Status Review for North American Green Sturgeon, *Acipenser medirostris*

Peter B. Adams[1], Churchill B. Grimes[1], Joseph E. Hightower[2]
Steven T. Lindley[1], and Mary L. Moser[3]

[1]National Marine Fisheries Service
Southwest Fisheries Science Center
110 Shaffer Road
Santa Cruz, California 95060

[2]North Carolina Cooperative Fish and Wildlife Research Unit
United States Geological Survey
North Carolina State University
Campus Box 7617
Raleigh, North Carolina 27695

[3]National Marine Fisheries Service
Northwest Fisheries Science Center
2725 Montlake Blvd. E.
Seattle, WA 98112

June 2002

CONTENTS

EXECUTIVE SUMMARY

In 2001, the National Marine Fisheries Service (NMFS) received a petition requesting Endangered Species Act (ESA) listing of North American green sturgeon (*Acipenser medirostris*) as a threatened or endangered species. In response to this petition, NMFS announced that it would initiate an ESA status review. The ESA allows the listing of ADistinct Population Segments@ (DPSs) of vertebrates as well as named species and subspecies. The combined U. S. Fish and Wildlife Service and NMFS policy on recognition of DPSs outlines two tests to identify separate units: discreteness and significance. A DPS may be considered discrete if it is markedly separate from other populations of the same taxon as a consequence of physical, physiological, ecological, or behavioral factors or if it is delimited by international governmental boundaries. The significance of the population will be decided on the basis of considerations including, but not limited to its persistence, evidence that loss of the DPS would result in a significant gap in spatial structure, evidence of the DPS representing the only surviving natural occurrence of a taxon, or evidence that the DPS differs markedly in its genetic characteristics. Once a DPS has been identified, a risk assessment is preformed to determine whether a listing is warranted for that unit.

Green sturgeon have a complex anadromous life history. They spend more time in the ocean than any other sturgeon. The majority of green sturgeon are thought to spawn in the Klamath River, but spawning also occurs in the Sacramento and Rogue rivers. First spawning occurs at 15 years for males and 17 years for females. Female green sturgeon are thought to spawn only every 5 years. Adults migrate into rivers to spawn from April to July with a May to June peak. Eggs are spawned among rocky bottom substrates and juveniles spend 1 to 4 years in freshwater. After green sturgeon enter the ocean, they appear to make northern migrations indicated from very limited tag information. Green sturgeon concentrate in coastal estuaries, particularly the Columbia River estuary and coastal Washington estuaries during the late summer and early fall. Neither feeding nor spawning occurs in association with these concentrations, and there is no information about how much of the population is in these concentrations each year or whether this varies. Most of the green sturgeon harvest occurs on these concentrations.

Two green sturgeon DPSs were identified based on the fact that sturgeon generally show fidelity to their spawning site so they have a general pattern of multiple DPSs, and on the preliminary genetic evidence that indicates differences at least between the Klamath River and San Pablo Bay samples. The northern DPS would include all green sturgeon populations starting with the Eel River and extending northward. The southern DPS would include all green sturgeon populations south of the Eel River with the only known population being in the Sacramento River. The Eel River boundary between the two DPSs is based on geography and may be modified as more information becomes available. The BRT recognizes that there may be additional DPS structure that is not apparent with the present level of information.

Northern Green Sturgeon Distinct Population Segment

A majority of the BRT concluded that there is not sufficient information showing that green sturgeon in this DPS are in danger of extinction or would be likely to become so in the foreseeable future, while a minority of the BRT concluded that green sturgeon in this DPS are not currently in danger of extinction but are likely to become so in the foreseeable future. However, the BRT concluded that green sturgeon in this DPS faced considerable threats to their populations and should be placed on the Candidates list and have their status review within five years.

Green sturgeon in this DPS did not have declining populations trends, but did face a large number of potential threats to their populations. Klamath River Yurok Tribal green sturgeon catch and catch-per-unit-effort (CPUE) were the best available data set since they were based on spawning fish and not fish involved in summer concentrations. Catch and CPUE data both had a non-negative slope, but neither trend was significant. The catch length data did not indicate that large fish were decreasing within the population, but sample sizes were very small. Potential threats to green sturgeon in this DPS included concentration of spawning, lack of population data, harvest concerns, and loss of spawning habitat. Most of the green sturgeon population appears to spawn in the Klamath River and the lack of any population trend information beyond catch raises concerns about their status. The BRT was extremely concerned about the unknown harvest impacts on a mixture of populations or DPSs (i.e., harvest of summer concentrations in coastal rivers and estuaries). Because these coastal concentrations likely represent a mix of fish originating in different river systems, it is also not feasible to assess population trends. Green sturgeon in this DPS have lost spawning habitat in the South Fork Trinity River, Eel River, and perhaps elsewhere.

Southern Green Sturgeon Distinct Population Segment

A majority of the BRT concluded that there is not sufficient information that shows green sturgeon in this DPS are in danger of extinction or would be likely to become so in the foreseeable future. A minority of the BRT concluded that green sturgeon in this DPS are not in danger of extinction but are likely to become so in the foreseeable future. However, the BRT unanimously had a higher level of concern about green sturgeon in this DPS than in the northern one. The BRT concluded that green sturgeon in this DPS should also be placed on the Candidates list and their status review within five years.

The southern green sturgeon DPS population trend information is even less definitive and the populations face an even larger number of potential threats. The San Pablo Bay population estimates had a non-negative trend, but were less persuasive due to being based on summer concentrations and issues with tag recovery effort used in white sturgeon estimation. In addition to the sizeable threats faced in the northern DPS, green sturgeon populations in the southern DPS face smaller population size, potentially lethal temperature limits, entrainment by water projects, and influence of toxic material and exotic species. Population sizes are unknown in this DPS, but are clearly much smaller than in the northern one and therefore more susceptible to catastrophic events. This makes the lack of population trend information an even greater risk factor here. Larval green sturgeon have been shown to have lethal temperature limits near the summer temperatures in the Sacramento River. Temperature control efforts for winter-run chinook have probably been very beneficial here. Spawning habitat may have been lost behind dams and water diversions throughout the Central Valley. Green sturgeon in this DPS also face entrainment in pumps associated with the California water project. The entrainment numbers have decreased dramatically since 1985. The reasons for this decrease are unknown. There are significant concerns for winter-run chinook from pesticides and introduced species and green sturgeon in this DPS are probably subject to similar risks.

ACKNOWLEDGMENTS

The status review for North American green sturgeon was conducted by a team of scientists from the NMFS and the United States Geological Survey (USGS). The members of the biological review team (BRT) contributed a substantial amount of time and effort to this process. The BRT included; Dr. Peter Adams, Dr. Churchill Grimes, and Dr. Steven Lindley of NMFS, Southwest Fisheries Science Center, Santa Cruz Laboratory; Dr. Mary Moser of NMFS, Northwest Fisheries Science Center, and Dr. Joseph Hightower, USGS, North Carolina Cooperative Fish and Wildlife Research Unit. Their review was dependent on information from scientific literature or provided by various state, tribal, and local agencies and individuals. For information and analyses provided to the status review teams, we particularly wish to acknowledge the efforts of Patrick Coulston, David Kohlhorst, and Raymond Shaffer of the California Department of Fish and Game; Thomas Rien of Oregon Department of Fish and Wildlife; Brad James and Olaf Langness of Washington Department of Fish and Wildlife; David Hillemeier of the Yurok Tribe; Joseph Cech, Josh Isreal, and Joel Van Eenennaam of University of California, Davis; Selina Heppell and Lina Hoffman of Oregon State University; and Phaedra Doukakis of the Wildlife Conservation Society. The states and tribes also provided comprehensive, helpful and timely reviews of the status review document. Charlene Bergeron and Heidi Fish of the Santa Cruz Laboratory provided assistance in preparation of the status review in numerous ways.

INTRODUCTION

The green sturgeon, *Acipenser medirostris*, is the most widely distributed member of the sturgeon family *Acipenseridae*. Like all sturgeons, green sturgeon are anadromous, but are also the most marine oriented of the sturgeons. The only known green sturgeon spawning locations are the Klamath, Sacramento, and Rogue rivers along the west coast of North America; however they are known to range in nearshore waters from Mexico to the Bering Sea and are commonly observed in bays and estuaries with particularly large concentrations entering the Columbia River Estuary, Willapa Bay, and Grays Harbor during the late summer (Moyle et al. 1992). The reasons for these concentrations are unclear, but are probably not due to spawning or feeding.

Sturgeons in general have a life history that is susceptible to overharvesting and a number of species have some kind of protection or status. Green sturgeon has a status designation of Special Concern in Canada (Houston 1988) because it has characteristics that make it particularly sensitive to human activities or natural events. Sakhalin sturgeon, *A. mikadoi*, a species that was at one time synonymized with green sturgeon, is extirpated throughout Japan, Korea, and China, and in Russia, is reduced in range to the Tumnin River where there is a hatchery. In the United States, there are five sturgeon listed under the Endangered Species Act (ESA): Shortnose Sturgeon, *A. brevirostrum*, Endangered 1967 (32 FR 4001); Pallid Sturgeon, *Scaphirhynchus albus*, Endangered 1990 (55 FR 36641 36647); Gulf Sturgeon, *A. oxyrinchus*, Threatened 1991 (USFWS 1991); White Sturgeon, Kootenai River Population, *A. transmontanus*, Endangered 1994 (9 FR 45989 46002); and Alabama Sturgeon, *S. suttkusi*, Endangered 2000 (65 FR 26437 26461).

Scope and Intent of the Present Document

This document is the status review in response to a petition to list green sturgeon under the Endangered Species Act (EPIC et al. 2001). Green sturgeon are a species that are not abundant with little information on their historical abundance, diversity and population status. In addition, like other sturgeon species, it is faced with threats from harvest, habitat loss or degradation, and entrainment. Further, the life history strategy of green sturgeon makes it vulnerable to depletion and slow to recover from that state. Therefore, the National Marine Fisheries Service (NMFS) decided that the petition had sufficient merit for consideration and that a status review was warranted.

Because the ESA stipulates that listing determinations should be made on the basis of the best scientific and commercial information available, NMFS formed a team of scientists with diverse backgrounds in sturgeon and conservation biology to conduct this status review. This Biological Review Team (BRT) discussed and evaluated scientific information contained in an extensive public record developed for green sturgeon. This document reports conclusions reached by the BRT for green sturgeon listing. These conclusions are subject to revision should important new information arise in the future.

Key Questions in ESA Evaluations

In determining whether a listing under the ESA is warranted, two key questions must be addressed:

1) Is the entity in question a "species" as defined by the ESA?
2) If so, is the "species" threatened or endangered?

These two questions are addressed in separate sections of this report. If it is determined that a listing is warranted, then NMFS is required by law (1973 ESA Sec. 4(a)(1)) to identify one or more of the following factors responsible for the species' threatened or endangered status: 1) destruction or modification of habitat; 2) overutilization by humans; 3) disease or predation; 4) inadequacy of existing regulatory mechanisms; or 5) other natural or human factors.

The "Species" Question

As amended in 1978, the ESA allows listing of "distinct population segments" of vertebrates as well as named species and subspecies. After determining whether the listing identifies a species, the next issue is whether there are Adistinct population segments@ (DPSs) within the species. However, the ESA provides no specific guidance for determining what constitutes a distinct population, and the resulting ambiguity has led to the use of a variety of approaches for evaluating this issue in vertebrate populations. This led the U. S. Fish and Wildlife Service and NMFS to publish Policy Regarding the Recognition of Distinct Vertebrate Population Segments Under the Endangered Species Act (USFWS and NMFS 1996). The policy identifies two elements in a decision regarding whether it is appropriate to identify separate DPSs: discreteness and significance of the population segment to the species. A DPS may be considered discrete if it is markedly separate from other populations of the same taxon as a consequence of physical, physiological, ecological, or behavioral factors or if it is delimited by international governmental boundaries. If a population segment is considered discrete, it=s biological and ecological significance will be considered on the basis of considerations including, but not limited to its persistence, evidence that loss of the DPS would result in a significant gap in spatial structure, evidence of the DPS representing the only surviving natural occurrence of a taxon, or evidence that the DPS differs markedly in its genetic characteristics. If it is deemed appropriate to identify separate DPSs, the status of each DPS should be considered separately in relation to the standards for ESA. These issues have been dealt with extensively for Pacific salmon. For a more detailed discussion of this topic, see Waples (1991).

The "Extinction Risk" Question

The ESA (section 3) defines the term "endangered species" as "any species which is in danger of extinction throughout all or a significant portion of its range." The term "threatened species" is defined as "any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range." NMFS considers a variety of information in evaluating the level of risk faced by a DPS. Important considerations include 1) absolute numbers of fish and their spatial and temporal distribution; 2) current abundance in relation to historical abundance and carrying capacity of the habitat; 3) any spatial and temporal trends in abundance; 4) natural and human-influenced factors that cause variability in survival and abundance; 5) possible threats to genetic integrity (e.g., artificial rearing); and 6) recent events (e.g., a drought or a change in management) that have predictable short-term consequences for abundance of the species. Additional risk factors, such as disease prevalence or changes in life history traits, may also be considered in evaluating risk to populations.

