore (Fitch and Lavenberg 1975, Ahlstrom and Moser 1976); in bays and estuaries (Eldridge and Bryan 1972, this study).

JUVENILES (Figure 41-2)

Dorsal fin	83–92 (Clothier 1950); 75–97 (Miller and Lea 1972); 79–82 (Hart 1973).
Anal fin	67–72 (Clothier 1956); 58–77 (Miller and Lea 1972); 59–72 (Hart 1973).
Pectoral fin	12 (Miller and Lea 1972).
Mouth	Terminal, moderate in size and gape (Hart 1973); mouth terminal, oblique, and large.
Vertebrae	37–38 (Clothier 1950); 34–39 (Miller and Lea 1972); mostly 36.
Distribution	Found inshore of bays and estuaries, such as San Francisco Bay and Moss Landing Harbor.

LIFE HISTORY

The speckled sanddab is found from Magdalena Bay, Baja California, to Montague Island, Alaska (Townsend 1935, Wilimovsky 1954, Miller and Lea 1972). In San Francisco Bay, speckled sanddab was one of the most abundant species found by Aplin (1967). This species was also recorded in Tomales Bay (Bane and Bane 1971) and in Moss Landing Harbor-Elkhorn Slough (Nybakken *et al.* 1977, this study). In this study most of the specimens were juveniles and were captured in winter and spring months.

Spawning probably occurs in coastal waters. Gravid fish were observed off Moss Landing Harbor and San Francisco Bay in fall and winter months (this study). However, Ahlstrom and Moser (1975) collected larvae of this species year-round, with high numbers in June and July. Ford (1965) has suggested that the spawning season of speckled sanddab is longer than that of other bothids. Richardson and Pearcy (1977) collected larvae of this species within 28 km of the Oregon coast. Eldridge (1977) observed larvae of *Citharichthys* spp. in Richardson Bay, and Nybakken *et al.* (1977) collected them in Moss Landing Harbor. In this study, sanddab larvae were collected in San Francisco Bay and Moss Landing Harbor. The majority of the larvae are believed to be the speckled sanddab (vertebra counts ranged from 34 to 39, whereas the Pacific sanddab has 39–40 vertebrae.

Larvae and early juveniles are bilaterally symmetrical. As they grow, the right eye migrates to the left side of the head. Juveniles are often found in bays and estuaries. They have been collected on the intake screens of the Potrero, Hunters Point, and Moss Landing Powerplants during various months.

In La Jolla Bay, the smallest juveniles were found in shallow water (15–25 m), while larger sizes were distributed at all depths (Ford 1965). Ehrlich *et al.* (1979) reported that speckled sanddab in King Harbor are more abundant from the winter through the early summer months than in the summer and fall months, and that this variation is probably related to temperature. Ford (1965) also noticed seasonal variations, but attributed then to the settling of larvae in the cooler months and subsequent predation losses later in the year. Juvenile speckled sanddab feed primarily on small crustaceans such as copepods, isopods, amphipods, and mysid shrimps and on annelids such as polychaete worms (Ford 1965, Bane and Bane 1971, Ambrose 1976, Nybakken *et al.* 1977).

The speckled sanddab matures after the first year of life, and the maximum age is approximately 4 years (Fitch and Lavenberg 1975). Because of its small size, this species is unsuitable for commercial or sport fishing, although they are abundant along the Pacific coast.

References

Ahlstrom 1965; Ahlstrom and Moser 1975; Aplin 1967; Ambrose 1976; Bane and Bane 1971; Clothier 1950; Eldridge 1977, 1979; Eldridge and Bryan 1972; Fitch and Lavenberg 1975; Ford 1965; Hart 1973; Miller and Lea 1972; Nybakken *et al.* 1977; Richardson and Pearcy 1977; Townsend 1935, Wilimovsky 1954.

CALIFORNIA HALIBUT, *Paralichthys californicus* (Ayres)

SPAWNING

Location	Shallow coastal waters (Frey 1971, Ahlstrom and Moser 1975).
Season	February through July, with a great number of mature fish in May (Clark 1930, Bane and Bane 1971); larvae found in October in Richardson Bay (Eldridge 1977); larvae taken from October through April (this study); all year, with a peak from January through August (Ahlstrom and Moser 1975).
Salinity	Seawater.
Substrates	None.

CHARACTERISTICS

EGGS

Shape	Spherical.
Diameter	Average, 0.9 mm (Ahlstrom and Moser 1975).
Yolk	Homogeneous (Ahlstrom and Moser 1975).
Oil globule	Single, small (Ahlstrom and Moser 1975).
Chorion	Transparent, unsculptured (Ahlstrom and Moser 1975).
Perivitelline space	Narrow (Ahlstrom and Moser 1975).
Egg mass	Single.
Adhesiveness	No.
Buoyancy	Pelagic (Ahlstrom and Moser 1975).

LARVAE (Figures 41-3, 41-4)

Length at hatching	Judging from the smallest specimens taken in this study, ca. 2.0 mm TL.
Snout to anus length	Ca. 48% of TL at 2.5 mm TL; ca. 38–45% of TL larvae at 6.5–8.3 mm TL.
Yolk sac	Spherical, in thoracic region.
Oil globule	Single, small.
Gut	Short, thick, coiled in one loop, in postlarval stage, anal region bends ventrally.
Air bladder	None.
Size at completion of yolk-sac stage	Ca. 2.5 mm TL.

Total myomeres	34–36.
Preanal myomeres	10–11.
Postanal myomeres	23–26.
Last fin(s) to complete development	Pectoral.
Pigmentation	2 rows of melanophores along body (1 on dorsum, 1 on ventrum), scattered melanophores on finfolds, head, gut, thoracic, and yolk-sac regions. A series of melanophores along the dorsal portion of vertebral column in postlarvae, ca. 65. mm TL and greater.
Distribution	Pelagic, mostly along coast (Ahlstrom and Moser 1975); some entering bays and estuaries (Eldridge 1977, Eldridge and Bryan 1972, Nybakken *et al.* 1977, this study).

JUVENILES (Figure 41-5)

Dorsal fin	68–74 (Clothier 1950); 70 (Bane and Bane 1971); 66–76 (Miller and Lea 1972, Ahlstrom and Moser 1975).
Anal fin	52–48 (Clothier 1950); 55 (Bane and Bane 1971); 49–59 (Miller and Lea 1972); 49–59 (Ahlstrom and Moser 1975).
Pectoral fin	10–13 (Miller and Lea 1972).
Mouth	Terminal, large, oblique.
Vertebrae	34–36 (Clothier 1950, Miller and Lea 1972); 36 (Ahlstrom and Moser 1975).
Distribution	Coastal waters, bays and estuaries (Haaker 1975); San Francisco Bay, San Pablo Bay, Moss Landing Harbor.

LIFE HISTORY

The California halibut ranges from Magdalena Bay, Baja California (Gilbert and Scofield 1898), to the Quillayute River, British Columbia (Pattie and Baker 1969), although the northern range has been reported as far as Alaska (Bane and Bane 1971). An isolated population is also known in the Gulf of California (Miller and Lea 1972). This species is common along the coastal bays and estuaries of southern California (Haaker 1975). Locally, California halibut were occasionally observed in San Francisco Bay (Aplin 1967), San Pablo Bay (Ganssle 1966), Tomales Bay (Bane and Bane 1971), and Moss Landing Harbor-Elkhorn Slough (Nybakken *et al.* 1977). Both larvae and juveniles were observed in San Francisco Bay, San Pablo Bay, and Moss Landing Harbor-Elkhorn Slough in this study.

Spawning occurs in shallow coastal waters from January to July (Clark 1930, Frey 1971, Fitch and Lavenberg 1975). Information from California Cooperative Oceanic Fisheries Investigations (CalCOFI) surveys suggests that spawning takes place along the southern California coast all year (Ahlstrom and Moser 1975). In the study area, larvae of this species were collected in summer and fall months (Nybakken *et al.* 1977, Eldridge 1971) or in fall and winter (this study).

Eggs are spherical, with an unsculptured chorion and a single small oil globule (Ahlstrom and Moser 1975). Eggs of a similar description were found in San Francisco Bay and Moss Landing Harbor, however, their identity could not be verified. Eggs were reported as demersal by Frey (1971); Ahlstrom and Moser (1975) have suggested that California halibut eggs are pelagic.

Newly hatched larvae are pelagic and bilaterally symmetrical (Ahlstrom and Moser 1975). The larval population remains along the coast (Ahlstrom and Moser 1975). Some larvae have been collected in bays and estuaries (Eldridge 1977, Nybakken *et al.* 1977, this study), therefore, either active or passive movement occurs in their early life, but the details of this movement are unclear in the literature.

Migration of the eye begins at ca. 8–9 mm SL (Ahlstrom and Moser 1975). Sinistral migration is common, but dextral migration may also occur in this species. Juveniles become demersal after the completion of metamorphosis, and they do not travel extensively (Frey 1971). Major food items for juvenile halibut include amphipods, cumaceans, copepods, mysids, and even some small gobies (Haaker 1979).

Male California halibut reach maturity as early as 2 years of age, females at the end of the fifth or sixth year. These fish may live as long as 30 years (Frey 1971). This species is one of the most desirable of commercial and sport fish in California (Frey 1971, Bane and Bane 1971).

References

Ahlstrom and Moser 1975, Aplin 1967, Bane and Bane 1971, Clark 1930, Clothier 1950, Eldridge 1977, Eldridge and Bryan 1972, Fitch and Lavenberg 1971, Frey 1971, Ganssle 1966, Gilbert and Scofield 1898, Haaker 1975, Miller and Lea 1972, Nybakken *et al.* 1977, Pattie and Baker 1969.

Characteristic Comparison: Lefteye Flounders

	Speckled Sanddab	**California Halibut**
Larvae		
Pigmentation	Dark blotch encircles body midway between anus and tail.	No dark blotch encircles body.
Dorsal finfold	No finrays developed in front of dorsal finfold	Ca. 5 elongated finrays develop in front of dorsal finfold.
Juveniles		
Dorsal fin	75–97	66–76
Anal fin	58–72	49–59
Pectoral fin	12	10–13
Vertebrae	34–39	34–36
Lateral line	High arch above pectoral	Slight arch or straight above pectoral

Figure 41.—Bothidae: *Citharichthys stigmaeus*, speckled sanddab.

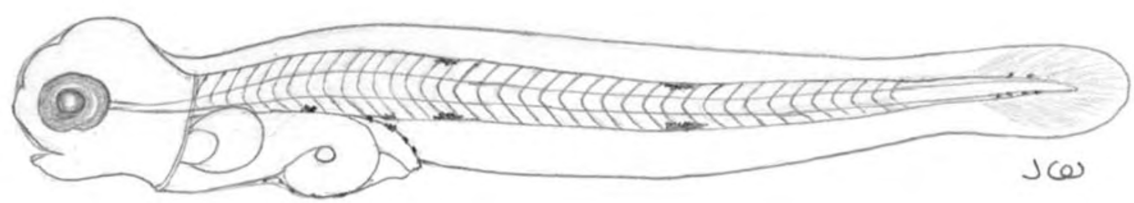


FIGURE 41-1.—Postlarva, 3.4 mm TL.