According to the ESA, the determination of whether a species is threatened or endangered should be made on the basis of the best scientific and commercial information available regarding its current status, after taking into consideration conservation measures that are proposed or are in place. In this review, we do not evaluate likely or possible effects of conservation measures. Therefore, we do not make recommendations as to whether the species or identified DPS should be listed as threatened or endangered. Rather, we have drawn scientific conclusions about the risk of extinction faced by identified DPS under the assumption that present conditions will continue (recognizing, of course, that natural demographic and environmental variability is an inherent feature of "present conditions"). Conservation measures will be taken into account by the NMFS Northwest and Southwest Regional Offices in making listing recommendations.

Summary of the Green Sturgeon Listing Petition

The petition to list North American green sturgeon (*Acipenser medirostris*) as an endangered or threatened species under the Endangered Species Act was filed by the Environmental Protection Information Center, the Center for Biological Diversity, and Waterkeepers Northern California in June of 2001. The petition (EPIC et al. 2001) stresses a recent American Fisheries Society assessment (Musick et al. 2000) that concluded that green sturgeon has suffered an 88% decline in most of its range. The petition also notes that the only formal review (Moyle et al. 1992) recommends that green sturgeon should be formally listed as a threatened species. The petition then goes on to propose that green sturgeon should be listed on all the five ESA factors listed except possibly disease and predation.

1. Present or threatened destruction, modification, or curtailment of its habitat or range.
   "Twice as many green sturgeon spawning populations have been extirpated in the last century as are know to currently remain. Spawning runs have disappeared from the San Joaquin river, Eel, and South Fork Trinity, probably the Umpqua river, and possible the Fraser River as well." In addition, the petition lists logging practices, land use practices, railroad construction, and building and operating dams, particularly in the Central Valley, as factors which have destroyed green sturgeon habitat.

2. Overutilization for commercial, recreational, scientific, or educational purposes.
   "Exploitation of green sturgeon in various commercial, sport, tribal, and illegal fisheries appear to be excessive for many years. ... Of particular concern are the Columbia River, Willapa Bay, and Grays Harbor fisheries, as no spawning adults have been documented in the region and the average size of green sturgeon caught there has been declining steadily (USFWS 1995)." The petition goes on to mention that there is no coast-wide

monitoring of green sturgeons and that there were large catches in the 1980's and the life history of sturgeons is prone to collapse from overfishing.

3. Disease and Predation.
   "Disease and predation are currently not know to be major factors in the decline of green sturgeon."

4. Inadequacy of Existing Regulatory Mechanisms.
   "The green sturgeon currently has no federal status or protections as a protected species. ... Various size limit restrictions on the commercial and sport harvest of sturgeon have been implemented in California, Oregon, and Washington in response to over-harvest or "mining" of large mature fish of breeding age. These regulations have been aimed mostly at white sturgeon, but also apply to green sturgeon. However, they are less protective of green sturgeon, since the largest green sturgeon of breeding age tend to still fall within the maximum size limit." The petition points out that the maximum commercial size limit is larger for green sturgeon than for white and that there is no active fishery management for green sturgeon in California. The United States Fish and Wildlife Service (USFWS) has set an overall restoration criterion for green sturgeon in the Central Valley of 1,000 fish over 1 m in length. It is unclear what the logic of this criterion was, or how well met it is.

5. Other Natural or Anthropogenic Factors.
   a. Entrainment.
      "Juvenile green sturgeon and an occasional adult sturgeon are entrained on an irregular basis at both the state and federal water export facilities."
   b. Toxic Substances.
      "The effects of toxic substances from heavy metals to pesticides on green sturgeon are unknown."

GREEN STURGEON LIFE HISTORY AND ECOLOGY

Distribution

This summary of information is from Moyle et al. 1992, EPIC et al. 2001, and California Department of Fish and Game (CDFG) 2002 except where otherwise noted.

Southern California

Green sturgeon occur occasionally in Southern California waters only as single small fish. Green sturgeon become more common north of Point Conception, but are still rare.

Sacramento-San Joaquin River

San Francisco Bay and its associated river systems contain the southern-most reproductive green sturgeon population. The species was first described here by Aryes (1854). White sturgeon (*A. transmontanus*) supports a large fishery here, particularly in San Pablo Bay, which has been extensively studied by CDFG since the 1940's. While green sturgeon are not common, they are taken in a white sturgeon trammel net monitoring program most years in numbers ranging from 5 to 110. An abundance estimate is produced by CDFG from white sturgeon monitoring which will be discussed in later sections. Green sturgeon juveniles are found throughout the Delta and San Francisco Bay, mostly in small numbers but sometimes as many as one hundred as indicated by fish taken in trammel net sampling, small boat trawls, presence in striped bass sampling, and entrainment by water export facilities.

Green sturgeon adults and juveniles occur throughout the upper Sacramento River, based upon observations incidental to winter-run chinook monitoring at the Red Bluff Diversion Dam (RBDD), Tehama County. Green sturgeon reportedly spawn in the Feather River, but this has not been substantiated. Green sturgeon spawning occurs predominately in the upper Sacramento River. Juvenile sturgeon are taken annually at trapping operations at the RBDD (1995-2001) and Glenn-Colusa Irrigation District (GCID) pumping plant (1986-2001). We assume that all larval and juvenile sturgeon caught at these locations are green sturgeon because 136 juveniles collected here and grown to identifiable size were all this species.

There is no documentation of green sturgeon spawning in the San Joaquin River, but there probably was spawning before construction of large-scale hydropower and irrigation development. White sturgeon persist in the San Joaquin River at population levels of ten percent of Sacramento River populations. Young green sturgeon have been taken occasionally in the Santa Clara Shoal area in the San Joaquin delta, but these fish may have originated somewhere else.

Coastal California

Green sturgeon also occur in the coastal waters of the Pacific Ocean off California. Small numbers have been taken in both Tomales Bay and Bodega Bay, and a single fish has been taken from the Noyo River. They are regularly taken in small numbers in Humboldt Bay, fifty were tagged by a CDFG tagging program in Arcata Bay in 1956; none were recovered. In 1992-1993, Humboldt State University also tagged 69 fish in Arcata Bay; one was recovered from within the bay within a few days, and one was recovered from the Yurok Tribal Klamath River fishery. Green sturgeon are also caught in coastal waters and in estuaries from Arcata Bay to the Oregon border.

Eel River

Both adult and juvenile green sturgeon have been observed in the Eel River. Seven adult green sturgeon were observed during snorkel surveys between 1995 and 1997 between rkm 100 and 160. Approximately 40 juvenile green sturgeon were taken in trapping operations on the mainstem between Rio Dell (rkm 20) and Dos Rios (rkm 191) from 1967 to 1970. These sturgeon were between 70 and 140 mm, and we consider the presence of juveniles smaller than 100 mm as evidence of spawning. In addition, two juvenile green sturgeon (282 and 510 mm FL) were collected from the upper Eel River estuary in July and October 1994.

Klamath-Trinity River

The largest known spawning population of green sturgeon occurs in the Klamath Rive. Adults are captured in the salmon Tribal gill net fishery (see Harvest) on the Yurok and Hoopa reservation and occur up to the natural barrier at Ishi Pishi Falls (107 rkm). Juvenile green sturgeon are captured each year in rotary-screw traps at Big Bar (rkm 80). Two juveniles (assumed to be green sturgeon) were visually observed in the lower 10 km of the Salmon River during October 1996. Green sturgeon sized 12-46 cm were taken with beach seines in the upper Klamath estuary from August to early October 1984-1990.

Adults occur in the Trinity River to Gray's Falls (rkm 69), but there is no evidence to confirm spawning upstream of Willow Creek trap (rkm 40). Moyle et al. (1992) reports no evidence of spawning in the South Fork of the Trinity River.

Rogue River

The Rogue River was recently confirmed as a third spawning area for green sturgeon (Erickson et al. 2001, Rien et al. 2001). Adult fish entering the estuary were caught in gill-nets and radio-tagged. Extended holding sites were identified which have been associated with spawning in other species of sturgeon. Juvenile fish are taken during beach seining for coho salmon in the estuary (Rien et al. 2001).

Umpqua River/Winchester Bay

Green sturgeon were more commonly caught in the Umpqua River gill net fisheries than whites prior to 1948 (EPIC et al. 2001). Green sturgeon adults are commonly taken in Winchester Bay, e.g., in 18 one-hour gill-net sets 205 green sturgeon were caught (Neill et al. 2000). Juvenile green sturgeon are reported from Winchester Bay (King 1998, Beamesderfer 2000).

Coastal Oregon

Green sturgeon adults are taken in almost all of the Oregon coastal estuaries from the Chetco River to Nehalem Bay (EPIC et al. 2001). During white sturgeon tagging projects in Coos Bay (Coos River), Winchester Bay (Umpqua River), Yaquina Bay (Yaquina River), and Tillamook Bay (Tillamook River) green sturgeon were incidently tagged. No green sturgeon tag recoveries have been reported (ODFW 2002).

Columbia River System

The Columbia River System has supported a large white sturgeon fishery for many years. Green sturgeon bycatch from this fishery ranges from 1,000s of fish in the 1980s to 100s of fish in recent years (Beamesderfer 2000). In the mid 1930s before Bonneville Dam, green sturgeon were found up to the Cascade Rapids. Today green sturgeon are found up river to the Bonneville Dam (rkm 235), but are predominately found in the lower 60 rkm. Tagging studies indicate a substantial exchange of Columbia River and Willapa Bay fish (WDFW 2002a).

Willapa Bay

Willapa Bay, along with the Columbia River and Grays Harbor, is one of the estuaries where green sturgeon concentrate in summer. Generally, green sturgeon are more abundant than white sturgeon here (Emmett et al. 1991). Catches have declined from 3,000-4,000 fish per year in the 1960's to few or none in recent years (WDFW 2002a). Much of this is probably due to reduced size limits and seasonal and area closures.

Grays Harbor

Grays Harbor is the northern most estuary with green sturgeon summer concentrations and there are both a tribal and commercial fisheries which land around 500 fish per year. There are no records of juveniles from Grays Harbor. Green sturgeon occur sporadically in small numbers throughout coastal Washington (WDFW 2002a).

Coastal Washington and Puget Sound

Green sturgeon are routinely encountered in the coastal trawl fishery as minor incidental catch (WDFW 2002b). Occasionally, green sturgeon are caught in small coastal bays and estuaries during tribal salmon fisheries. A few green sturgeon are recovered in Puget Sound as incidental harvest (mostly trawl fisheries). There is no commercial target fishery for sturgeon in the region.

Canada

Green sturgeon occur in small numbers along the western coast of Vancouver Island (Houston 1988), and the Skeena River. Historically, green sturgeon were not uncommon at the mouth of the Fraser River (EPIC et al. 2001). Since the collapse of the Fraser River white sturgeon fishery, green sturgeon are only taken occasionally.

Spawning

Green sturgeon are thought to spawn every three to five years (Tracy 1990). Their spawning period is March to July, with a peak in mid-April to mid-June (Moyle et al. 1992). Mature males range from 139-199 cm FL and ages 15 to 30 years old (VanEenennaam 2002), while mature females range from 157-223 cm FL and ages 17 to 40 years old. Most of the spawning males are 160-170 cm Fl and 17-18 years old, while most of the spawning females are 182-192 cm FL and 27-28 years old. However, smaller and younger green sturgeon have sexual differentiated gonads and can be artificially induced to produce sperm and eggs (Cech et al. 2000).

Green sturgeon spawning occurs in deep pools or Aholes@ in large, turbulent river mainstreams (Moyle et al. 1992). Specific spawning habitat preferences are unclear, but are likely large cobbles, but can range from clean sand to bedrock. Eggs are likely broadcast over the large cobble substrate where they settle into the space between the cobbles. Green sturgeon females produce 60,000-140,000 eggs (Moyle et al. 1992), and they are the largest egg mean diameter (4.34 mm) of any sturgeon (Cech et al. 2000). The large egg size provides larger yolk stores for the nourishment of embryos, resulting in more viable larvae. However, this is balanced by a lower fecundity. The adhesiveness of green sturgeon eggs is lower than that of white sturgeon (Deng 2000), and it is possible that the eggs may not attach to the substrate after fertilization, but become trapped in crevices and gravel where development starts. Temperatures above 20^{B} C are lethal to green sturgeon embryos (Cech et al. 2000).