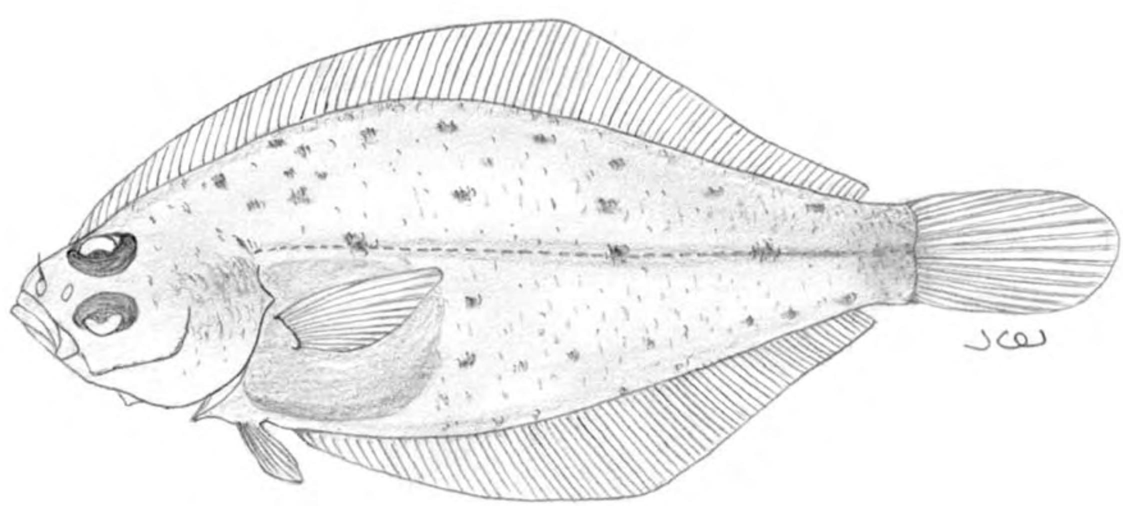


FIGURE 41-2.—Juvenile, 52 mm TL.

Bothidae: *Paralichthys californicus*, California halibut.

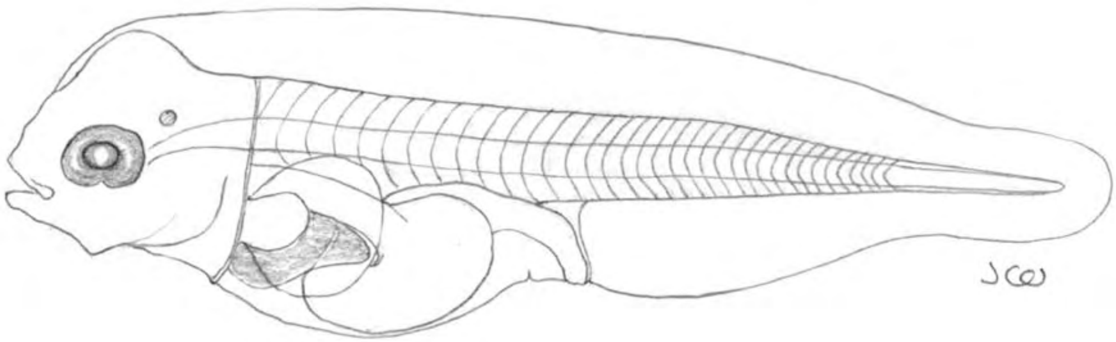


FIGURE 41-3.—Postlarva, 3.2 mm TL.

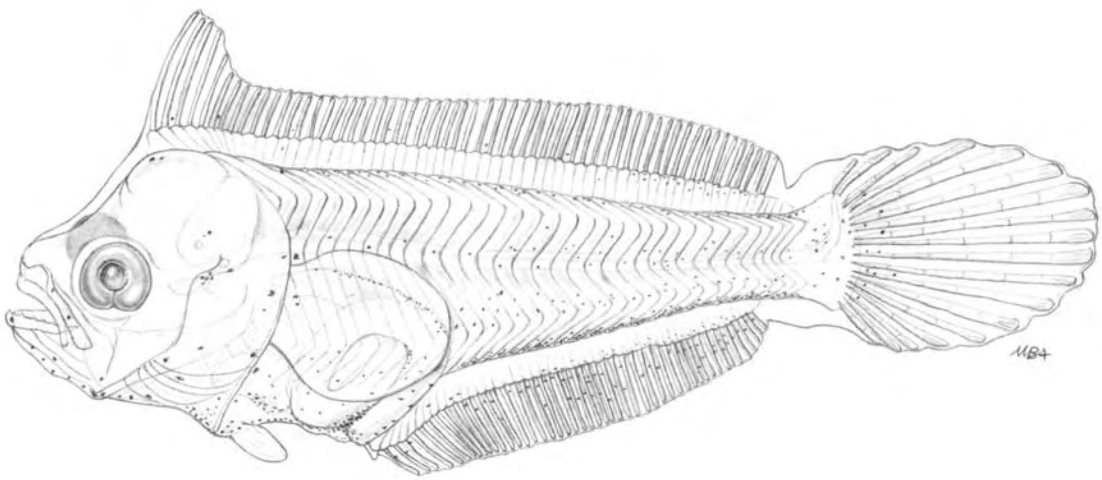


FIGURE 41-4.—Postlarva, 8.4 mm TL.

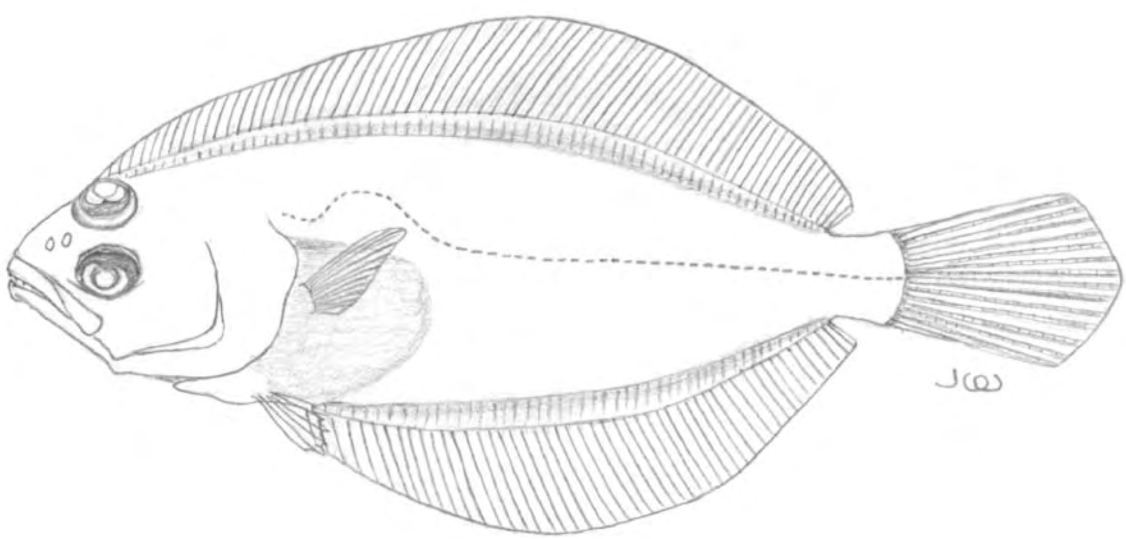


FIGURE 41-5.—Juvenile, 42.5 mm TL.

42. Pleuronectidae – Righteye Flounders

At least 11 of the known 20 pleuronectid species have been found in the study area:

Species	**Distribution**
Rex sole, *Glyptocephalus zachirus*	Coast, offshore, continental shelf, deep sea
Pacific halibut, *Hippoglossus stenolepis*	Bay, coast, continental shelf, deep sea
Diamond turbot, *Hypsopsetta guttulata*	Bay, coast, continental shelf
Butter sole, *Isopsetta isolepis*	Coast, continental shelf
Rock sole, *Lepidopsetta bilineata*	Coast, continental shelf
Slender sole, *Lyopsetta exilis*	Bay, coast, offshore, continental shelf
English sole, *Parophrys vetulus*	Bay, coast, continental shelf
Starry flounder, *Platichthys stellatus*	Coast, bay, estuary, freshwater
Curlin turbot, *Pleuronichthys decurrens*	Bay, coast, continental shelf, deep sea
Hornyhead turbot, *Pleuronichthys verticalis*	Bay, coast, northern margin
Sand sole, *Pleuronichthys melanostictus*	Bay, coast, continental shelf

The rex sole, Pacific halibut, butter sole, rock sole, slender sole, and hornyhead turbot are not discussed in this chapter, because not enough is known of their early life stages.

Righteye flounder and their eggs are pelagic, and those in the genus *Pleuronichthys* have only general sculptures on the chorion to assist buoyancy. Newly hatched larvae are pelagic and bilaterally symmetrical (Ganssle 1966; Alpin 1967; Bane and Bane 1971; Miller and Lea 1972; Hart 1973; Green 1975; Standing *et al.* 1975; Eldridge 1977; Nybakken et al. 1977; Richardson and Pearcy 1977). They drift into shallow coastal waters and estuaries or the outer continental shelf, which serve as their nursery ground. Juveniles and adults are completely adapted to bottom habitats, including development of protective coloration to blend with substrates. They are found in both shallow coastal waters and the deep sea, one species, the starry flounder, may remain in brackish water for most of its life.

References

Aplin 1967, Bane and Bane 1971, Eldridge 1977, Ganssle 1966, Green 1975, Hart 1973, Miller and Lea 1972, Nybakken *et al.* 1977, Richardson and Pearcy 1977, Standing *et al.* 1975.

DIAMOND TURBOT, *Hypsosetta guttulata* (Girard)

SPAWNING

Location	Coastal Pacific waters (Fitch and Lavenberg 1975, Lane 1975, Sumida *et al.* 1979); in Richardson Bay

	(Eldridge 1975, Green 1975); in central and south San Francisco Bay.
Season	Larvae were taken from June through October in Richardson Bay (Eldridge 1977); spring through fall (Fitch and Lavenberg 1975); September through February in Anaheim Bay (Lane 1975). Judging from larvae taken in San Francisco Bay, spawning likely occurs all year and peaks in winter months.
Temperature	Ca. 12.9–19.4˚C (estimated from water temperature when larvae were taken).
Salinity	Seawater (perhaps polyhaline).
Substrates	None.

CHARACTERISTICS

EGGS

Diameter	Average 0.80 mm (Eldridge 1975); a range of 0.78–0.89 mm with an average of 0.84 mm (Sumida *et al.* 1979); ca. 0.80–0.90 for live eggs in late embryo stages.
Yolk	Homogeneous (Orton and Limbaugh 1953, Sumida *et al.* 1979); clear.
Oil globule	One large oil globule (ca. 0.14 mm in diameter) and numerous smaller globules (Eldridge 1975); 0.12–0.14 mm single oil globule (other small oil globules a result of damage) (Sumida *et al.* 1979).
Chorion	Transparent, smooth (Orton and Limbaugh 1953, Sumida *et al.* 1979).
Perivitelline space	Very narrow.
Egg mass	Broadcast in water column.
Adhesiveness	None.
Buoyancy	Pelagic (Fitch and Lavenberg 1975, Eldridge 1975, Sumida *et al.* 1979).

LARVAE

Length at hatching	Average 1.6 mm SL (Eldridge 1975).
Snout to anus length	Ca. 44–52% of TL of larvae at 2.1–6.8 mm TL.
Yolk sac	Very large, spherical to oval, extends from head to abdominal region.
Oil globule	Single (Eldridge 1975, Sumida *et al.* 1979); ca. 0.1 mm in diameter, in middle or posterior section of the yolk sac.

Gut	Straight in prolarvae, thick and coiled in one loop in postlarval stage.
Teeth	Small and pointed in postlarvae.
Size at completion of yolk-sac stage	Ca. 2.0–2.5 mm TL.
Total myomeres	34–36.
Preanal myomeres	12–16.
Postanal myomeres	20–23.
Last fin(s) to complete development	Pelvic.
Pigmentation	Eye unpigmented in newly hatched larvae (Eldridge 1975). Yolk-sac larvae have stellate melanophores on head and trunk, gradually extending to yolk sac and gut; postlarvae have large heavy stellate melanophores (some encircled) covering head, trunk, and port of tail, but caudal peduncle remains completely unpigmented (Eldridge 1975, Sumida *et al.* 1979, this study).
Distribution	Pelagic in coastal waters and continental shelf (Sumida *et al.* 1979); in Richardson Bay (Eldridge 1975, Green 1975), central and south San Francisco Bay, lower portion of Napa River, Suisun Bay, and Moss Landing Harbor-Elkhorn Slough.

JUVENILES (Figure 42-3)

Dorsal fin	66–73 (Norman 1934), 66–75 (Clothier 1950, Miller and Lea 1972), 66–75, with an average of 71 (Eldridge 1975).
Anal fin	48–54 (Norman 1934, Clothier 1950, Miller and Lea 1972); 48–52, with an average of 50 (Eldridge 1971).
Pectoral fin	11–13 (Miller and Lea 1972).
Mouth	Small, jaws developed on blind side (Bane and Bane 1971); terminal, small, oblique.
Vertebrae	33–36 (Lane 1975).
Distribution	Mostly in coastal waters, some found in quiet back bays, lagoons, and sloughs (Fitch and Lavenberg 1975), in San Francisco Bay.

LIFE HISTORY

The diamond turbot ranges from Magdalena Bay, Baja California, to Cape Mendocino, California (Miller and Lea 1972). Another, isolated population has been reported in the upper portion of the Gulf of California (Norman 1934, Fitch 1963, Miller and Lea 1972). Locally, diamond turbot are common in San Francisco Bay (Aplin 1967, this study). They were also reported in Moss Landing Harbor-Elkhorn Slough (Nybakken *et al.* 1977), Tomales Bay (Bane and Bane 1971), and Bodega Bay (Standing *et al.* 1975).

Early life stages of this species have been described by Eldridge (1975) and by Sumida *et al.* (1979). In this study diamond turbot eggs, larvae, and juveniles were collected from San Francisco Bay, they were particularly abundant in the South Bay. Judging from the times at which eggs and larvae were taken, spawning occurs year-round (Eldridge 1975, 1977, this study), with peak spawning occurring in the winter months. In this study, eggs were observed in the South Bay, suggesting that some spawning takes place in the Sacramento-San Joaquin Estuary, although Eldridge (1977) and Lane (1975) have stated that the bulk of the spawning occurs offshore. Eggs may have been carried into the estuary by upwelling and coastal current patterns.

Newly hatched larvae are heavily pigmented and have a single oil globule in the yolk sac (Eldridge 1975, Sumida *et al.* 1979). Larvae of the diamond turbot are pelagic, the majority of them remain close to shore, but others move out onto the continental shelf (Sumida *et al.* 1979). In this study, many small yolk-sac larvae (ca. 2.0–2.5 mm TL) were observed in the estuary, particularly in south San Francisco Bay. Larvae were also observed in San Pablo Bay, at the mouth of the Napa River, and in Suisun Bay.

In early juveniles, ca. 8.0–10.0 mm TL, the eye migrates to the right side of the head. The juveniles assume a bottom habitat after metamorphosis. Eldridge (1975) captured more than 40 specimens of juvenile diamond turbot by anchored net set in Richardson Bay. Juvenile diamond turbot feed on polychaete worms, small crustaceans, and debris (Lane 1975).

Female diamond turbot mature at two or three years of age (Fitch and Lavenberg 1975). No literature is available concerning the maturation age of the male fish. The maximum life expectancy of this species is eight or nine years (Fitch and Lavenberg 1975). In Anaheim Bay mortality rates of the 1– and 2–year classes have been reported as high as 94 % (Lane 1975).

Diamond turbot have negligible commercial value, but they are often taken by sport fishermen from Point Conception southward along the California coast (Fitch and Lavenberg 1975).

References

Aplin 1967; Bane and Bane 1971; Clothier 1950; Eldridge 1975, 1977; Fitch 1963; Fitch and Lavenberg 1975, Green 1975; Lane 1975; Limbaugh 1955; Miller and Lea 1972; Norman 1934; Nybakken *et al.* 1977; Orton and Limbaugh 1953; Standing *et al.* 1975, Sumida *et al.* 1979.

ENGLISH SOLE, *Parophrys vetulus* Girard

SPAWNING

Location	Southern part of Monterey Bay (Budd 1940); sheltered water, channels, or bights, and banks in Hecate Strait Canada (Ketchen 1956); in bays of south British Columbia (Taylor 1946), offshore of Yaquina Bay, Oregon (Pearcy and Myers 1974); coastal waters near San Francisco Bay, but mainly south of Point Conception (Ahlstrom and Moser 1975); outside of San Francisco Bay (Eldridge 1977, this study).
Season	November–May, peaking in late March and early April (Budd 1940); December–early April in British Columbia (Ketchen 1956); January–March (Taylor 1946); January–May (Bane and Bane 1971); October–May, with peak in January and February (Frey 1971); larvae were taken every month except November, with peak of abundance in March and April (Ahlstrom and Moser 1975); larvae were collected from San Francisco Bay upstream to Suisun Bay from February through May.
Temperature	13.0˚C (Budd 1940); optimal temperature 8–9˚C (Alderdice and Forrester 1968); 10.2–11.0˚C (Orsi 1968); 7–9˚C (Hickman 1959); 8–10.3˚C (Frey 1971); larvae were collected at temperatures of 4.0–13.0˚C.
Salinity	10–40 ppt (Alderdice and Forrester 1968); seawater.
Fecundity	150,000–1,950,000 (Ketchen 1947, Harry 1959).

CHARACTERISTICS

EGGS

Shape	Spherical (Budd 1940, Orsi 1968).
Diameter	0.89–.093 mm, with an average of 0.99 mm (Budd 1940); 0.93–1.05 mm, with an average of 0.99 mm (Orsi 1968).
Yolk	Transparent, homogeneous (Budd 1940).
Oil globule	None (Budd 1940); none, but many oil droplets roughly linked in chains (Orsi 1968).
Chorion	Transparent, thin, finely wrinkled (Budd 1940, Orsi 1968).
Perivitelline space	Very narrow or small (Orsi 1968).

Egg mass	Broadcast into water column.
Adhesiveness	None (Budd 1940).
Buoyancy	Pelagic, very buoyant, begin to sink slowly several hours before hatching (Budd 1940).

LARVAE (Figures 42.4, 42.5)

Length at hatching	Ca. 2.8 mm SL (Budd 1940); 2.85 mm TL (Orsi 1968).
Snout to anus length	Ca. 43–45% of TL of larvae at 2.83–3.2 mm TL; ca. 33–40% of TL of larvae at 3.3–6.3 mm TL.
Yolk sac	Colorless newly hatched larvae have a large yolk sac extending from head to abdominal region.
Oil globule	None.
Gut	Short, coiled in single loop, bends ventrally in 90˚ angle in anal region.
Air bladder	None.
Teeth	Small and pointed in postlarvae.
Size at completion of yolk-sac stage	Ca. 4.0–4.6 mm TL.
Total myomeres	40–44.
Preanal myomeres	10–12.
Postanal myomeres	29–34.
Last fin(s) to complete development	Pelvic.
Pigmentation	Melanophores scattered on head, middorsal, thoracic, and postanal regions, 1–3 dark blotches encircle body (or almost) between anus and tail; as larvae grow to 4–8 mm TL, 2 scattered melanophores appear on ventral finfold, which is located posterior to anus.
Distribution	Pelagic, mostly in shallow coastal waters of southern California (Ahlstrom and Moser 1975); some are carried into bays and estuaries by currents (Eldridge 1977, Eldridge and Bryan 1972, Misitano 1976, this study); common offshore of Yaquina Bay Oregon, absent or rare in Yaquina Bay (Pearcy and Myers 1974); transforming larvae enter Humboldt Bay (Misitano 1976).

JUVENILES (Figure 42-6)

Dorsal fin	71–86 (Clothier 1950); 71–73 (Miller and Lea 1972); 72–93 (Hart 1973).

Anal fin	54–68 (Clothier 1950); 52–70 (Miller and Lea 1972); 54–70 (Hart 1973).
Pectoral fin	10–12 (Miller and Lea 1972).
Mouth	Terminal, small, with narrow gape (Hart 1973); small, oblique.
Vertebrae	42–45 (Clothier 1950); 41–44 (Hart 1973); 41–47 (Miller and Lea 1972).
Distribution	Early transforming stages are pelagic, but gradually settle on bottom after metamorphosis is completed; bulk of population is along coast, some enter bays (Misitano 1976, Eldridge 1977, Toole 1978); juveniles abundant in Yaquina Bay (Pearcy and Myers 1973, Westrheim 1955). Juveniles found in San Francisco Bay.

LIFE HISTORY

The English sole, formerly known as the lemon sole, ranges from San Cristobal Bay, Baja California, to Unimak Island, Alaska (Forrester 1969), to northwest Alaska (Miller and Lea 1972). Frey (1971) identified four different stocks of this species along the Pacific coast. In the study area, English sole are common in San Pablo Bay (Ganssle 1966), in San Francisco Bay (Aplin 1967), and off San Francisco Bay.

The reproductive biology of this species has been investigated by Budd (1940). Spawning takes place in coastal waters from November through May and peaks in March and early April in the Monterey Bay area. Eggs are spherical and have no oil globule in the yolk (Budd 1940). However, Orsi (1968) reported that English sole eggs have many small oil droplets, roughly linked in chains. The incubation period is about 90 hours at 13.0˚C (Budd 1940), 3.5 days at 12.0˚C, and 11.8 days at 4.0˚C. A temperature of 2.0˚C is lethal to the eggs (Alderdice and Forrester 1969). Hickman (1959) reported that it takes 5 days to hatch English sole eggs at 7–9°C. Budd (1940) described English sole eggs as gradually sinking several hours before hatching. Incubation at the lower temperatures may enhance the development and survival of larvae, so that their chance of reaching the nursery ground is higher (Ketchen 1956).

Newly hatched larvae have a large yolk sac and are found near the surface in an upside down position (Budd 1940). English sole larvae are bilaterally symmetrical and are found swimming in coastal waters (Richardson and Pearcy 1977). Misitano (1976) sampled Humboldt Bay for English sole larvae during the peak of their spawning and found only a small number of larvae. Eldridge (1977) reported a few larvae in Richardson Bay, and commented that English sole spawn outside of San Francisco Bay. In this study, English sole larvae were seldom collected in San Francisco Bay from 1978 to 1981, but a large number were observed in March and April 1982, they were also taken in San Pablo Bay and up to Suisun Bay. Prolarvae were collected at Horseshoe Cove, just inside of the Golden Gate Bridge. Apparently they had drifted there under the influence of coastal currents.

The body of the late postlarva and transforming juvenile becomes deeper, but still remains bilaterally symmetrical. When the fish is about 15–20 mm TL, the left eye starts to migrate to the right side. At this time, the English sole begins to assume a demersal habitat.

Transforming larvae and early juveniles may descend into deeper water near the mouths of estuaries, where two-layered transport can move them into the estuary. Within the estuary they can ascend to the upper layers and disperse. (Westrheim 1955, Kulm and Byrne 1967, Olsen and Pratt 1973, Pearcy and Myers 1974, Misitano 1973).

The bays and estuaries are important nursery grounds for English sole, particularly during their first year of life (Olsen and Pratt 1973). Juvenile English sole feed on small crustaceans such as copepods, amphipods, and polychaete worms (Toole 1978).

A female English sole reaches sexual maturity at an age of 3 years, at a total length of about 300 mm. A male becomes mature at a shorter length, between 250 mm and 270 mm (Ketchen 1947). English sole support one of the most important commercial fisheries along the California coast (Frey 1971).

References

Ahlstrom and Moser 1975, Alderdice and Forrester 1968, Aplin 1967, Bane and Bane 1971, Budd 1940, Clothier 1950, Eldridge 1977, Eldridge and Bryan 1972, Forrester 1969, Frey 1971, Ganssle 1966, Harry 1959, Hart 1973, Hickman 1959, Ketchen 1947, 1956, Kulm and Byrne 1967, Miller and Lea 1972, Misitano 1976, Orsi 1968, Pearcy and Myers 1974, Taylor 1946, Toole 1978, Westrheim 1955.