Green sturgeon spawning has only been documented in the Klamath, Sacramento (Moyle et al. 1992, CDFG 2002) and Rogue (Erickson et al. 2001, Rien et al. 2001) rivers during recent times. The Klamath Basin supports the largest green sturgeon spawning population (Moyle et al. 1992), where the Yurok and Hoopa Tribal fisheries catch adults predominately in the spring on the upstream spawning migration, but also in the fall during the out-migration after spawning. In the Klamath River, breaching and other sturgeon courtship behaviors have been observed in the ASturgeon Hole@ upstream of Orleans (rkm 96). Larvae and juveniles are caught in the Big Bar trap (rkm 80) on the Klamath River and in the Willow Creek trap (rkm 40) on the Trinity River. Numbers at both traps peak in July (Healey 1973).

In the Sacramento River, green sturgeon spawn in late spring and early summer above Hamilton City, and perhaps as far upstream as Keswick Dam (CDFG 2002). Green sturgeon occur in the upper river, particularly around the RBDD, and the opening of the RBDD gates to improve winter-run chinook passage is believed to have provided substantial increases in green sturgeon spawning habitat. The gates were first opened in 1986 and the current regime of being closed from May 15 to September 15 started in 1992. Juvenile green sturgeon are taken in both RBDD and GCID traps (see Distribution).

Green sturgeon spawning has been recently documented in the Rogue River (Erickson et al. 2001, Rien et al. 2001). Adult fish were radio-tagged in the estuary during May-June 2000. After release, tagged ripe fish moved up the Rogue River to spawn, while non-reproductive fish remained close to the tagging site. Spawning fish spent more than six months in freshwater and traveled as far as rkm 39; preferred habitats were low-gradient reaches and off-channel coves. Home ranges within holding sites were restricted so that relocated individuals were within a 100 x 100 m area and often within a 50 x 50 m area. All tagged individuals emigrated from freshwater during fall and winter when water temperatures fell below 10^{B} C. Juvenile green sturgeon have been taken in beach seines in the Rogue River estuary from April until the end of November (Appendix D. Fig. D-1, Rien et al. 2001).

Apparently, green sturgeon no longer spawn in several former spawning river systems (CDFG 2002). Juvenile green sturgeon were captured in the Eel River in traps at Rio Dell (rkm 20) and Dos Rios (rkm 191) during the period from 1967 to 1970 (Puckett 1976). Single or small numbers of adult green sturgeon are also observed periodically in the Eel River up until the present time, and within the last year a single juvenile was tentatively identified. Similarly, green sturgeon are reported to have spawned in the South Fork Trinity River, but apparently no longer do so due to extensive sedimentation from the 1964 flood (Moyle et al. 1992). The validity of reports of green sturgeon spawning in the Umpqua River is unclear (Lauman et al. 1972), and the possibility of current spawning activity is being investigated (ODFW 2002).

Early Life History

Green sturgeon larvae are different from all other sturgeon because of the absence of a distinct swim-up or post-hatching stage (Deng 2000). The larvae are distinguished from white sturgeon by their larger size, light pigmentation, and size and shape of the yolk sac. Larvae hatched in the laboratory are photonegative and exhibit hiding behaviors after the onset of exogenous feeding. The larvae and juveniles become nocturnal (Cech et al. 2000). These may be adaptions for avoiding downstream displacement and predation, respectively.

Green sturgeon larvae are robust and easy to rear in captivity. Five-day-old larvae were almost twice as heavy as white sturgeon larvae and optimal larval growth rates occur at temperatures of 15EC (Cech et al 2000). Growth is reduced at 11EC and 19EC, and substantially reduced at 24EC. First feeding occurs at 10 days post hatch, and metamorphosis to juveniles is complete at 45 days. Larvae grow fast, reaching a length of 66 mm and a weight of 1.8 g in 3 weeks of exogenous feeding. Young fish grow to 74 mm 45 days after hatching (Deng 2000). Juveniles averaged 29 mm at the peak of occurrence in June-July at the RBDD trap and 36 mm at their peak abundance in July at the GCID trap (Fig. 16). These growth rates are consistent with rapid juvenile growth to 300 mm in one year, and to over 600 mm within 2-3 years for the Klamath River (Nakamoto et al. 1995). Juveniles appear to spend one to three years in freshwater before they enter the ocean (Nakamoto et al. 1995).

Ocean Residence

Green sturgeon disperse widely in the ocean after their out-migration from freshwater and before their return spawning migration into freshwater (Moyle et al. 1992). Tagged fish from the Sacramento River are primarily captured to the north in coastal and estuarine waters (Fig 1); of the 15 tagged green sturgeon recaptured outside of San Francisco Bay, 13 were recovered to the north (CDFG 2002). Tagged fish from the Columbia River also moved to the north; of the 28 tag recoveries from the Lower Columbia River, 23 were from north of the Columbia River (Fig. 1), ranging up into British Columbia (WDFW 2002a). While there is some bias associated with recovery through commercial fishing, the idea of a northern migration is also supported by the large concentrations of green sturgeon entering in the Columbia River estuary, Willapa Bay, and Grays Harbor, peaking in August. These fish tend to be immature, however mature fish and at least one ripe fish have been found in the lower Columbia River (WDFW 2002a). Genetic evidence may suggest that Columbia River green sturgeon are a mixture of fish from the Sacramento, Klamath, and Rogue Rivers (Israel et al. 2002). The reasons for concentrations in Oregon and Washington estuaries during the summer are unknown as there is no spawning in these rivers and all stomachs examined to date have been empty (Beamesderfer 2000). Green sturgeon return to the Klamath River beginning at age 15 for males and 17 for females.

Age and Growth

Green sturgeon are a long-lived, slow-growing species as are all of the sturgeons (Nakamoto et al. 1995, Farr et al. 2002). There are three age studies; two from the Columbia River and one from the Klamath River. The two studies from the Columbia River are from reading fin-spine sections (Farr et al. 2002) and tag recaptures (Rien 2002a). The Klamath River study is from reading fin-spine sections. Ages are read from fin-spine sections; however, there are several reasons to be skeptical of the assigned ages. Age estimates are based on a limited number of individuals and the technique has not been validated for green sturgeon. In addition, there are substantial differences between the different published fin-spine studies (Fig.2). Finally, white sturgeon age validation studies have found this technique to be neither accurate nor precise (ODFW 2002). The potential exists to validate growth measurements using captive fish, but captive fish most likely grow at a much higher rate than those in the wild.

Size-at-age is consistently smaller for the Klamath River fish (Nakamoto et al. 1995) compared to the Oregon fish until around age 25 thereafter the reverse is true (Fig. 2). This could be the result of actual differences in growth, or in aging techniques. The asymptotic length, L_4, for Klamath River fish of 218 cm is close to the maximum observed size of 230 cm reported by Moyle et al. (1992), but substantially larger than for Oregon fish (Females 182 cm, Males 168 cm).

Feeding

Little is known about green sturgeon feeding other than general information. Adults captured in the Sacramento-San Joaquin delta are benthic feeders on invertebrates including shrimp, mollusks, amphipods, and even small fish (Houston 1988, Moyle et al. 1992). One 100 cm green sturgeon from the Sacramento-San Joaquin estuary was examined in Fall 2001 and opisthobranch mollusks (*Philline* sp.) were the most common prey, but there was also one bay shrimp (*Crangon* sp.) and overbite clams (*Potamocorbula amurensis*). Juveniles in the Sacramento River delta feed on opossum shrimp, *Neomysis mercedis*, and *Corophium* amphipods (Radtke 1966).

INFORMATION RELATING TO THE "SPECIES" QUESTION

Green sturgeon that occur within United States and Canadian waters are a geographically isolated and genetically distinct species. The species was first described as *Acipenser medirostris* by Ayres (1854) from San Francisco Bay. The North American form was considered conspecific with a previously described Asian species Sakhalin sturgeon, *A. mikadoi*, and the two forms were synonymized (Berg 1948). More recent molecular data on three mitochondrial genes show large differences between the North American and Asian forms (Birstein and DeSalle 1998), and these two forms are now considered separate species. Morphometric data shows differences between the two forms with the snout of the Asia form being longer (North et al. In Press). Other morphometric and meristic data between the two forms are similar. Both Green and Sakhalin sturgeon occur in coastal waters and in estuaries. The only documented Sakhalin sturgeon spawning population occurs in the Tumnin River, Russia, which has a hatchery.

Preliminary green sturgeon population genetic results suggest that fish from the Klamath River are distinct from fish from San Pablo Bay (Israel et al. 2002). These data are from a preliminary report prepared for consideration of the listing petition, and are not final. Therefore, the results should be considered suggestive, but not conclusive. Data were analyzed from 66 green sturgeon sampled from the Klamath River in 1998, 46 fish from San Pablo Bay in 2001, 15 from the Rogue River in 2000, and 29 from the Columbia River estuary in 1995. These are small numbers of fish and more samples are available, raising the possibility of different results when the complete set of samples are analyzed. Four microsatellite loci were amplified for analysis of allele frequencies; three of these loci were tetrasomic and therefore do not permit standard genetic analysis. The Klamath River samples had unique alleles at the *Ame 1* locus (272 bp) and the *Ame 12* locus (221 bp) (Figs. 3 and 6). For the *Ame 6* locus, the most common allele for the San Pablo Bay samples was at 240 bp (freq = 0.512), which was rare in the other samples (Fig 4). Other alleles also showed lesser degrees of different frequencies (Fig 5).

The preliminary genetic results also suggests that Klamath and Rogue River samples are similar to each other. The allele frequencies at *Ame 1* appear to be similar and were most frequent at 274 bp which was much less frequent in the San Pablo Bay samples (Fig. 3). For *Ame 11* locus, five of the six most common alleles (183 bp, 187 bp, 191 bp, 199 bp, and 207 bp) are in similar rank order of frequency, only allele 195 bp is an exception (Fig. 5). Other loci appear to be in similar levels of frequency (Figs. 3, 4, and 6).

The Columbia River samples appear to be a mixture of other populations (Figs. 3-6). However, unique alleles were found at low frequencies at *Ame 1* (380 bp) and at *Ame 11* (171 and 235 bp). Israel et al. (2002) suggests this indicates spawning populations from some unknown location, but these alleles may be found from larger samples sizes in known locations, or they could be an artifact of the differences in years of collection.

DISCUSSION AND CONCLUSIONS ON THE "SPECIES" QUESTION

North American green sturgeon are clearly a species under the ESA. The North American species, *A. medirostris*, is clearly a separate species from the western Pacific Tumnin River population, *A. mikadoi*, due to the lower chromosome number (Birstein et al. 1993).

Distinct Population Segments

The BRT concluded that green sturgeon have at least two DPSs; a northern DPS extending north from and including the Eel River and a southern DPS beginning south of the Eel River. The only known populations in the southern DPS would be in the upper Sacramento river. This decision is based on: 1) sturgeons generally show fidelity to their spawning sites so they have a general pattern of multiple DPSs, and 2) the preliminary genetic evidence indicates that there are differences at least between the Klamath and San Pablo Bay populations. This meets the requirement for both discreteness and significance in the DPS policy (USFWS and NMFS 1996). These population segment may be considered discrete due their being markedly separated as evidenced by quantitative genetic measures. These population segments may be considered significant also due to differences in their genetic characteristics. The BRT=s decision to recognize two DPSs simply means that it was confident of at least those two DPSs, but there may well be additional ones identified when more information is available. The Eel River boundary between the two DPSs is somewhat subjective and may be modified when there is further evidence.

Sturgeon are known to have strong homing capabilities and this leads to high spawning site fidelity (Bemis and Kynard 1997). Large numbers of genetically separated races or morphs within species is a common pattern for the family Acipenseridae (Wirgin et al. 1997). The trend of sturgeon homing to individual rivers is so strong that river by river analysis is common in sturgeon ESA recovery plans. This general pattern in sturgeon population genetics led the BRT to postulate that green sturgeon would have multiple DPSs

Preliminary genetic evidence (Israel et al. 2002) suggests differences between the Klamath River and San Pablo Bay fishes, and this evidence plus the general pattern of sturgeon population units led the BRT to conclude that there were at least two DPSs. However, there are several reasons why the genetic conclusions should be viewed cautiously. First, sample sizes are small because the research is in its initial stages. The results will have more authority when all the samples are analyzed. Second, there is the problem of green sturgeon summer concentrations in estuaries. There is no assurance that the green sturgeon samples from San Pablo Bay are fish that would spawn there. The Klamath River fish were ripe and thus in spawning condition and are clearly part of that river=s spawning population. The best samples for this type of genetic work would be from outmigranting juveniles which are known to be part of the spawning population. Finally, it is unclear why the Klamath River fish had unique alleles. If this is the largest spawning population, then logically Columbia River fish should be predominantly fish derived from the Klamath River spawning population plus fewer fish from the Sacramento River. The most likely explanation is that Columbia River sample sizes were not sufficient to detect all the alleles from the Klamath River. A fully developed genetic study is the most urgent need for green sturgeon conservation.

ASSESSMENT OF EXTINCTION RISK

Harvest

Green sturgeon harvest is all bycatch in two fisheries. The smaller portion of the bycatch results from the Klamath Tribal and other Tribal salmon gill-net fisheries. The larger portion is bycatch from white sturgeon commercial and sport fisheries. Large commercial fisheries developed in the late 1800's for previously unexploited white sturgeon, and these fisheries collapsed because fishing mortality far exceeded sustainability (Galbreath 1985). The excessive white sturgeon fishing mortality must have caused an accompanying decline in green sturgeon, however the degree of green sturgeon decline is uncertain. One argument is that the green sturgeon decline was much less than for white sturgeon because green sturgeon reside for extended periods in the marine environment and therefore are less available to the fishery.

The total annual harvest of green sturgeon declined substantially to 1,192 fish in 1999-2001 from 6,871 in1985-1989 (Table 1). Most of the harvest has been taken in the Columbia River (51%) and Washington coastal fisheries (28%). The rest of the harvest came from the Oregon fishery (8%) and the California Tribal fishery (8%). In recent years, Columbia River and Washington coastal fisheries have been substantially reduced, and in 2001, Columbia River, Washington, and Klamath Tribal fisheries were approximately equal in numbers of fish taken.

Columbia River green sturgeon harvest has accounted for more than half of the total harvest for the period from 1985 to 2001 (Table 1), but the harvest has been declining in recent years. Columbia River harvest prior to 1985 was at least as large as current catches (Fig. 7). Much of the harvest reduction in recent years is due to increasingly restrictive Columbia River fishing regulations (Appendix 1). Both white and green sturgeon have been co-managed by the states of Washington and Oregon since the federally mandated Columbia River Compact (1918). The Columbia River fishery is currently managed through a joint Washington and Oregon accord to manage white sturgeon. Probably the most important regulation was the introduction of slot limits starting in 1950 for both the sport and commercial fishery. For the sport fishery, the slot limits currently prohibit retention of fish less than 42 inches and greater than 60 inches for both green and white sturgeon and 48-66 inches for green sturgeon in the commercial fishery. Average length of Columbia River commercially-caught green sturgeon has been increasing since 1990 (Fig. 8), and the largest average sizes have been in the last five years. Fish in the larger length classes have been an increasing proportion of the catch. Although the sample sizes are small, the data are suggestive of a strong year-class moving through the fishery.

Washington state has the next largest green sturgeon harvest (Table 1). Overall, Washington state harvest accounted for 28% over the period 1985 to 2001, and that percentage has declined in recent years. The largest component of the commercial fishery has been Willapa

Bay followed by Grays Harbor. There appears to be a general decline in green sturgeon landings relative to the total (green and white) sturgeon effort (deliveries or trips) even after accounting for decline due to reduced seasons, size and gear restrictions, and fleet reduction (WDFW 2002a).

Oregon commercial and sport fisheries accounted for about 8% of the green sturgeon harvest (Table 1), with approximately equal portions of sport and commercial. Harvest has declined substantially in the last few years. ODFW chartered a trawler with expertise in green sturgeon ocean fisheries and found that the change of the commercial upper slot limit from 72 to 66 inches reduced landed poundage by one-half (King 2000).

The California Klamath Tribal fishery has also accounted for approximately 8% of green sturgeon harvest (Table 1). This fishery is especially important because the Klamath is thought to have most of the green sturgeon spawning population. Harvest averaged 266 fish annually with no apparent trend from 1985 to 2001 (Fig. 9). There were two years of extremely high catches in 1980-81 averaging 765 fish. Green sturgeon catch is incidental to the chinook gill-net fishery by the Yurok and Hoopa Tribes on the lower portions of the Klamath and Trinity Rivers. The green sturgeon catch is monitored but there is no direct regulation of the fishery for green sturgeon. The portion of green sturgeon over 175 cm TL remained unchanged from 1984 until 2001 (Fig. 10). Larger fish are increasing in proportion to the total catch in recent years.

California sport catch of green sturgeon, primarily in San Pablo Bay, is not monitored, but is thought to be only a few fish each year. There is no differentiation between green and white sturgeon in the regulations and the current slot limits are 117 cm to 183 cm (46 to 72 inches).

It is difficult to evaluate the impact of harvest on green sturgeon. No estimates of fishing mortality or exploitation rates exist for green sturgeon, although Beamesderfer and Webb (2002) examined preliminary age data for the Klamath River and suggested that annual survival was about 85%. Secor et al. (2002) note that sturgeon populations can be harvested on a sustainable basis, but only if sufficient spawner escapement is maintained. They suggest that sturgeon populations typically cannot tolerate more than 5% fishing mortality during spawning runs. Similar rates of annual survival (S) have been assumed in population models for adult Gulf sturgeon in the Suwannee River, Florida (S=0.84, maximum age 25; Pine et al. 2001) and age-1+ shortnose sturgeon (S=0.865, max age 37; Gross et al. 2002). Higher survival rates were assumed in models for Hudson River Atlantic sturgeon (S=0.93, max age 60; Gross et al. 2002) and lower Columbia River white sturgeon (S=0.91, max age 100; Gross et al. 2002). Fishing mortality rates for green sturgeon would be affected by several slot limit regulations that mostly confine harvest to subadults. In terms of population impacts, however, it is worth noting that sturgeon populations can be substantially affected by harvest of subadults, because of the long interval prior to maturity (Gross et al. 2002; Secor et al. 2002).

One way to judge the impact of fishing is to examine age structure and consider how many opportunities an adult sturgeon would have to spawn. This is particularly critical for sturgeon species, given that strong year classes occur infrequently and adults may only spawn every 3-5 years. Based on preliminary age data (Beamesderfer and Webb 2002), female green sturgeon in 1999-2000 Klamath River catches ranged in age from 17 to 33 although most were 25-31. Using the Beamesderfer and Webb (2002) female maturity of age 20 and their 5 year spawning periodicity, most female green sturgeon would only spawn twice. In comparison, a restoration goal for Atlantic sturgeon (NMFS 1998) is to have at least 20 adult age classes in the spawning stock prior to any consideration of lifting the current harvest moratorium.

Population Abundance

The only non-harvest green sturgeon population estimate is made incidentally to monitoring of white sturgeon in San Pablo Bay (CDFG 2002). Legal-size green sturgeon population abundance shows no long-term trend with an upturn in 2001 (Fig. 11, Table 2). These estimates are calculated from a multiple-census or Peterson mark-recapture estimate of legal-size white sturgeon taken by trammel nets. Tagging experiments have been conducted irregularly since 1954, but since 1990, tagging has been conducted for two years consecutively and then the next two are skipped. Over this period, a total of 536 green sturgeon were captured and 233 were tagged. The green sturgeon estimate is obtained by multiplying the ratio of legal-size (earlier minimum slot limits of 102 cm) green sturgeon to legal-size white sturgeon caught in the tagging program by the legal-size white sturgeon population estimate. There are a number of problems with this estimate; the most important being the assumption of equal vulnerability of both species to the gear. That green sturgeon concentrate in estuaries only during summer as opposed to white sturgeon which remaining in estuaries year around means that the temporal and spatial vulnerabilities of the two species are different. It is interesting to note that no tagged green sturgeon have been recaptured in trammel nets. The legal-size green sturgeon to white sturgeon ratios (only sturgeon of legal size, $102 cm, are tagged) shows no apparent trend over time but both increased in 2001 (Table 2). The $102 cm size class numbers and ratio in 2001 are the highest of any year. The sublegal size green to white sturgeon ratios are consistently larger than the legal-size ratios (11 of 13 years, Table 2) meaning that there are more small green sturgeon relative to white sturgeon than when they are larger. Average size of green sturgeon tagged has no apparent trend (Fig. 12), but sample sizes are very small.

Musick et al. (2000) state that green sturgeon has suffered Aan 88% decline in most of their range.@ Further elaboration of this statement was obtained from D. Ha, one of the authors, AThe abundance of all west coast sturgeons, including green, suffered approximately an 88% decline in California, inferred from commercial catch rates (Cech 1992).@ The only statistics in the Cech (1992) article are the reduction of all commercial sturgeon landed (white and green) from 1.63 million pounds in 1887 to 0.2 million pounds in 1901 which is an 88% reduction. If these statistics are the basis of the 88% decline reported in Musick et al (2000), these 100 year-old data have no relevance to current status of green sturgeon.

Juvenile Abundance

Juvenile green sturgeon are taken from two sites on the Sacramento River by trapping. Rotary screw trapping was conducted below RBDD (rkm 391) from July 1995 through July 2000. At the GCID (rkm 330), a fyke net was used for sampling only during June-August before

1991. In 1991 and after, a rotary screw trap was used to sample year-around, although no sampling was done 1998. All juvenile sturgeons are assumed to be green sturgeon based upon grow-out experiments described earlier.

The annual catch of juvenile green sturgeon in the traps ranges from 0 to 2,068 with no similarity between RBDD and GCID (Fig. 13) nor any trends through time. The seasonal trend shows a peak between June and July at RBDD and a July peak at GCID (Fig.14). Juvenile appearance starts in May and ends in August. Fish caught after August are largely from the GCID trap and included four to five adults and similar numbers of juveniles. Average monthly size does not change through the season, but is always greater at the GCID than at the RBDD (Fig. 15).

Population Time Series

Three green sturgeon population time series were selected for analysis by the BRT because of their length, their relative lack of bias, and their geographical importance. These were the Klamath Yurok tribal fishery catch-per-unit-effort (CPUE) series, the San Pablo Bay estimate based on white sturgeon tagging, and Columbia River commercial landings. All green sturgeon population time series are fisheries-dependent or derived from sampling that targeted other species. The raw catch time series suffers from changing regulations and effort levels. Also, green sturgeon are not an abundant species, and therefore the numbers are small and variable with a large number of zero observations. Simple linear regressions were calculated for each time series providing a slope with a standard error and confidence intervals.

The Klamath Yurok Tribal fishery catch and CPUE are the most consistent green sturgeon data sets. Catch and CPUE data are available since 1984 and it is the time series least impacted by changes in regulations. Analyses were performed on $\log_e$-transformed catch and CPUE from April and May. This time period was considered to be the most representative of the numbers of green sturgeon in the river. The $\log_e$-transformed catch had an increasing slope (r^2 = 0.115, slope = 0.031, SE of slope = 0.021, p = 0.168, Fig. 16), but was only significant at 0.168 probability level. The regression analysis for CPUE showed no significant trend (r^2 = 0.019, slope = -0.0008, SE of slope= 0.0014, p = 0.591, Figure 17) and was also not significant. Log_e transformed catch and CPUE were not well correlated (r^2 = 0.402, p=0.098). Length-frequency data over this time period showed no trends (Fig 10).

The San Pablo Bay green sturgeon population estimate is the only research oriented measure of abundance; however it depends on tag recoveries from the sport fishery and therefore suffers from varying levels of effort. The regression analysis of green sturgeon abundance suggested an increasing trend, but again the slope was not significant (r^2 = 0.146, slope = 0.029, SE of slope = 0.020, p = 0.177, Fig. 18) even with the very high 2001 estimate of 8,421 fish which is nearly three-fold higher than any previous annual estimate.

The Columbia River commercial landing is the longest green sturgeon time-series available and represents the largest source of removals from the population (Fig 7). Landings were recorded in pounds in early years, but catch in numbers were estimated by ODFW. Fishery regulations drastically changed in 1993, so the analysis was only conducted until 1992. Catch in numbers is not only affected by effort and size regulations, but also by the degree to which green sturgeon concentrate in estuaries during the summer which is controlled by unknown factors. The regression analysis of $\log_e$-transformed catch in numbers on years did not have a significant slope ($r^2 = 0.082$, slope = 0.020, SD of slope = 0.012, $p = 0.188$, Fig 19). Length-frequency distribution of catch from 1985 to 2001 shows no trend (Fig. 8). Rien (2002b) analyzed Lower Columbia River commercial CPUE (log (green sturgeon landing+1)/total sturgeon daily landing tickets)) over the same 1981-1993 time period and found a significant positive trend (r^2=0.083, slope=0.022, p<0.0001).

Entrainment

Substantial numbers of green sturgeon have been taken in pumping operations at state and federal water export facilities in the Sacramento Delta (Table 3), and these numbers are higher in the period prior to 1986 than from 1986 to the present. For the state facility (1968-2001), the average number of green sturgeon taken per year prior to 1986 was 732; while from 1986 on the average number was 47. For the federal facility (1980-2001), the average number prior to 1986 was 889; while from 1986 on, the average was 32. In 1974, 7,313 green sturgeon were taken at the state facility, and this was also the year when the highest ratio of sublegals to legal-size green sturgeon ratio was the highest (1.661) in the San Pablo Bay trammel net sampling (Table 2). However, it should be noted that the green sturgeon taken in the trammel nets are significantly larger (70 cm vs 40 cm) than are those taken at the pumps. When the data are adjusted for volume of water pumped (per 1,000 acre-feet), trends were similar. Green sturgeon taken in both water export facilities are juvenile fish in the 28 to 38 cm FL size range (Fig. 20), based on a very limited data (n = 86 and 41). These entrainment estimates suffer from problems of species identification (green sturgeon were not identified until 1981 at the federal facility), and the estimates are expanded catches from brief sampling periods (CDFG 2002).