STARRY FLOUNDER, *Platichthys stellatus* (Pallas)

SPAWNING

Location	Shallow water near river mouths and sloughs (Orcutt 1950); may occur in the lower portion of San Joaquin River (Radtke 1966b). Outside of San Francisco Bay (Eldridge 1977); mostly in coastal waters, but may occur in the Sacramento-San Joaquin Estuary.
Season	November–January in Elkhorn Slough (Orcutt 1950); February–April in Puget Sound (Smith 1936); December–January in British Columbia (Hart 1973); from September through March.
Temperature	10.5–12.5˚C (Orcutt 1950); judging from the temperature at locations when small larvae were taken, ca. 11–13°C.

Salinity	Mostly seawater to polyhaline.
Substrates	None.
Fecundity	Estimated at 11,000,000 for 254 mm TL specimen (Orcutt 1950).

CHARACTERISTICS

EGGS

Shape	Spherical (Orcutt 1950).
Diameter	0.89–0.94 mm (Orcutt 1950).
Yolk	Colorless, smooth or undivided (Orcutt 1950).
Oil globule	None (Orcutt 1950).
Chorion	Transparent, thin, finely wrinkled (Orcutt 1950).
Egg mass	Broadcast in water column.
Adhesiveness	None.
Buoyancy	Pelagic (Orcutt 1950).

LARVAE (Figures 42-7, 42-8, 42-9, 42-10)

Length at hatching	1.93–2.08 mm TL (Orcutt 1950).
Snout to anus length	Ca. 35–40% of TL of larvae at 4.9–6.6 mm TL, decreasing to ca. 28–29% of TL of larvae at 7.7–8.4 mm TL.
Yolk sac	Colorless, very large in newly hatched larvae, extending from snout to abdominal region, size of yolk sac decreases and becomes restricted to thoracic region as larva grows larger.
Oil globule	None.
Gut	Coiled in single loop, short, bends ventrally (45–90˚) in anal region.
Air bladder	None.
Teeth	Pointed (some embedded in tissue) in postlarvae.
Total myomeres	34–38.
Preanal myomeres	8–12.
Postanal myomeres	26–28.
Last fin(s) to complete development	Pelvic.
Pigmentation	Stellate melanophores scattered on dorsal and ventral finfolds, head, trunk, tail, gut, and yolk-sac regions; 2 dark blotches on finfold between anus and tail (Orcutt 1950, this study).

Distribution	Pelagic in coastal waters and San Francisco Bay, Richardson Bay (Eldridge 1977); Elkhorn Slough (Nybakken *et al.* 1977).

JUVENILES

Dorsal fin	56–62 (Clothier 1950); 52–64 (Miller and Lea 1972); 52–66 (Hart 1973).
Anal fin	40–46 (Clothier 1950); 38–47 (Miller and Lea 1972, Hart 1973).
Pectoral fin	12
Mouth	Terminal, small with narrow gape, asymmetrical (Hart 1973).
Vertebrae	34–37 (Townsend 1936, Clothier 1950).
Distribution	Coastal waters up to freshwater Delta sloughs (Radtke 1966b); some have been recorded in San Luis Reservoir and O'Neill Forebay (Moyle 1976). Demersal from San Francisco Bay to the Delta and in Moss Landing Harbor and Elkhorn Slough.

LIFE HISTORY

The starry flounder is an ambidextrous flatfish which is found along the Pacific coast from Santa Ynez River, Santa Barbara County, California, northward to the Alaskan Peninsula, from there they extend to the Aleutian Island chain, the Kamachatka Peninsula, the Kurile Islands, and southward to Japan (Orcutt 1950). This species is also known in Korea (Okada 1955). In San Francisco Bay and the Delta, the starry flounder is one of the most common flatfish found (Ganssle 1966, Radtke 1966b, Aplin 1967). Some of the starry flounder observed in San Luis Reservoir and O'Neill Forebay were apparently transported via the California Aqueduct from the southern Sacramento-San Joaquin Delta (Moyle 1976).

Spawning takes place in shallow coastal waters or tidal sloughs such as Elkhorn Slough (Orcutt 1950). In this study, gravid female starry flounder were observed in anglers' catches at the jetty of Moss Landing Harbor in February 1980. Eldridge (1977) collected starry flounder larvae in Richardson Bay in March and August. In this study, starry flounder larvae were observed from September through March. Therefore, the spawning period is estimated to occur in the fall and winter months.

Radtke (1966b) collected many 8- to 15-mm TL larvae and juveniles in the lower San Joaquin River and assumed that starry flounder spawn in Suisun Bay and the lower San Joaquin River. Moyle (1976) appears to have agreed with this hypothesis. In this study, however, neither mature starry flounder nor their eggs or prolarvae were observed in those areas from 1978 to 1982. It is suggested that all spawning occurs in coastal waters or the higher-salinity portions of estuaries, since the adults are commonly found in these areas (Gunter 1942, Westrheim 1955, Pearcy and Myers 1974). The larvae are transported to the upper estuaries by the two-layered currents, like the hogchoker, *Trinectes maculatus*, and the winter flounder, *Pseudopleuronectes americanus*, in Atlantic estuaries (Wang and Kernehan 1979).

Newly hatched larvae initially float with their yolk sac facing up in the water. The older larvae thrash in the water and eventually turn around so the yolk sac is facing down. Orcutt (1950) has given a detailed description of the early development of the starry flounder. The larvae, with high finfolds, are pelagic and have been observed in Richardson Bay (Eldridge 1977). Small larvae were taken from Horseshoe Cove in the vicinity of the Potrero and Hunters Point Powerplants in San Francisco Bay. Late postlarvae and early juveniles were collected mostly in the upper estuaries. Newly hatched larvae were also observed near the jetty of Moss Landing Harbor.

Ganssle (1966) reported an upstream movement of young-of-the-year of starry flounder in the Sacramento-San Joaquin Estuary. Juveniles gradually settle on the bottom by the end of April and can then be found in many sections of this estuary. Juveniles feed mainly on small crustaceans (Orcutt 1950), barnacle larvae and cladocerans (Barraclough 1967), and softshell clams and dipteran larvae (Porter 1964).

Male starry flounder reach maturity in 2 years (Orcutt 1950), the females in 3 years (Orcutt 1950, Smith 1936). The starry flounder is not highly regarded as a commercial species (Frey 1971, Hart 1973), but it is a popular sport fish, taken by anglers along the Pacific coast, including San Francisco Bay and Moss Landing Harbor.

References

Aplin 1967, Barraclough 1967, Clothier 1950, Eldridge 1977, Frey 1971, Ganssle 1966, Gunter 1942, Hart 1973, Miller and Lea 1972, Moyle 1976, Nybakken *et al.* 1977, Okada 1955, Orcutt 1950, Pearcy and Myers 1974, Porter 1964, Radtke 1966b, Smith 1936, Townsend 1936, Wang and Kernehan 1979, Westrheim 1955.

CURLFIN SOLE, *Pleuronichthys decurrens* Jordan and Gilbert

SPAWNING

Location	In Monterey Bay (Budd 1940); along and offshore of the California coast (Sumida *et al.* 1979); in San Francisco Bay.
Season	November (Budd 1940); January–March (this study); March–August (Bane and Bane 1971).
Salinity	Seawater.
Substrates	None.

CHARACTERISTICS

EGGS

Shape	Spherical.
Diameter	1.84–2.08 mm (Sumida *et al.* 1979); 1.80–1.90 mm.
Yolk	Clear, transparent (Budd 1940).
Oil globule	None (Budd 1940, Sumida *et al.* 1979).
Chorion	With polygonal sculptures (Budd 1940, Sumida *et al.* 1979).
Perivitelline space	Narrow.
Egg mass	Broadcast in water column.
Adhesiveness	None.
Buoyancy	Pelagic.

LARVAE

Length at hatching	5.54 mm TL (Budd 1940); less than 4.9 mm NL (Sumida *et al.* 1979).
Snout to anus length	Ca. 45–53% of NL of larvae at 4.9–9.8 mm NL (Sumida *et al.* 1979).
Yolk sac	Small bulbous structure (Budd 1940).
Oil globule	None.
Gut	Straight tube, anal region bends vertically for larvae at 5–7 mm NL; the gut coiled and anal region slanted to anterior for larvae at 8 mm NL (Sumida *et al.* 1979).
Air bladder	None.
Last fin(s) to complete development	Pelvic (Sumida *et al.* 1979).
Pigmentation	Finfolds and body covered with heavy pigmentation, with exception of caudal region (Budd 1940, Sumida *et al.* 1979); tip of tail colorless and transparent (Budd 1940).
Distribution	Offshore and inshore on California coast (Sumida *et al.* 1979).

JUVENILES (Figure 42-11)

Dorsal fin	70–75 (Clothier 1950); 67–79 (Miller and Lea 1972, Hart 1973).
Anal fin	47–50 (Clothier 1950); 45–53 (Miller and Lea 1972); 46–52 (Hart 1973).

Pectoral fin	9–14 (Miller and Lea 1972).
Mouth	Terminal, small, with narrow gape, asymmetrical (Hart 1973).
Vertebrae	39–40 (Clothier 1950); 37–40 (Miller and Lea 1972); 37–39 (Hart 1973).
Distribution	In San Francisco Bay (Aplin 1967, this study).

LIFE HISTORY

The curlfin sole ranges from San Quintin Bay, Baja California, to southeastern Alaska (Wilimovsky 1954), to northwestern Alaska (Miller and Lea 1972). In local records, the curlfin sole has been reported in San Francisco Bay (Aplin 1967) and Moss Landing Harbor.

Eggs were found in Monterey Bay from November through April (Budd 1940); eggs were collected in San Francisco Bay between January and March. Sumida *et al.* (1979) observed curlfin sole eggs both inshore and offshore. This indicates that the curlfin sole may have a wide spatial spawning range. Eggs averaged 1.88 mm (Budd 1940) and ranged from 1.84 to 2.08 mm in size, with hexagonal sculptures on the chorion (Sumida *et al.* 1979). The eggs are pelagic and about the same density as seawater (Budd 1940).

The embryonic development of the eggs and descriptions of the eggs and various larval stages have been given by Budd (1940) and Sumida *et al.* (1979). Some of Budd's work was corrected by Sumida *et al.* (1979). During this study period, larvae of the curlfin sole were not present in the samples, although eggs, in the late embryonic stage, were observed several times. Presumably, curlfin sole larvae are rare in San Francisco Bay. Like other flatfish, curlfin sole larvae are pelagic (Sumida *et al.* 1979).

Small numbers of curlfin sole were taken in trawls by Aplin (1967), and they were found in impingement samples from the Potrero and Hunters Point Powerplants on San Francisco Bay at various times of the year (this study). Stomach content analysis revealed that small crustaceans, polychaete worms, clams, mollusc eggs, fragments of fish, and unidentified debris are eaten by juvenile and adult curlfin sole (Bane and Bane 1971, this study).

Age of maturity and life expectancy are unclear in the literature. The curlfin sole is recognized as one of the best tasting flatfish in the San Francisco Bay area (Bane and Bane 1971). In this study, adult curlfin sole were found concentrated along the coast and less common in San Francisco Bay.

References

Aplin 1967, Bane and Bane 1971, Budd 1940, Hart 1973, Miller and Lea 1972, Sumida *et al.* 1979, Wilimovsky 1954.

SAND SOLE, *Psettichthys melanostictus* Girard

SPAWNING

Location	In Puget Sound (Smith 1936, Hickman 1959); larvae were observed in Richardson Bay, but spawning takes place outside of San Francisco Bay, due to negative upwelling index (Eldridge 1977); probably coastal waters.
Season	January–March in Bellingham Bay, Puget Sound (Smith 1936, Hart 1973); larvae were collected in Richardson Bay in February (Eldridge 1977); January–April.
Temperature	7–9˚C (Hickman 1959).
Salinity	Seawater.

CHARACTERISTICS

EGGS

Shape	Spherical (Hickman 1959).
Diameter	Ca. 1.0 mm (Hickman 1959).
Yolk	Colorless, smooth, unsegmented (Hickman 1959).
Oil globule	None (Hickman 1959).
Chorion	Transparent (Hickman 1959).
Egg mass	Broadcast in water column.
Adhesiveness	None (Hickman 1959).
Buoyancy	Pelagic (Hickman 1959).

LARVAE (Figures 42-12, 42-13, 42-14)

Length at hatching	2.8 mm TL (Hickman 1959).
Snout to anus length	Ca. 35–45% of TL of larvae at 3.4–4.7 mm TL.
Yolk sac	Spherical, medium size, extends from jugular to abdominal region.
Gut	Short in prolarvae; coiled in one loop, anal region bends vertically in sharp angle in postlarvae.
Air bladder	None.
Teeth	Sharp, pointed in postlarvae.
Size at completion of yolk-sac stage	Ca. 4.0–4.5 mm TL.
Total myomeres	37–39 (Hickman 1959).
Preanal myomeres	8–10.

Postanal myomeres	28–30.
Last fin(s) to complete development	Pelvic.
Pigmentation	In newly hatched larvae, stellate melanophores scattered on head, yolk sac, trunk, and tail, a single row of melanophores runs along edge of finfolds, and a dark blotch encircles the body midway between tail and anus; in postlarvae, melanophores concentrated on 5 major areas of body between trunk and tail (three on dorsum and 2 on ventrum in alternating pattern), melanophores along edge of finfolds become dense and some connect into chains, and large stellate melanophores appear in anal region (Hickman 1959, this study).
Distribution	Pelagic in coastal waters and bays; collected in Richardson Bay (Eldridge 1977); Moss Landing Harbor (Nybakken *et al.* 1977). Offshore of Yaquina Bay, Oregon (Pearcy and Myers 1974); Puget Sound (Hickman 1959); in San Francisco Bay.

JUVENILES (Figure 42-15)

Dorsal fin	72–90 (Miller and Lea 1972); 72–88 (Hart 1973).
Anal fin	53–66 (Miller and Lea 1972, Hart 1973).
Pectoral fin	10–12 (Miller and Lea 1972).
Mouth	Terminal, large, with wide gape (Hart 1973).
Vertebrae	37–39 (Townsend 1936); 37–41 (Miller and Lea 1972).
Distribution	Demersal in San Francisco Bay, Moss Landing Harbor, Tomales Bay; mostly in coastal waters.

LIFE HISTORY

Sand sole range from Port Hueneme to the Bering Sea (Clemens and Wilby 1961, Miller and Lea 1972). In the study area, the sand sole has been recorded in San Francisco Bay and upstream of Carquinez Strait (Ganssle 1966, Aplin 1967). In areas near San Francisco Bay, sand sole were reported in Moss Landing Harbor-Elkhorn Slough (Nybakken *et al.* 1977, this study), Tomales Bay (Bane and Bane 1971), and Bodega Bay (Standing *et al.* 1975). Adults seem to prefer coastal sandy habitats.

Judging from the time larvae were taken in this study, the spawning period is from January through April. In the northern Pacific, such as Sydney Inlet, Vancouver Island, Manzer (1947) recorded a July spawn. Because of a negative upwelling index, Eldridge (1977) concluded that most of the flatfishes spawned outside of San Francisco Bay.

However, in this study some prolarvae were found in the South Bay, indicating that a limited spawn inside the Bay may have occurred.

Hickman (1959) described the eggs of sand sole as spherical, colorless, without oil globule, and pelagic. Eggs hatched in about 5 days at 7–9°C in Puget Sound, Washington.

Hickman (1959) also conducted laboratory rearing experiments. He observed that sand sole larvae have high finfolds, alternating pigmentation patterns on the body, and an orange color near the posterior of the coelom. Sand sole larvae can be easilty separated from those of other flatfishes by these characteristics.

The left eye migrates to the right side at about 22–27 mm TL (Hickman 1959). Juveniles live near the bottom and have been found in both coastal waters and estuaries. The major food items for juvenile sand sole include small crustaceans, polychaete worms, mollusks, and fish (Miller 1965, Miller 1967a,b, Bane and Bane 1971).

The literature is not clear regarding the age at which sand sole mature. They are taken mostly by sport fishermen, and constitute only a minor part of the commercial catch in California. The flesh has a delicate flavor (Bane and Bane 1971).

References

Aplin 1967; Bane and Bane 1971; Clemens and Wilby 1961; Eldridge 1977; Ganssle 1966; Hart 1973; Hickman 1959; Manzer 1947; Miller 1965, 1967a,b; Miller and Lea 1972; Nybakken *et al.* 1977; Pearcy and Myers 1974; Smith 1936; Standing *et al.* 1975, Townsend 1936.

Characteristic Comparison: Righteye Flounders

Characteristic	Diamond Turbot	English Sole	Starry Flounder
Eggs			
Shape	Spherical	Spherical	Spherical
Diameter (mm)	0.80	0.89–0.93	0.89–0.94
Oil globule	One large or numerous small	None or numerous small	None
Larvae			
Total myomeres	34–36	41–44	34–37
Pigmentation	Heavy, large stellate melanophores on head, trunk, and front part of tail; caudal peduncle unpigmented	Scattered melanophores on head, trunk, and tail; 1–3 dark blotches encircle body between anus and tail; two blotches of melanophores on finfold posterior to anus	Stellate melanophores scattered over finfolds, head, trunk, tail, gut, and yolk-sac regions; 2 dark blotches on finfolds between anus and tail
Juveniles			
Dorsal fin	66–75	71–93	52–66
Anal fin	48–54	52–70	38–47
Pectoral fin	11–13	10–12	12
Eye side	Right	Right	Right, occasionally left
Distinguishing characters	Light blue spots on body; dorsal branch of lateral line elongate	Left eye visible from blind side	Alternating light and dark bars on dorsal and anal fins

Characteristic	Curlfin Sole	Sand Sole
Eggs		
Shape	Spherical, hexagonal sculptures	Spherical
Diameter (mm)	1.8–2.1	1.0
Oil globule	None	None
Larvae		
Total myomeres	37–40 (estimated)	37–39
Pigmentation	Finfolds and body covered with heavy pigmentation, except tip of tail transparent	Prolarvae: scattered melanophores on head, trunk, tail, and yolk-sac regions; single row of melanophores along edge of finfolds and a dark blotch encircles body midway between anus and tail; Postlarvae: melanophores scattered on 5 areas between trunk and tail (3 on dorsum, 2 on ventrum)
Juveniles		
Dorsal fin	67–79	72–90
Anal fin	45–53	53–66
Pectoral fin	9–14	10–12
Eye side	Right	Right
Distinguishing characters	At least nine dorsal fin rays extend into blind side	First 4–5 dorsal fin rays are free from membrane

Figure 42.—Pleuronectidae: *Hypsopsetta guttulata*, diamond turbot.

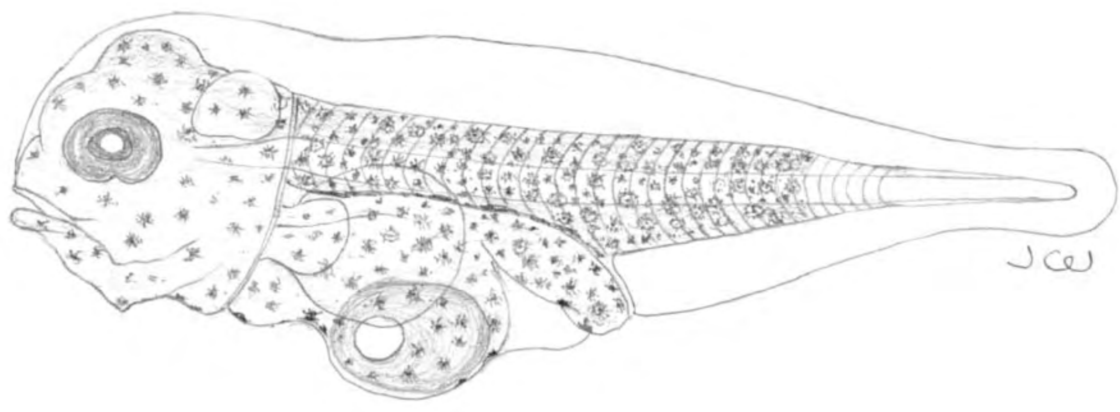


FIGURE 42-1.—Prolarva, 2.5 mm TL.

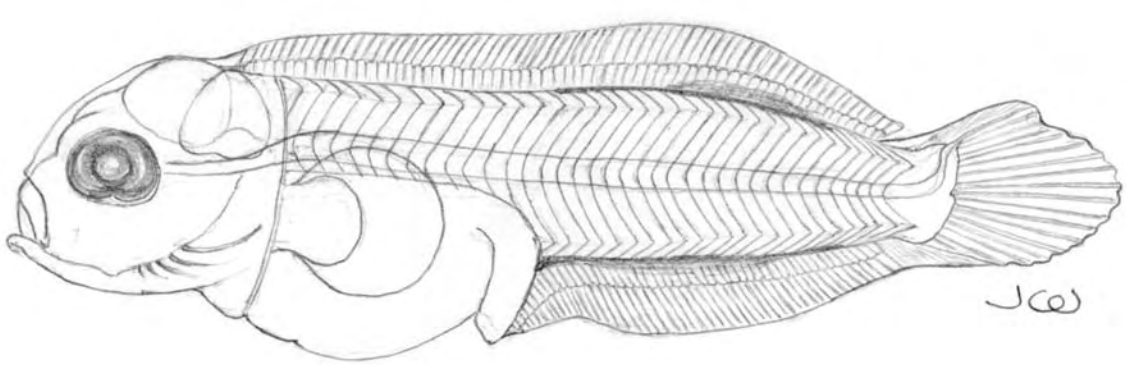


FIGURE 42-2.—Postlarva, 5.9 mm TL.

Pleuronectidae: Righteye flounders.

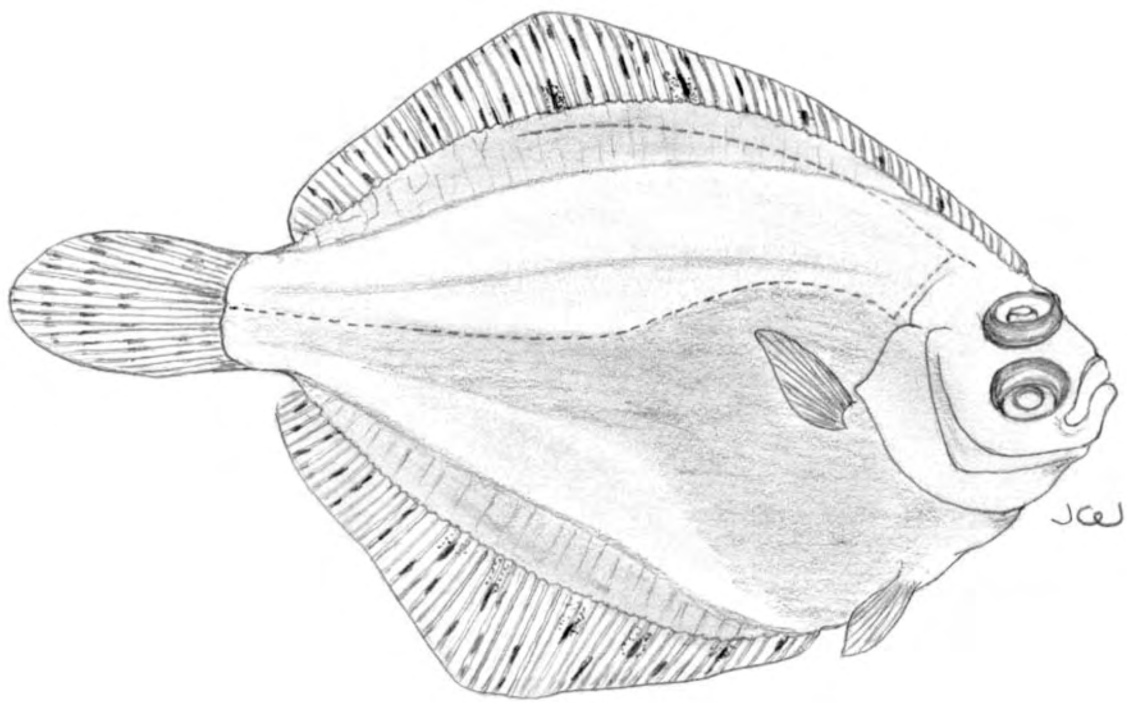


FIGURE 42-3.—*Hypsopsetta guttulata*, diamond turbot, juvenile, 32 mm TL.