DISCUSSION AND CONCLUSION ON RISK ANALYSIS

The ESA (section 3) defines the term "endangered species" as "any species which is in danger of extinction throughout all or a significant portion of its range." The term "threatened species" is defined as "any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range." According to the ESA, the determination of whether a species is threatened or endangered should be made on the basis of the best scientific and commercial information available regarding its current status, after taking into consideration conservation measures that are proposed or in place. This review is the scientific one and conservation measures will be taken into consideration with the final listing decision.

Green sturgeon do not have adequate population abundance or trend data to assess their population status. Due to this, the potential threats from risk factors to the populations take on greater consideration under the assumption that a population facing a greater amount of threat has a larger risk of extinction than one that faces a smaller amount of threat. In fact, the lack of population trend information itself is a significant potential threat due to the resulting uncertainty about the proper listing status. The BRT concluded that an immediate effort toward population monitoring was essential, with perhaps out-migrant trapping being the best approach. In addition, green sturgeon are harvested from a mixture of both DPSs. Since it is unknown to what extent either DPS is part of Columbia River and Washington Coast summer concentrations and their associated fisheries, it is impossible to differentiate the harvest impact between the two DPS.

Northern Green Sturgeon Distinct Population Segment

A majority of the BRT concluded that there is not sufficient information that shows green sturgeon in this DPS are in danger of extinction or would be likely to become so in the foreseeable future. A minority of the BRT concluded that green sturgeon in this DPS are not currently in danger of extinction but are likely to become so in the foreseeable future. The BRT felt that green sturgeon in this DPS faced significant threats to their population and they should be placed on the Candidates list and their status reviewed within five years.

Northern green sturgeon population information from this DPS showed no negative trends, but also these trends were not statistically significant. The BRT judged the Klamath River data to be the most representative available population measure since the data were based on spawning fish rather than on fish involved in their summer concentration behavior. Both catch and CPUE did not have a negative slope, but neither trend was significant either. The length data did not indicate that large fish were decreasing within the population, but sample sizes were very small.

Green sturgeon populations in this DPS face a large number of potential threats including concentration of spawning, lack of population data, harvest concerns, and loss of spawning habitat. The Klamath is thought to contain most of the total spawning population of green sturgeon; however, this is not well documented. This concentration of the spawning population increases this species' vulnerability to possible catastrophic events. Lack of population data left the BRT unable to determine the status of this species, and this situation raised concerns about how close green sturgeon populations are to critical thresholds. The BRT could find no way to assess the harvest impacts on green sturgeon. The slightly positive non-significant trend in Columbia River commercial landings and CPUE were impossible to interpret in the context of the non-targeted fishery interacting with green sturgeon's summer concentration behavior. Population trends cannot be evaluated reliably until much more is known about the summer concentrations within coastal rivers and estuaries, in terms of population structure (i.e., the mixture of populations or DPSs) and impacts of harvest. Finally, green sturgeon has faced loss of spawning habitat in the South Fork Trinity River.

Southern Green Sturgeon Distinct Population Segment

A majority of the BRT concluded that there is not sufficient information that shows green sturgeon in this DPS are in danger of extinction or would be likely to become so in the foreseeable future. However, the level of concern about green sturgeon in this DPS is higher than in the northern DPS. A minority of the BRT concluded that green sturgeon in this DPS are not in danger of extinction but are likely to become so in the foreseeable future. The BRT unanimously felt that green sturgeon in this DPS faced significant threat to their population. There should be some attempt to address these threats, particularly to begin population trend monitoring, and green sturgeon in this DPS should be placed on the Candidates list and their status reviewed within five years.

The southern green sturgeon DPS population trend information was even less definitive, and less convincing. The San Pablo Bay population estimates had a non-negative trend, but were not statistically significant. Their persuasiveness was reduced due to being based on summer concentrations of green sturgeon, a phenomena which is not understood, and to the unknown tag recovery effort used in the estimate. The year 2001 did have the largest number of legal-sized green sturgeon tagged of any year.

Green sturgeon populations in this DPS face an even larger number of potential threats than the northern DPS including concentration of spawning, smaller population size, lack of population data, potentially lethal temperature limits, harvest concerns, loss of spawning grounds, entrainment by water projects, and influence of toxic material and exotic species. In the southern DPS, spawning appears to be concentrated in the upper Sacramento River above RBDD. Catastrophic events have occurred in this DPS when a large-scale herbicide spill killed everything in a ten-mile stretch of river. Population sizes are unknown in this DPS, but are clearly much smaller than in the northern one and therefore more susceptible to catastrophic events. In this DPS, the total lack of population trend information is again a risk factor. Larval green sturgeon have been shown to have lethal limits near summer temperatures in this drainage. Temperature control efforts for winter-run chinook have probably been very beneficial here. Harvest concerns are the same for this DPS as they are for the northern one. Green sturgeon have probably lost an unknown amount of spawning habitat behind water projects in the Central Valley. More recently, they have had increased access to spawning grounds above RBDD beginning in 1986 which may have substantially increased their recent total spawning grounds. Green sturgeon in this DPS also face entrainment in pumps associated with the California water project. The entrainment numbers have decreased since 1985 for unknown reasons. Finally, green sturgeon in this DPS are probably subject to risks from pesticides and exotic species that are similar to those being investigated for winter-run chinook.

Citations

Ayres, W. O. 1854. Descriptions of three new species of sturgeon San Francisco. Proceedings of the California Academy of Natural Sciences 1: 14-15 (1854-1857).

Beamesderfer, R. C. 2000. Green sturgeon workshop, March 22-23, 2000, Weitchpec, CA . Oregon Department of Fish and Wildlife, Portland Oregon. Agenda and Notes. 13 p.

Beamesderfer, R. C. P., and M. A. H. Webb. 2002. Green sturgeon status review information. S. P. Cramer and Associates, Gresham, Oregon. 44p.

Bemis, W. E. and B. Canard. 1997. Sturgeon rivers: an introduction to acipenseriform biogeography and life history. Env. Biol. Fishes 48: 167-183.

Berg, L. S. 1948. Freshwater fishes of the U.S.S.R. and the adjacent countries. Vol I, fourth edition. Academy of Sciences of the U.S.S.R. Zoological Institute. Published for the National Science Foundation, Washington, D.C. by the Israel Program for Scientific Translations, Jerusalem 1962..

Birstein, V. J., A. I. Poletaev, and B. F. Goncharov. 1993. DNA content in Eurasian sturgeon species determined by flow cytometry. Cytometry 14(4): 377-383

Birstein, V. J. and R. DeSalle. 1998. Molecular phylogeny of Acipenserinae. Molecular Phylogentics and Evolution 9: 141-155.

California Department of Fish and Game. 2002. California Department of Fish and Game Comments to NMFS Regarding Green Sturgeon Listing. 129 p.

Cech, J. J. Jr. 1992. White Sturgeon. *In* California=s Living Marine Resources and Their Utilization. W. S. Leet, C. M. Dewees, and C. W. Haugen (ed.) California Sea Grant, Sea Grant Extension Publication UCSGEP-92-12. pp 70-72.

Cech, J. J. Jr., S. I. Doroshov, G. P. Moberg, B. P. May, R. G. Schaffter, and D. M. Kohlhorst. 2000. Biological assessment of green sturgeon in the Sacramento-San Joaquin watershed (phase 1). Final Report to the CALFED Bay-Delta Program. Project # 98-C-15, Contract #B-81738.

Deng, X. 2000. Artificial reproduction and early life stages of the green surgeon (*Acipenser medirostris*). Unpub. PhD thesis. University of California, Davis.

Emmett, R. L., Stone, S. L., Hinton, S. A., and Monaco, M. E. 1991. Distribution and abundance of fishes and invertebrates in west coast estuaries, Volume II: species life history summaries. 329 p.. Rockville, MD, Strategic Environmental Assessments Division.

Environmental Protection Information Center, Center for Biological Diversity, and Waterkeepers Northern California. 2001. Petition to list the North American green sturgeon (*Acipenser medirostris*) as an endangered or threatened species under the endangered species act. National Marine Fisheries Service.

Erickson, D. L., J. A. North, J. E. Hightower, J. Webb, and L. Lauck. 2001. Movement and Habitat use of green sturgeon *Acipenser medirostris* in the Rogue River, Oregon . Unpub. Draft. 24 p.

Farr, R. A., M. L. Hughes, and T. A. Rien. 2002. Green sturgeon population characteristics in Oregon. Annual Progress Report. Sport Fish Restoration Project F-178-R. 27 p.

Frank, B. Jr. 2002. Northwest Indian Fisheries Commission unpublished green sturgeon catch data.

Galbreath, J. L. 1985. Status, life history, and management of Columbia River white sturgeon, *Acipenser transmontanus*. P 119-125. in F. P. Binkowshi and S. I. Doroshov, editors. North American Sturgeons: Biology and Aquaculture Potential. Dr. W. Junk, publisher.

Gross, M. R., J. Repka, C. T. Robertson, D. H. Secor, and W. Van Winkle. 2002. Sturgeon conservation: insights from elasticity analysis. American Fisheries Society Symposium 28:13-30.

Healey, T. P. 1973. Studies of steelhead and salmon emigration in the Trinity River. Anadromous Fisheries Branch Administrative Report . 37: 1-70. California Department of Fish and Game.

Houston, J. J. 1988. Status of green sturgeon, *Acipenser medirostris,* in Canada. Canadian Field-Naturalist 102: 286-290.

Hillemeier, D. 2001. Yurok Tribe green sturgeon unpublished catch data. Yurok Tribe.

Israel, J., M. Blumberg, J. Cordes, and B. May. 2002. A preliminary report on the development and use of molecular genetic markers for North American green sturgeon (*Acipenser medirostris*). Unpub. Draft. 24 p. University of California, Davis.

King, S. 1998. Green sturgeon. Memo to Jim Greer (Director Oregon Department of Fish and Wildlife). 39 p.

King, S. 2000. Green sturgeon ocean fishery. Exhibit to Oregon Fish and Wildlife Commission. 8 p.

Lauman, J. E., K. E. Thompson, and J. D. Fortune, Jr. 1972 Fish and wildlife resources of the Umpqua basin, Oregon, and their water requirements. Prepared for Oregon State Water Resources Board. Environmental Investigations. 134 p.

Moyle, P. B., Foley, P. J., and Yoshiyama, R. M. 1992. Status of green sturgeon, *Acipenser medirostris*, in California. Final Report submitted to National Marine Fisheries Service. 11 p. University of California Davis.

Musick, J. A., Harbin, M. M., Berkeley, S. A., Burgess, G. H., Auckland, A. M., Lindley, L., Gilmore, R. G., Golden, J. T., Ha, D. S., Huntsman, G. R., McGovern, J. C., Parker, S. J., Poss, S. G., Sala, E., Schmidt, T. W., Sedberry, G. R., Weeks, H., and Wright, S. G. 2000. Marine, estuarine, and diadromous fish stocks at risk of extinction in North America (exclusive of Pacific salmonids). Fisheries 25: 6-30.

Nakamoto, R. J., Kisanuki, T. T., and Goldsmith, G. H. 1995. Age and growth of Klamath River green sturgeon (*Acipenser medirostris*). U.S. Fish and Wildlife Service. Project # 93-FP-13, 20 p. U.S. Fish and Wildlife Service.

National Marine Fisheries Service. 1998. Status review of Atlantic sturgeon (*Acipenser oxyrhynchus oxyrhynchus*). National Marine Fisheries Service, Gloucester, Massachusetts.

Neill, T., K. Melcher, and J. Whisler. 2000. The 1998 NEAP funded green sturgeon tagging project in Winchester Bay. 10 p. Oregon Department of Fish and Wildlife.

North, J. A., R. A. Farr, and P. Vescei. In Press. Meristic and morphological characters for North American and Asian forms of green sturgeon *Acipenser medirostris* with reference to white sturgeon *Acipenser transmontanus*. Proceedings of the 4th International Sturgeon Symposium in Oshkosh, Wisconsin, July 8-13, 2001. 19 p.

Oregon Department of Fish and Wildlife. 2002. NMFS Status Review for North American Green Sturgeon. ODFW Memorandum. 5 p.

Pine, W. E., III, M. S. Allen, and V. J. Dreitz. 2001. Population viability of the Gulf of Mexico sturgeon: inferences from capture-recapture and age-structured models. Transactions of the American Fisheries Society 130:1164-1174.