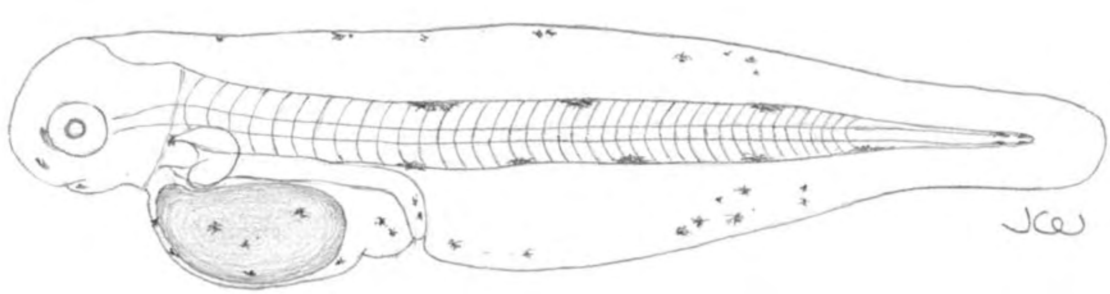


FIGURE 42-4.—*Parophrys vetulus*, English sole, prolarva, 3 mm TL.

Pleuronectidae: *Parophrys vetulus*, English sole.

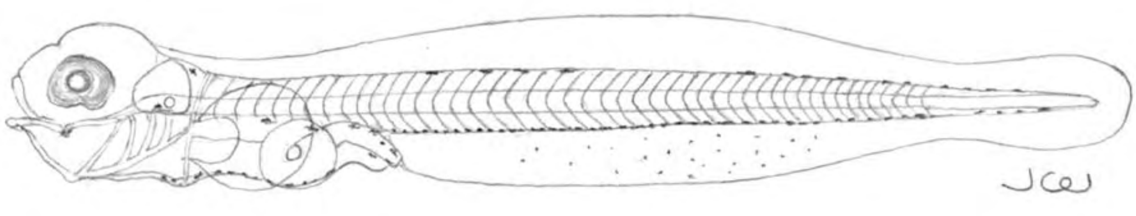


FIGURE 42-5.—Postlarva, 8.8 mm TL.

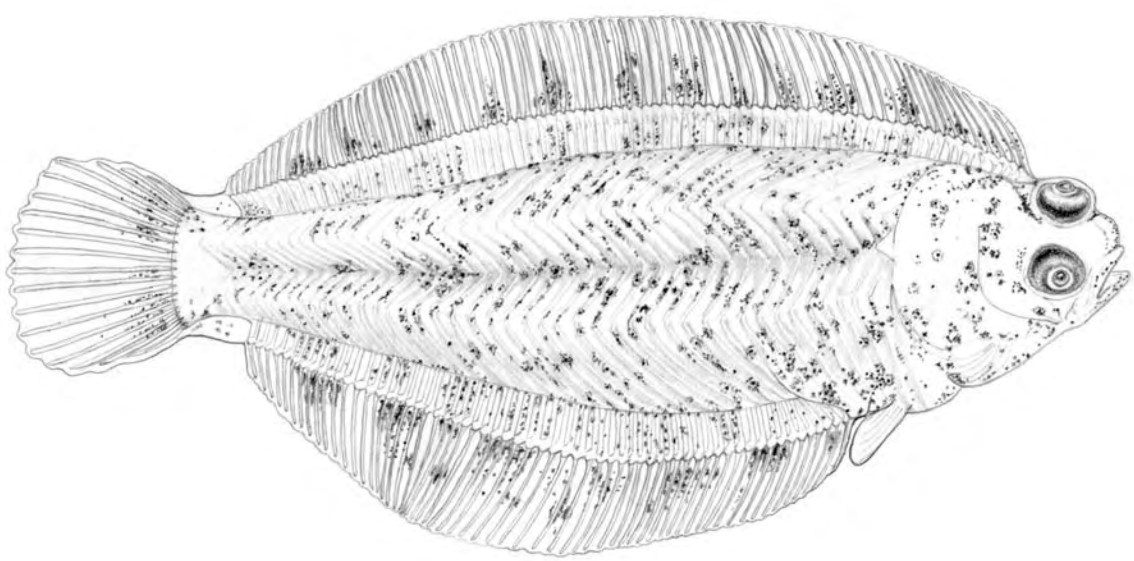


FIGURE 42-6.—Juvenile, 23.3 mm TL.

Pleuronectidae: *Platichthys stellatus*, starry flounder.

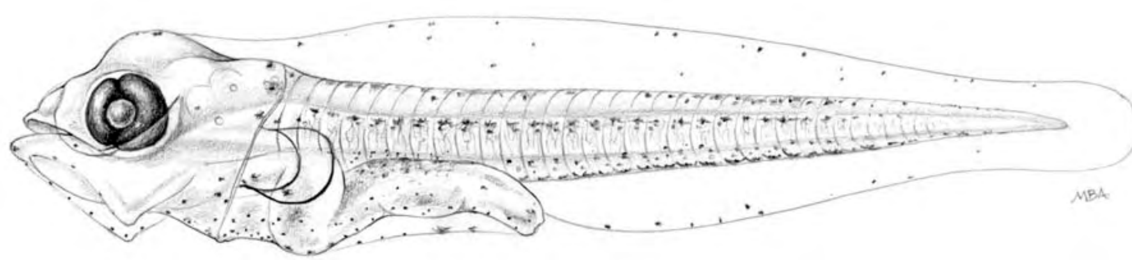


FIGURE 42-7.—Postlarva, 3.7 mm TL.

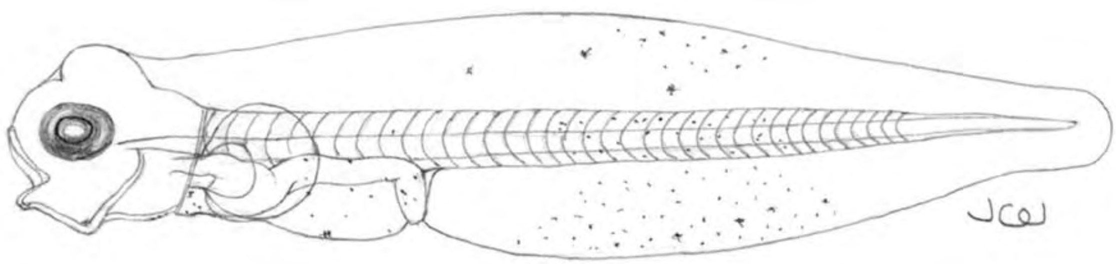


FIGURE 42-8.—Postlarva, 3.9 mm TL.

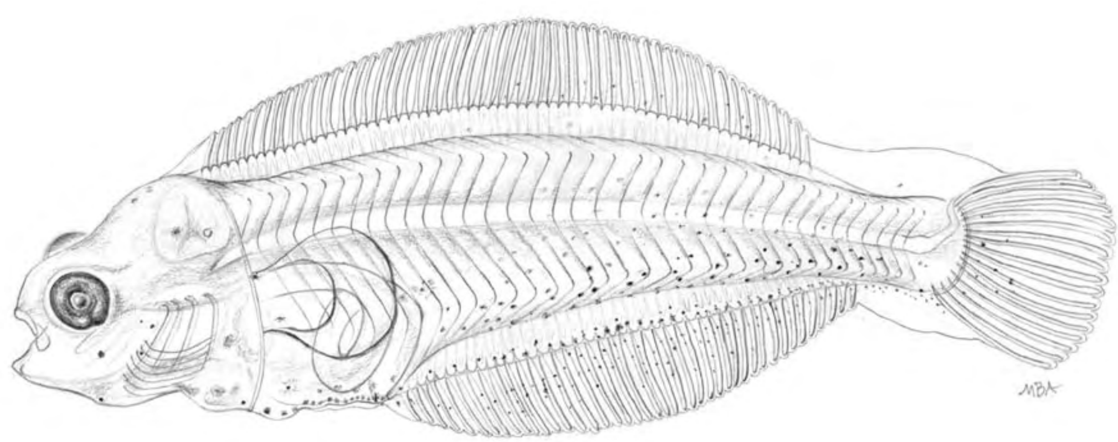


FIGURE 42-9.—Postlarva, 8.5 mm TL.

Pleuronectidae: Righteye flounders.

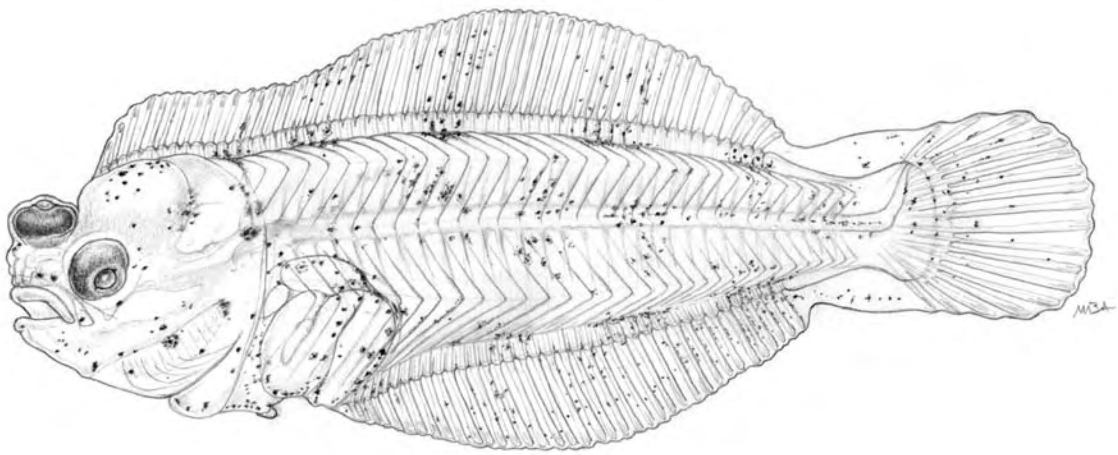


FIGURE 42-10.—*Platichthys stellatus*, starry flounder postlarva, 8.5 mm TL.