Puckett, L. K. 1976. Observations on the downstream migrations of anadromous fishes within the Eel River system. California Department of Fish and Game. Memorandum Report. 35 p. California Department of Fish and Game.

Radtke, L. D. 1966. Distribution of smelt, juvenile sturgeon, and starry flounder in the Sacramento-San Joaquin Delta with observations on food of sturgeon. In Turner, J. L. and D. W. Kelly (ed.) Ecological studies of the Sacramento-San Joaquin Estuary. Part II; California Department of Fish and Game, Fish Bulletin 136: 115-119.

Rien, T. A. 2002a. Green sturgeon growth from recapture data. Memorandum. Oregon Dept. of Fish and Wildlife. 6 pages.

____. 2002b. Lower Columbia River green sturgeon catch rates from commercial landings tickets. Memorandum. Oregon Dept. of Fish and Wildlife. 14 p.

Rien, T. A., L. C. Burner, R. A. Farr, M. D. Howell, and J. A. North. 2001. Green sturgeon population characteristics in Oregon. Annual Progress Report. Sportfish Restoration Project F-178-R. 41 p.

Secor, D. H., P. J. Anders, W. Van Winkle, and D. A. Dixon. 2002. Can we study sturgeons to extinction? What we do and don't know about the conservation of North American sturgeons. American Fisheries Society Symposium 28:3-10.

Tracy, C. 1990. Memorandum: Green sturgeon meeting and comments. State of Washington Department of Fisheries 10 p.

United States Fish and Wildlife Service. 1967. Endangered and Threatened Wildlife and Plants; Endangered Status for the Gulf Sturgeon. Federal Register 32 4001.

United States Fish and Wildlife Service. 1990. Endangered and Threatened Wildlife and Plants; Endangered Status for the Pallid Sturgeon. Federal Register 55(173) 36641 - 36647.

United States Fish and Wildlife Service. 1991. Endangered and Threatened Wildlife and Plants; Threatened Status for the Gulf Sturgeon. Federal Register 56(189) 49633 - 49658.

United States Fish and Wildlife Service. 1994. Endangered and Threatened Wildlife and Plants; Determination of Endangered Status for the Kootenai River Population of the White Sturgeon. Federal Register 56 (189) 49633 - 49658.

United States Fish and Wildlife Service. 1995. Sacramento-San Joaquin Delta Native Fishes Recovery Plan. U. S. Fish and Wildlife Service. Portland, OR. 208 p.

United States Fish and Wildlife Service. 2000. Endangered and Threatened Wildlife and Plants; Final Rule To List the Alabama Sturgeon as Endangered; Final Rule. Federal Register 65 26437-26461.

United States Fish and Wildlife Service and National Marine Fisheries Service. 1996. Policy regarding the recognition of distinct vertebrate population segments under the Endangered Species Act. Federal Register 51(26) 4722 - 4725.

Van Eenennaam, J. P. 2002. Personnel Communication.

Waples, R. S. 1991. Definition of ASpecies@ under the Endangered Species Act: Application to Pacific Salmon. U. S. Dep. Commer., NOAA Tech. Memo., NMFS, F/NWC-194, 29 p.

Washington Department of Fish and Wildlife. 2002a. Letter to Ms. Donna Darm. 24 p.

Washington Department of Fish and Wildlife. 2002b. Letter to Dr. Peter Adams. 3 p.

Wirgin, I.. I., J. E. Stabile, and J. R. Waldman. 1997. Molecular analysis in the conservation of sturgeons and paddlefish. Env. Biol. Fishes 48: 385-398

Appendix 1. Table 1. Lower Columbia River Commercial Fishery Regulations. (WDFW 2002a,b)

Year	Size Limits	Other Rules
1899	4' min.	Chinese gang lines prohibited (snagging setlines).
1899-1908	"	Sturgeon sales closed.
1909	"	Sturgeon sales allowed during salmon seasons.
1938	" "	Beacon Rock-Bonneville Dam sanctuary established.
1950	48" min.-72" max.	
1968	" "	Zone 6 became exclusive treaty Indian fishery.
1975-1982	" "	Setline seasons allowed outside of salmon seasons.
1983-1985	" "	Setline seasons phased out.
1983-1988	" "	Target sturgeon gill-net seasons (in-lieu of setlines).
1989	" "	Target sturgeon gill-net seasons eliminated.
1990-1992	" "	9-1/4" max. mesh restriction in late fall salmon seasons.
1991	" "	WA--adopted 2 lbs lead/fathom of leadline rule.
1992	" "	WA--adopted 60" max. length for fall seasons.
1993	48" min.-66" max.	9-1/4" max. mwsh adopted as permanent rule, sturgeon sales
		closed during last 2 weeks of fall salmon season (6,000 catch expectation for 1993 reached).
1994	" "	Catch ceiling of 6,000 for year, sturgeon sales closed after first day
		of fall salmon season.
1995-1996	" "	Annual catch ceiling of 8,000 during salmon seasons, of which not more than 6,800 (85%) may be taken in fall fisheries.
1997-1998	" "	Closed to retention Sept. 1-Dec. 31.
1996	" "	
1997-1998	48" min.-60" max. (whites)	Annual harvest guideline of 13,460 whites. Target sturgeon gillnet allowed. 9-3/4" max. mesh adopted.
	48" min.-66" max. (greens)	
1999	" "	Annual harvest guideline of 10,000 whites.
2000		Harvest guideline of 10,000 whites.
2001		Harvest guideline of 9,100 whites.

Appendix 1. Table 2. Lower Columbia River Sport Fishery Regulations. (WDFW 2002a,b)

Year	Daily Bag Limit	Size Limits	Other Rules
Pre-1940	None	None	None
1940	Only 3 <4'	"	"
1942	3 <4' and 2 ≥4'	"	"
1950	" "	30" min. - 72" max.	"
1951	3 fish	"	"
1957	"	"	Cannot remove head or tail in field.
1958	"	36" min. - 72" max.	
1986	2 fish	"	OR--sturgeon tag w/30 annual limit.
"	"		WA--no gaffing.
1989	"	"	WA--sturgeon tag w/15 annual limit.
"	"	40" min. - 72" max.	(Effective Apr. 1).
1990	"	"	Single-point barbless hooks.
"	"	"	OR--annual limit 15 and no gaffing.
1991	1 <48" and 1 ≥48"	"	
1992	"	"	WA--60" max. length (effective Apr. 16, 1992-Apr 15, 1993
"	"	"	WA--Beacon Rock-Bonn. Dam sanctuary (Apr. 16-June15, 1992).
1994	"	42" min.-66" max.	Annual limit 10.
1995	"	"	Closed to retention Sept. 1-Dec. 31.
1996	1 fish as of April 1.	"	Beacon Rock-Bonn. Dam sanctuary (closed to boat angling May and June).
1997-1998	1 fish.	42" min.-60" max.	53,840 white harvest guideline.
1999	"	"	40,000 white harvest guideline.
2000			Beacon Rock-Bonn. Dam sanctuary (closed to boat angling May 1-July 15). Annual limit 10 (WA and OR combined). 40,000 white harvest guideline.
2001			39,500 white harvest guideline.

Appendix 1. Table 3. California Sport and Commercial Sturgeon Fishing Regulations. The commercial fishery for all sturgeon has been legislatively closed since 1917. California regulations are not species specific (CDFG 2002).

Year	Daily Bag Limit	Size Limits	Other Rules
1901	0		Commercial fishery closed
1910			Commercial fishery reopened
1912	0		Commercial Fishery closed
1917	0		Legislative closure of sturgeon fishery, sport
1954	1/day	Min. TL 102 cm	Sport fishing only Legislatively reopened.
1956	1/day	Min. TL 122.5 cm	Sport only-no snagging
1958	1/day	Min. TL 102 cm	Sport only-no snagging
1972	1/day	Min. TL 102 cm	No gaffing undersized sturgeon
1978	1/day	Min. TL 102 cm	Closure April 1 through July 15 in Klamath River from the mouth of the Trinity to and including Ishi Pishi Falls. No use of firearms to dispatch sturgeon.
1980	1/day	Min. TL 102 cm	Central San Francisco Bay closure
1990	1/day	Min. TL107 cm Max. TL 183 cm	Sport only-no snagging Klamath River closure still applies
1991	1/day	Min. TL112 cm Max. TL 183 cm	Sport only-no snagging Klamath River closure still applies
1992	1/day	Min. TL 117 cm	Sport only-no snagging
1993	1/day	Min. TL 117cm Max. TL 183cm	All sturgeon fishing prohibited in Del Norte, Humboldt, Siskiyou and Trinity
1994	1/day	Min. TL 117 cm Max. TL 183 cm	From Mendocino County south, green sturgeon are subject to general sturgeon angling regulations.
2002	1/day	Min. TL 117cm Max. TL 183cm	No snagging. no gaffing or firearm usage. Previous closures of San Francisco Bay and northern counties still apply.

TABLES

Table 1. Harvest of green sturgeon (Numbers) from California, Oregon, and Washington from 1985 to 2001. See footnotes for data sources.

	California			Oregon[c]				Washington[d]								
		Klamath[b]				Columbia River[c]		Willapa Bay			Grays Harbor					
Year	SF Bay[a]	Yurok	Hoopa	Sport	Trawl	Sport	Comm.	Comm.	Sport	Treaty[e]	Comm.	Sport	Treaty[e]	Trawl	Other Treaty[e]	Total
1985	Few	320	10		726	533	1600	1289			227		5	348	67	5125
1986	Few	368	30	153	190	407	6000	925		1	626		3	142	167	9012
1987	Few	138	20	170	124	228	4900	877			770		8	52	349	7636
1988	Few	207	20	258	120	141	3300	1598	4		609		1	34	213	6505
1989	Few	268	30	202	210	84	1700	461			870		2	133	91	4051
1990	Few	239	20	157	143	86	2200	953			734		9	66	120	4727
1991	Few	309	11	366	242	22	3190	957			1527		3	99	59	6785
1992	Few	212	3	197	94	73	2160	1002			737		3	66	4	4551
1993	Few	417	36	293	250	15	2220	290	32		542	112	3	37	20	4267
1994	Few	293	6	160	154	132	240	268	13	6	17	25	22	5	1	1342
1995	Few	108	6	78	29	21	390	78	8		374	96	7	3	65	1263
1996	Few	119	8	210	182	63	610	129	24		137	70	132	1	7	1704
1997	Few	296	16	158	400	41	1614	16	4		316	105	198	6	19	3170
1998	Few	313	6	103	77	73	894	65	12	2	25	28	55			1653
1999	Few	193	25	73	21	93	967	9			0		58	4		1443
2000	Few	162	30	15	12	32	861	224	5		0	38	50			1429
2001	Few	268	10		17	50	264	106	9		0	27	32			783

[a]CDFG 2002
[b]USFWS 1992, Hillemeier 2001
[C]Farr et al. 2002
[d]WDFW 2002a,b
[e]Frank 2002

Table 2. White and green sturgeon numbers caught, ratios and abundance estimates by size limit category from CDFG white sturgeon tagging program. Green sturgeon abundances are estimated using the white sturgeon abundance and ratios of green to white sturgeon caught in tagging. (Data from CDFG 2002).

		$102 cm			<102 cm		White	Green
Year	White	Green	G/W	White	Green	G/W	Abundance	Abundance
1954	961	17	0.018	33	8	0.242	11200	198
1967	1612	26	0.016				114700	1850
1968	1080	28	0.026				40000	1037
1974	713	7	0.01	62	103	1.661	20700	203
1979	1368	26	0.019	62	9	0.145	100300	1906
1984	2551	24	0.009	148	7	0.047	117600	1106
1985	2419	19	0.008	68	47	0.691	107800	847
1987	982	6	0.006	42	5	0.119	97800	598
1990	701	15	0.021	273	5	0.018	75600	1618
1991	546	9	0.016	387	2	0.005	72700	1198
1993	534	2	0.004	271	3	0.011	46700	175
1994	593	0	0	231	11	0.048		
1997	1321	12	0.009	34	2	0.059	141900	1289
1998	1469	7	0.005	55	12	0.218	144400	688
2001	855	60	0.07	87	26	0.299	120000	8421

Table 3. Green sturgeon numbers and numbers per 1,000 acre-feet of water exported from the State and Federal water export facilities at the Sacramento Delta. Annual estimates are expansions of brief sampling periods. (Data from CDFG 2002).