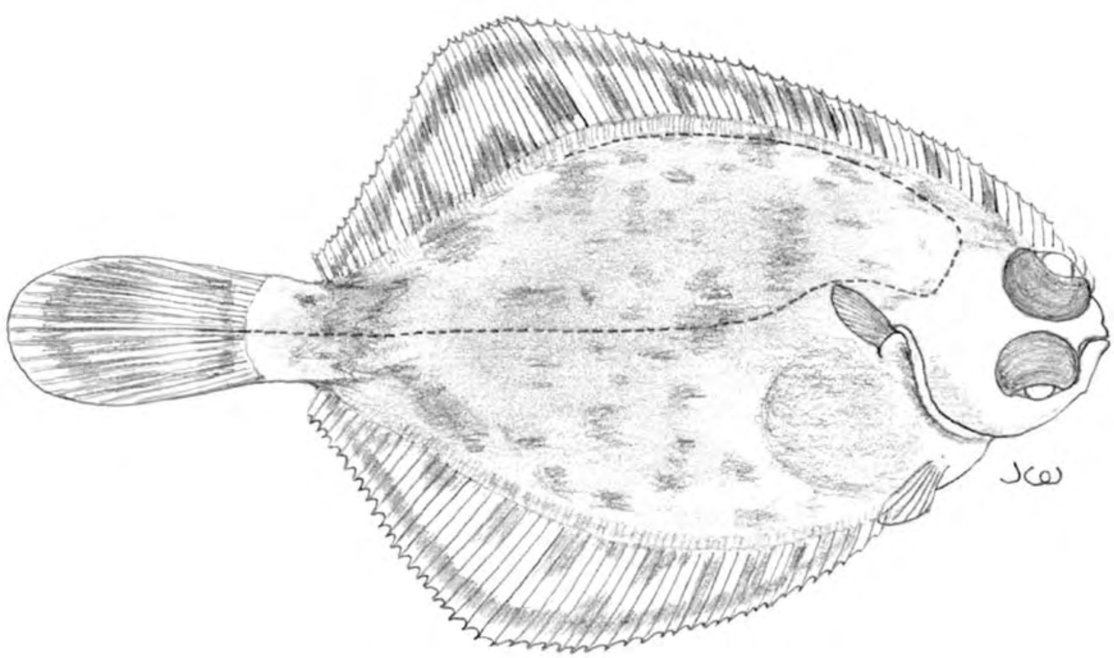


FIGURE 42-11.—*Pleuronicthys decurrens*, curlfin sole juvenile, 68 mm TL.

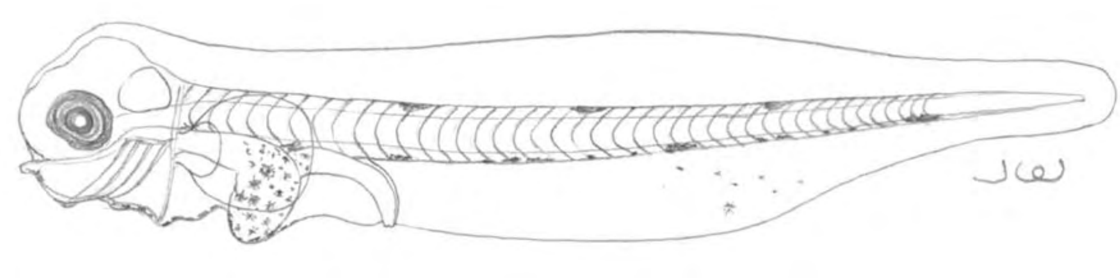


FIGURE 42-12.—Postlarva, 4.3 mm TL.

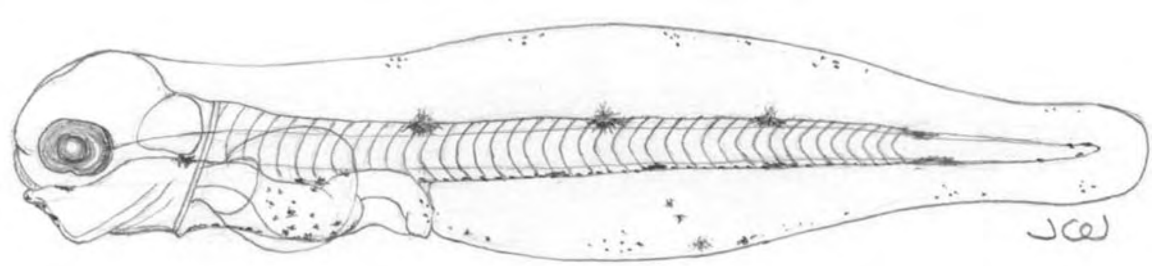


FIGURE 42-13.—Postlarva, 5.2 mm TL.

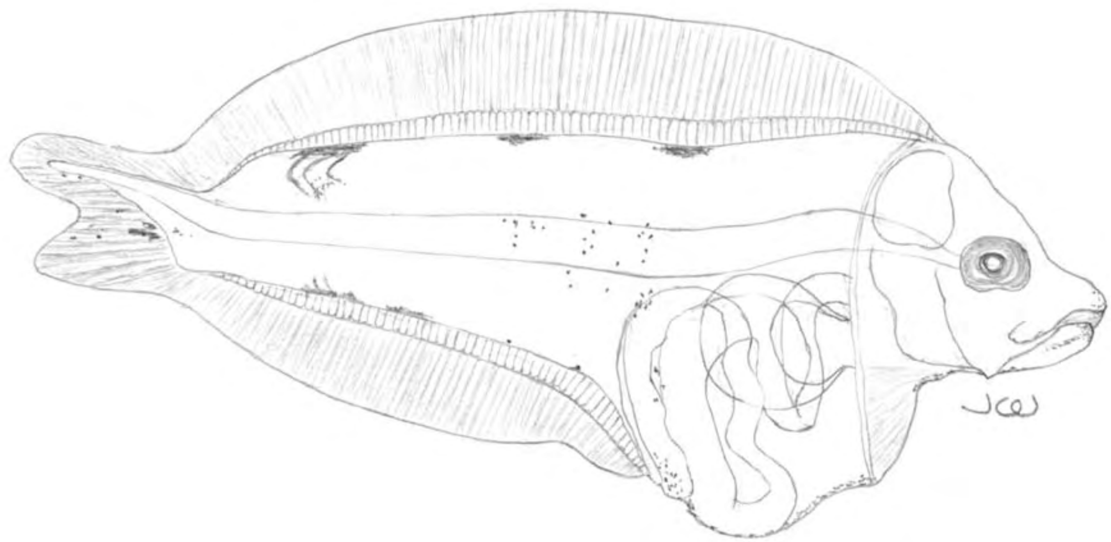


FIGURE 42-14.—Postlarva, 7.5 mm TL.

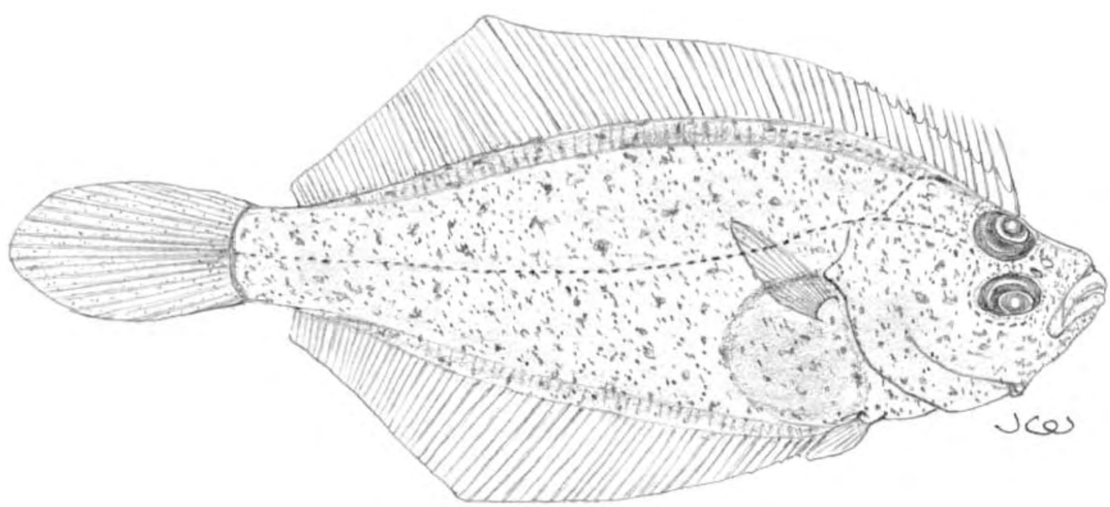


FIGURE 42-15.—Juvenile, 79 mm TL.

43. Cynoglossidae – Tonguefishes

Eleven species of tonguefishes are known to the coastal waters of the United States (Robins *et al*. 1980). Only one of them, the California tonguefish, *Symphurus atricauda*, is found along the Pacific coast of California. Tonguefish can be distinguished from other flatfishes by the presence of a continuous dorsal-caudal-anal fin.

Reference

Robins *et al.* 1980.

CALIFORNIA TONGUEFISH, *Symphurus atricauda* (Jordan and Gilbert)

SPAWNING

Location	May occur in coastal waters or the continental shelf (judging from the small specimens taken in Moss Landing Harbor and San Francisco Bay in this study).
Season	June through September (Fitch and Lavenberg 1975); estimated in fall and winter (this study).
Salinity	Seawater.

CHARACTERISTICS

EGGS

Shape	Unfertilized eggs, spherical (this study).

LARVAE

Length at hatching	Ca. 2.0 mm SL (S. Goodwin 1979, personal communication).
Gut	Coiled (S. Goodwin 1979, personal communication).
Air bladder	None.
Total myomeres	Ca. 50 (based on myomere counts from juvenile specimens in this study).
Last fin(s) to complete development	Pectorals, which develop and then degenerate.
Pigmentation	In small larvae, ca. 2.0–4.0 mm SL, melanophores on midventral region and anal region of gut and a dark blotch between anus and tip of notochord; melanophores appear on edges of finfolds; in large larvae, ca. 6.5 mm SL, large dark blotch on dorsal finfold and two on ventral finfold behind anus;

	melanophores appear on lower jaw, isthmus, and gut region (S. Goodwin 1979, personal communication).
Distribution	Pelagic offshore of California current region (Ahlstrom 1965).

JUVENILES (Figure 43-1)

Dorsal fin	101–106 (Clothier 1950); 95–106 (Miller and Lea 1972).
Anal fin	83–90 (Clothier 1950); 77–90 (Miller and Lea 1972).
Pectoral fin	Pectoral fin develops in larval stage and then degenerates in early juvenile.
Mouth	Inferior.
Vertebrae	50–52 (Clothier 1950).
Distribution	Sandy and mud bottoms from 1.5 to 200 m (Fitch and Lavenberg 1975). Juveniles were taken in the shallow inshore areas of Moss Landing Harbor.

LIFE HISTORY

The distribution of the California tonguefish is from Cape San Lucas, Baja California, to the Big Lagoon, Humboldt County, California (Miller and Lea 1972, Fitch and Lavenberg 1975). The California tonguefish has been observed in San Francisco Bay (Aplin 1967), San Pablo Bay (Ganssle 1966), and Moss Landing-Elkhorn Slough (Kukowski 1972b, Nybakken *et al.* 1977, this study).

Fitch and Lavenberg (1975) reported that California tonguefish spawn primarily from June through September. However, judging by the females collected at Moss Landing Harbor in November and small juveniles (25–28 mm TL) taken in December and January, spawning takes place in the fall and early winter months also. California tonguefish larvae were among the 32 most abundant species in the offshore, California current region (Ahlstrom 1965). This indicates that spawning occurs in coastal waters, as does the spawning of the related species, the blackcheek tonguefish, *Symphurus plagiusa*, found along the Atlantic coast (Hildebrand and Cable 1930). Collection of mature California tonguefish in Moss Landing Harbor provides evidence that a limited spawn may take place in embayments also. The blackcheek tonguefish has had a similar spawning situation reported in Tampa Bay, Gulf of Mexico (Topp and Hoff 1972) and in Chesapeake Bay, Atlantic coast (Olney and Grant 1976).

The eggs and larvae of the California tonguefish were not collected in this study.

After the completion of eye migration (sinistral), juveniles settle on the sandy bottom in coastal waters and estuaries, but probably not in deeper water (Miller and Lea 1972). They have been reported off San Francisco Bay (this study) and in San Francisco Bay (Aplin 1967), San Pablo Bay (Ganssle 1966), and Moss Landing-Elkhorn Slough (Kukowski 1972b, Nybakken *et al.* 1977, this study). Stomach contents of juvenile tonguefish include small crustaceans, polychaetes, and other small invertebrates (Fitch and Lavenberg 1975).

Age of maturity and lifespan are not reported in the literature. Adults (110–135 mm TL) were captured on the intake screens of the Moss Landing Powerplant from September through November. Because of its small size, this species is of insignificant value as a sport fish.