Year	State Facility Numbers	State Facility Numbers per 1,000 Acre-feet	Federal Facility Numbers	Federal Facility Numbers per 1,000 Acre-feet
1968	12	0.0162		
1969	0	0		
1970	13	0.0254		
1971	168	0.2281		
1972	122	0.0798		
1973	140	0.1112		
1974	7313	3.9805		
1975	2885	1.2033		
1976	240	0.1787		
1977	14	0.0168		
1978	768	0.3482		
1979	423	0.1665		
1980	47	0.0217		
1981	411	0.1825	274	0.1278
1982	523	0.2005	570	0.2553
1983	1	0.0008	1475	0.653
1984	94	0.043	750	0.2881
1985	3	0.0011	1374	0.4917
1986	0	0	49	0.0189
1987	37	0.0168	91	0.0328
1988	50	0.0188	0	0
1989	0	0	0	0
1990	124	0.0514	0	0
1991	45	0.0265	0	0
1992	50	0.0332	114	0.0963
1993	27	0.0084	12	0.0045
1994	5	0.003	12	0.0068
1995	101	0.0478	60	0.0211
1996	40	0.0123	36	0.0139
1997	19	0.0075	60	0.0239
1998	136	0.0806	24	0.0115
1999	36	0.0133	24	0.0095
2000	30	0.008	0	0
2001	54	0.0233	24	0.0106

FIGURES

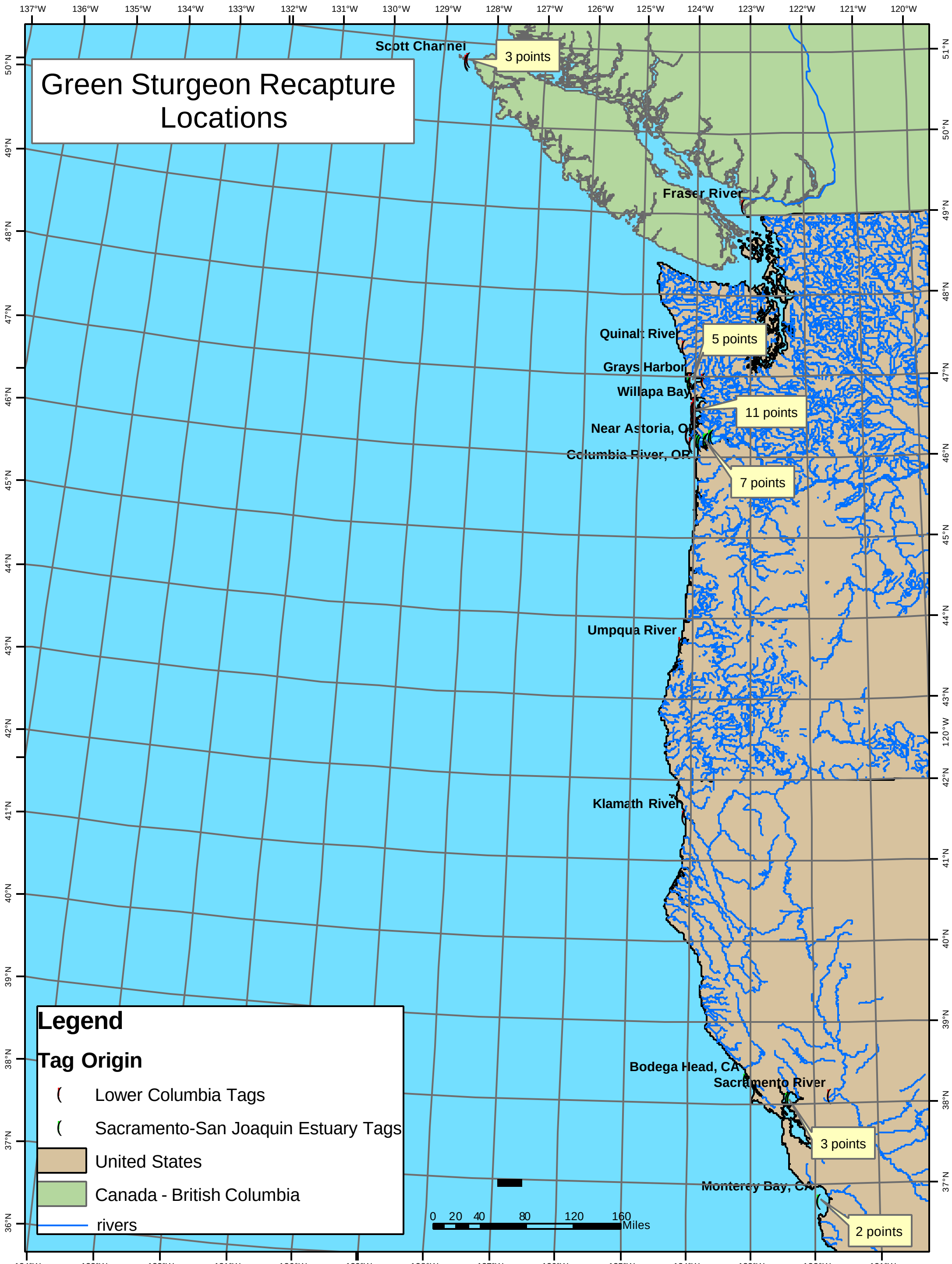


Figure 1. Location of green sturgeon tag recoveries from tagging studies in San Pablo Bay, California (red, Data from CDFG 2002) and Lower Columbia River (green, Data from WDFW 2002).

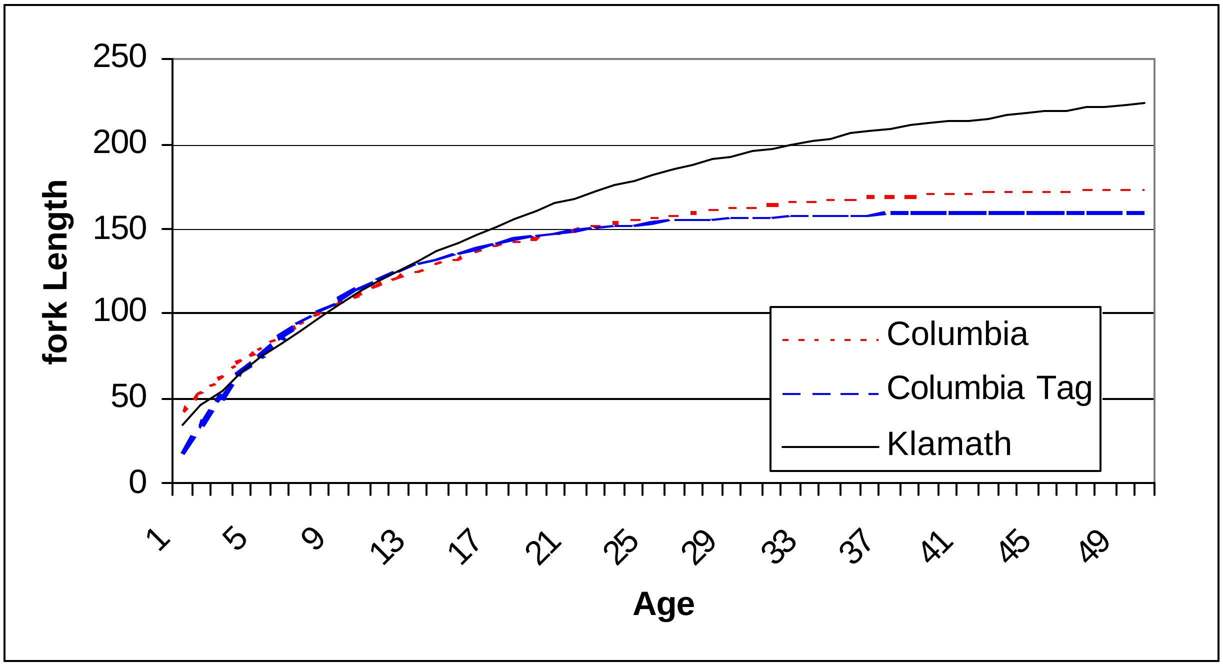
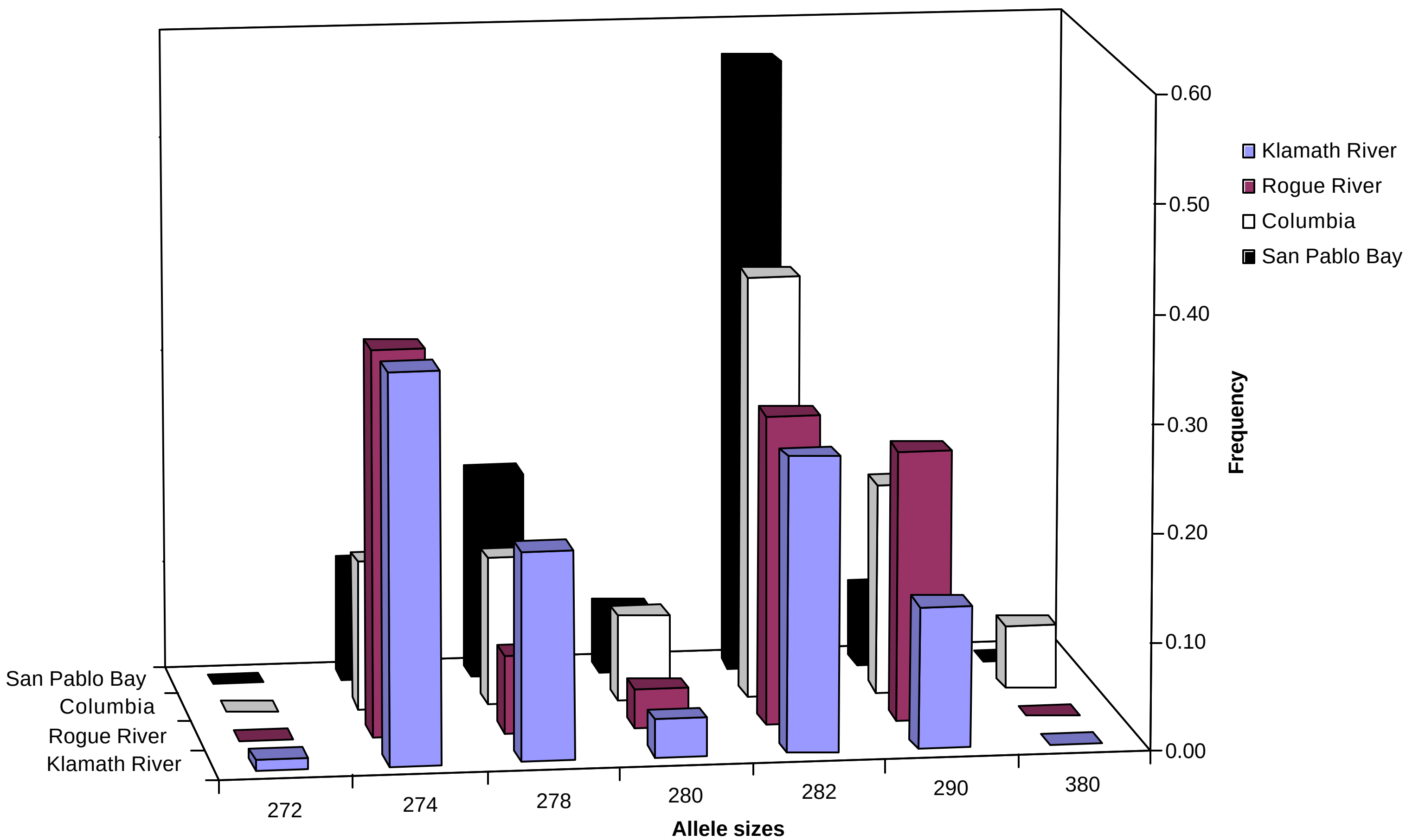


Figure 2. Green sturgeon von Bertalanffy growth curves from the Columbia River and the Klamath River sexs combined (Columbia, Farr et al. 2002; Columbia Tag, Rien 2002a, and Klamath, USFWS 1983, Nakatomo et al. 1995).



0.60
0.50
0.40
0.30
0.20
0.10
0.00
Frequency
Klamath River
Rogue River
Columbia
San Pablo Bay
San Pablo Bay
Columbia
Rogue River
Klamath River
272
274
278
280
282
290
380
Allele sizes

Figure 3. Ame 1 Allele Frequencies (from Israel et al. 20002).