References

Ahlstrom 1965; Aplin 1967; Clothier 1950; Fitch and Lavenberg 1975; Ganssle 1966; Goodwin 1979, personal communication; Hildebrand and Cable 1930; Kukowski 1972b; Miller and Lea 1972; Nybakken *et al.* 1977; Olney and Grant 1976; Topp and Hoff 1972.

Figure 43.—Cynoglossidae: *Symphurus atricauda*, California tonguefish.

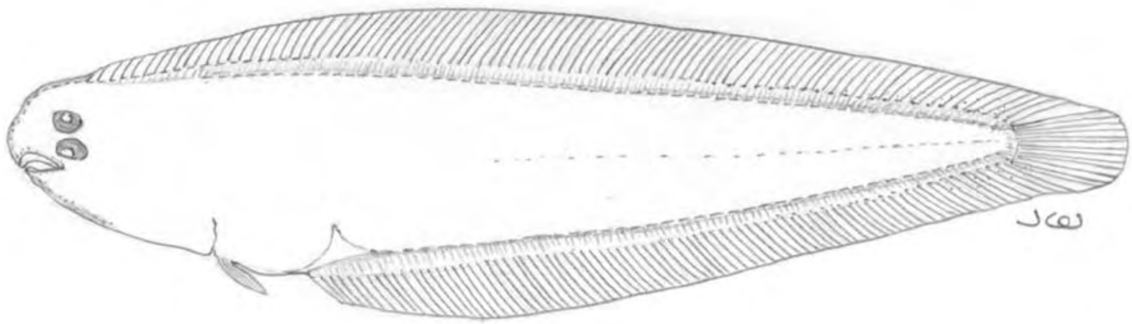


FIGURE 43-1.—Juvenile, 25 mm TL.

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GLOSSARY

A. Abbreviation for the anal fin.

Adhesive egg. An egg that adheres to a substrate or to another egg.

Adipose fin. A fleshy, rayless fin usually located on the middorsum between the dorsal and caudal fins.

Air bladder. A membranous gas-filled sac present in the dorsal portion of the body cavity.

Ammocoets. The larval stage of lampreys.

Anadromous species. Fishes that inhabit marine waters during juvenile and adult life stages but migrate to freshwater for spawning.

Anterior. Located in front of.

Anus (vent). The posterior opening of the digestive tract.

Barbel. A fleshy, elongated sensory structure located at the corner of the jaws or adjacent to the mouth.

Benthic. Living beneath or on the surface of the bottom substrate.

Blastocoele. The central cavity of the egg which surrounds the yolk in the blastula stage.

Blastoderm. The single-layered geminal cells that lie on top of the yolk in the early developmental stage of an egg and later form an embryo.

Blastodisc. A disc-like blastula.

Blastomeres. Individual cells produced during early embryonic cleavage.

Blastula. An early embryonic stage of active cleavage characterized by the presence of a blastoderm and a blastocoele.

Branchial. Pertaining to the gills.

Branchiostegal rays. A series of elongated flexible bones connected by membranes between the interopercle and the isthmus in the gills.

CalCOFI. California Cooperative Oceanic Fisheries Investigations.

Catadromous species. Fishes that inhabit freshwater but spawn only in marine waters.

Caudal peduncle. The slender portion of the body that is between the anal and caudal fins.

Chorion. The outermost semipermeable layer of an egg, also known as egg capsule.

Chorion filament. A filamentous structure that grows from the chorion for buoyancy and attachment to other eggs or the substrate.

Chromatophore. A pigment cell.

Cleavage stages. The initial stages of embryonic development that involve division of the entire egg or the blastomeres.

Cleithrum. A dermal bone in the pectoral girdle.

Clustered eggs. Eggs which adhere to one another with the chorion or chorion filaments.

Compressed. Laterally constructed.

Ctenoid scale. Scales having spines or serrae along the exposed portion.

Cycloid scale. Nearly spherical scales having no spines or serrae.

D. Abbreviation for the dorsal fin.

Demersal. Living on or close to the bottom substrate, usually relates to fish species.

Depressed. Dorsoventally flattened.

Diameter of eye. The maximum distance between two points on the outer margin of the eyeball.

Dorsal finfold. The median fold of integument that extends along the middorsum from the cephalic to the caudal regions from which the dorsal fin develops.

Early embryo. The embryonic stage in which the embryonic axis and somites are evident.

Embryonic axis. An elongate thickening of the blastoderm that forms during the initial differentiation and orientation of the embryo.

Embryonic shield. Thickened, shieldlike area of the blastoderm at the caudal edge of the germinal ring.

Epibenthic. Living on the surface of the bottom substrate, usually relates to invertebrate species.

Euryhaline. Capable of tolerating a wide range of salinities.

Fin bud. An undifferentiated fin.

Finfold. Median fold of integument that extends along the middorsum or midventrum from which the median fins develop.

Frenum. A ridge of skin between the upper jaw (premaxillary bone) and the nasal bone at the top of the snout.

Freshwater. Salinities less than 0.3 ppt.

Germinal (Germ) ring. The thickened peripheral rim of the blastoderm evident in the envelopment of the yolk in the gastrular stage.

Gill arch. The branchial skeleton that supports the gill rakers and gill lamellae.

Gill lamellae. Subdivisions within the gills were gas exchange occurs.

Gill rakers. Slender rodlike structures projecting into the mouth cavity from the gill arch.

Gill slits. Gill opening.

Gonopodium. A modified structure of the anterior anal rays of male poeciliid fishes used as an intromittent copulatory organ.

Head length of larvae. The distance from the tip of the snout to the posterior margin of the auditory vesicle for prolarvae, the distance from the tip of the snout to the posterior margin of the opercles for larvae and later stages.

Heterocercal. A condition where the caudal vertebrae are bent upward, and the dorsal lobe of the caudal fin is much larger than the ventral lobe.

Homocercal. Tail morphology where both dorsal and ventral lobes of the caudal fin are of a similar size.

Holoblastic cleavage. The stage at which the entire egg undergoes division (such as in lampreys).

Hypural. A serial bony structure below the urostyle which supports the caudal fin.

Incubation period. The elapsed time between fertilization and hatching of the egg.

Inferior mouth. A mouth located on the ventral side of the snout, upper jaw extends over lower jaw.

Insertion of fin. The point at which the last fin ray attaches to the body.

Interopercle. A bone in the gill region above the branchiostegal rays.

Interorbital. The space between the eyes on the top of the head.

Isthmus. The narrow area between the sets of branchiostegal rays across the jugular.

Jugular. Throat area.

Juvenile. The stage of completion of fin and scale development.

Late embryo. The final phase of embryonic development, characterized by a free tail and a resemblance to yolk-sac larvae.

Lateral line. Part of the sensory system extending in two major branches from the cranial nerves to the lateral sides of the body, several small branches extend to the head region.

Lateral plates. Thickened, hardened scales located laterally along the body.

Length of upper jaw. The distance between the tip of the snout and the proximal end of the maxillary.

Littoral. Related to shallow, inshore waters where light penetrates, an intertidal zone.

Major axis of egg. The longest axis of a nonspherical egg.

Mandible. Lower jaw.

Maxillary. Upper jaw.

Melanophore. A black pigment cell.

Meroblastic cleavage. Egg cleavage which is restricted to the blastodisc and only the blastodern forms the embryo.

Mesohaline. Salinities ranging from 5.0 to 18.00 ppt.

Micropyle. A differentiated area on the surface of the chorion where spermatozoa enter an egg.

Middorsum. The middle region of the dorsal surface.

Minor axis of egg. The shortest axis of a nonspherical egg.

Morula. Embryonic stage in which blastomeres form a raspberry like cluster on top of the yolk.

Myomere. A single muscular segment between tow myosepta.

Myoseptum (pl. myosepta). The partitions of connective tissue between myomeres.

Myotomes. Blocks of muscles joined together by myosepta.

Nape. The area along the middorsum between the head and origin of the dorsal fin.

Notochord. The longitudinal cartilaginous rod that is eventually replaced by the vertebral column in the body of teleostean fishes.

Notochord length (NL). The distance from the tip of the snout to the posterior end of the notochord.

Occipital (cephalic). The top of the head.

Oil globule. A clear lipid droplet in the yolk of an egg or yolk-sac larval stage, it is an additional food source and maintains buoyancy of the egg.

Oligohaline. Salinities ranging from 0.3 to 5.0 ppt.

Operculum (opercle). A bony flap covering the gills.

Optical vesicles. Embryonic structures that give rise to the eyes.

Origin of the fin. The anteriormost point of attachment of a median fin.

Ovoviviparous (live-bearing). Fishes that produce and hatch (but do not nourish) eggs within the female's oviduct, young are born as free-swimming larvae or juveniles.

Oviparous. The most common form of reproduction in fishes, eggs are released from the females and later hatch.

Pelagic. In the water column (not necessarily near the surface).

Papillae. Fleshy tissue on the lips.

Peritoneum. The lining of the body cavity.

Perivitelline space. Vitreous space between the chorion and the yolk.

Pharyngeal teeth. Teeth attached to the pharyngeal bone of the throat.

Polyhaline. Salinity levels ranging from 18.0 to 30.0 ppt.

Postanal myomeres. The myomeres between the posterior margin of the anus (first complete myomere behind the vent) and the most posterior true myoseptum.

Posterior. Located behind.

Postlarva (larva). The stage of development between the absorption of the yolk sac and complete differentiation of the fin rays, finfolds retreat or disappear in the same period.

Postorbital head length. The distance between the posterior margin of the eye and the posterior margin of the opercles.

Preanal myomeres. The myomeres between the most anterior myoseptum and the posterior margin of the anus.

Preoperculum (preopercle). An L-shaped bony flap anterior to the margin of the opercles.

Prolarva (yolk-sac larva). The stage of development in which a larva has not yet absorbed the yolk sac.

Primary caudal rays. Straight rays in the caudal fin attached to hypural bones, or their derivatives in larvae and early juveniles.

Ripe fish. Fishes with free-flowing milt or eggs evident upon gentle abdominal squeezing.

Scute. Thickened, hardened scales on the midline of the belly.

Sea water. Salinity levels greater than 30.0 ppt.

Secondary caudal rays. Recurved rays of the caudal fin which are not associated with hypural bones, or their derivatives in larvae and early juveniles.

Serra (pl. serrae). Sawlike teeth along the margin of a structure.

Snout length. The distance between the anterior margin of the eye and the tip of the snout.

Snout to anus length. The ratio of the distance from the tip of the snout to the anus to the total length of the fish.

Spine. An unsegmented, unbranched, uniserial rigid ray in a fin.

Standard length (SL). The distance from the tip of the snout to the base, or point of inflection, of the urostyle.

Superior mouth. Located on the dorsal side of the snout, lower jaw extends beyond upper jaw.

Terminal mouth. Jaws meet at the tip of the snout.

Thoracic. Posterior to the throat area.

Total length (TL). The distance from the tip of the snout to the tip of the tail or caudal fin.

Urogenital opening. The common opening of both excretory and reproductive systems, always posterior to the anus.

Urostyle. Rodlike bone consisting of a number of fused vertebrae at the posterior tip of the notochord, usually bending upward.

Ventral finfold. The median finfold on the ventral side of the body, divided by the anus into the preanal fold and the postanal finfold.

Viviparous (live-bearing). Eggs are fertilized internally, and embryos are mourished through a placenta or placenta-like structure within the female's oviduct, yound are released as juveniles (c. ovoviviparous).

Water hardening. A process after fertilization of an egg in which the chorion expands because of absorption of water into the perivitelline space.

Weberian ossicles. Modified anterior vertebrae joining the ear with the air bladder.

Width of perivitelline space. The distance between the yolk and the chorion.

Yolk. Source of basic nutrients for the egg and larva prior to the ability to ingest food.

Yolk diameter. The distance across the outer margin of the yolk.

Yolk-sac larva. See Prolarva.

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