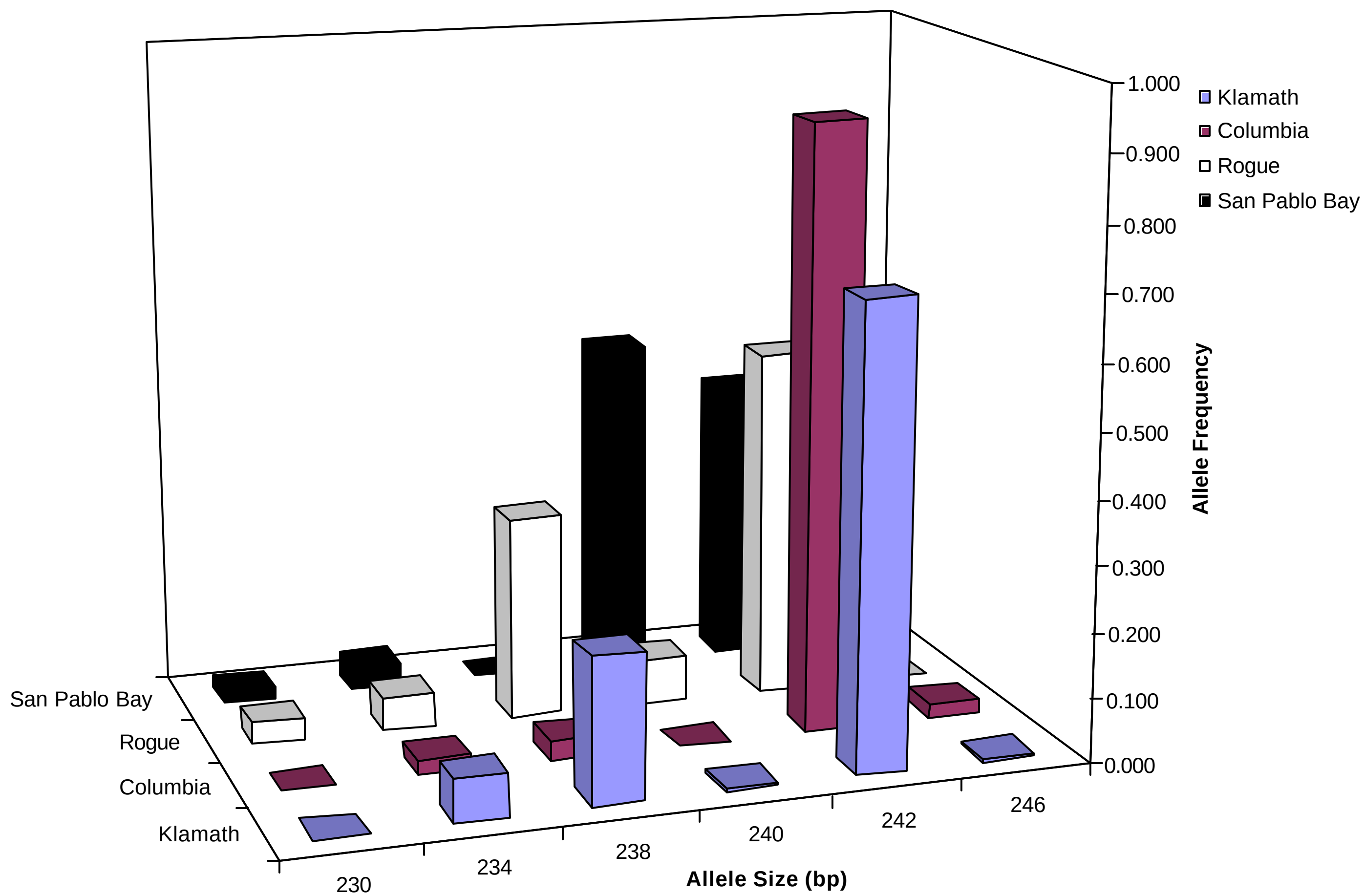


Figure 4. Ame 6 Allele Frequencies (from Israel et al. 2002).

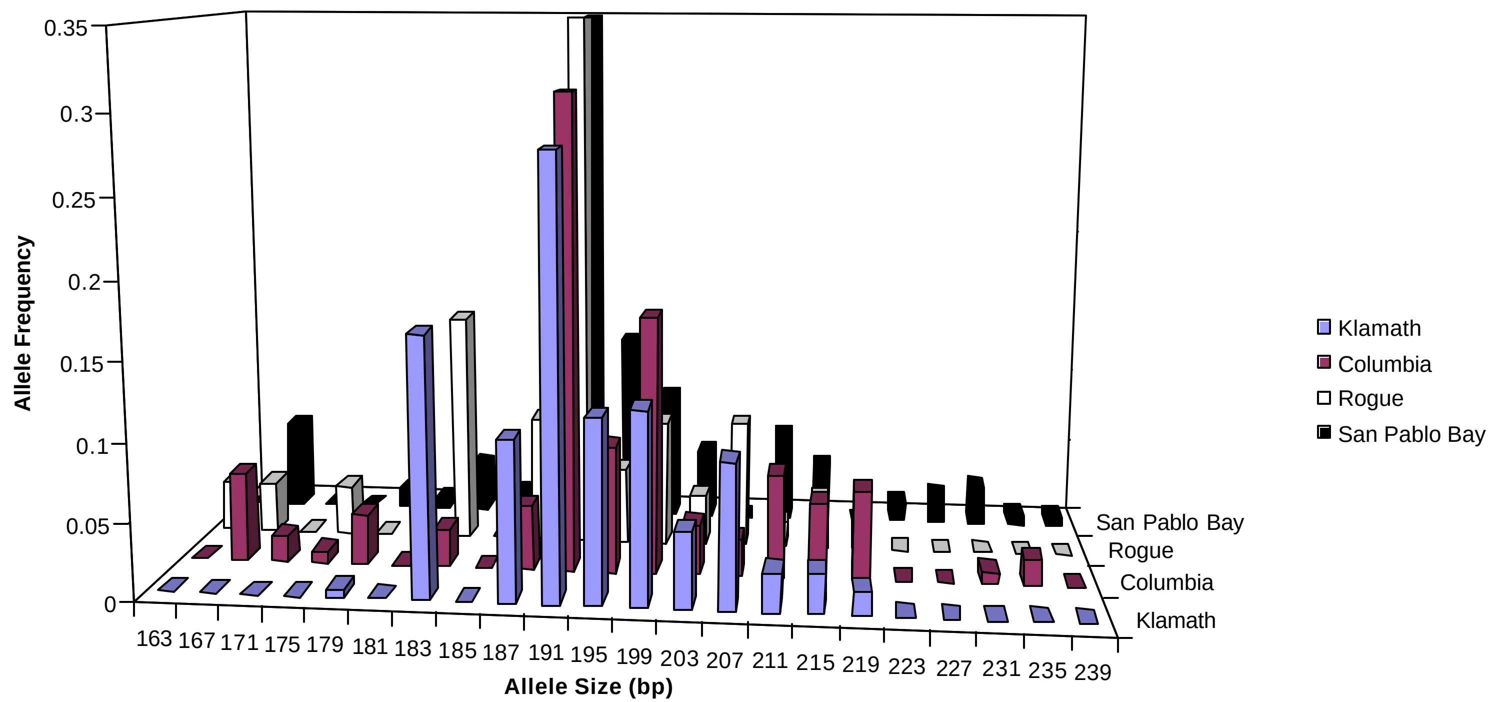


Figure 5. Ame 11 Allele Frequencies (from Israel et al. 2002)

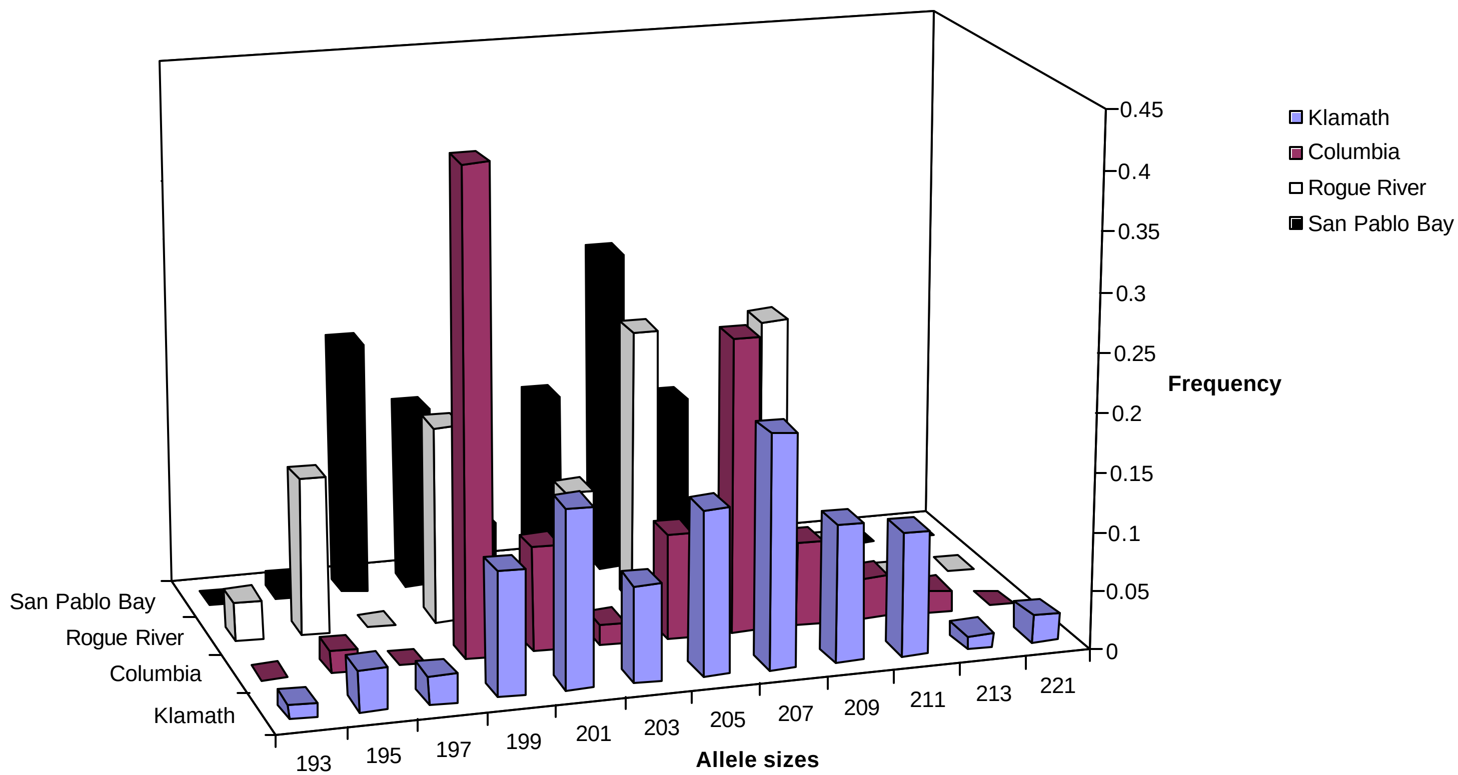


Figure 6. Ame 12 Allele Frequencies (from Israel et al. 2002).

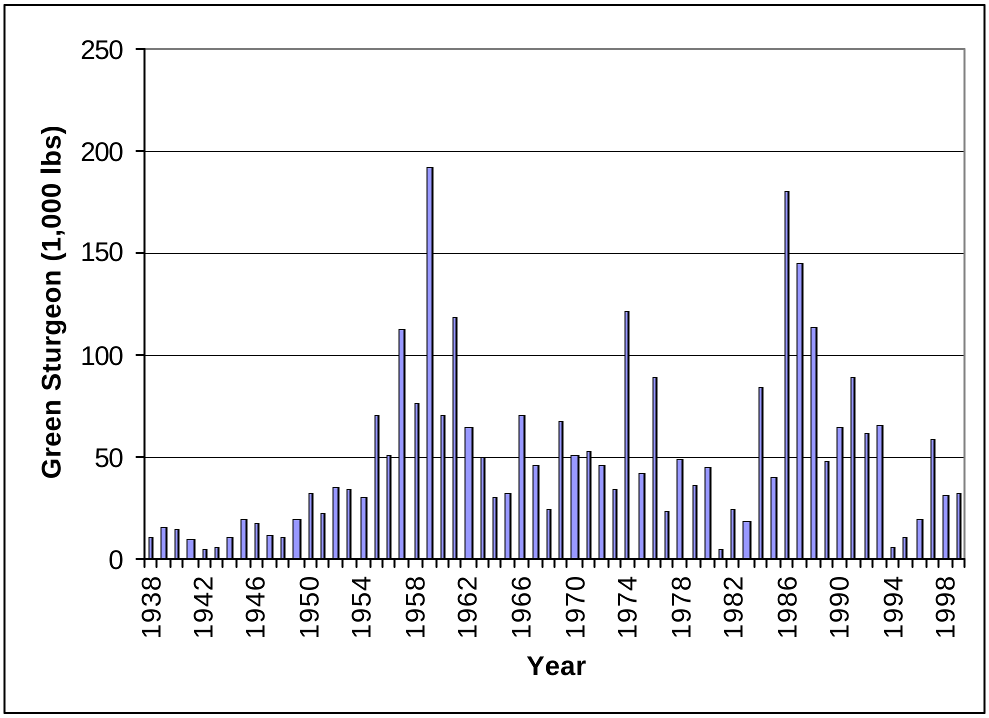


Figure 7. Columbia River green sturgeon harvest (1,000 lbs) from 1938 to 1999. (Data from ODFW and WDFW 2000).

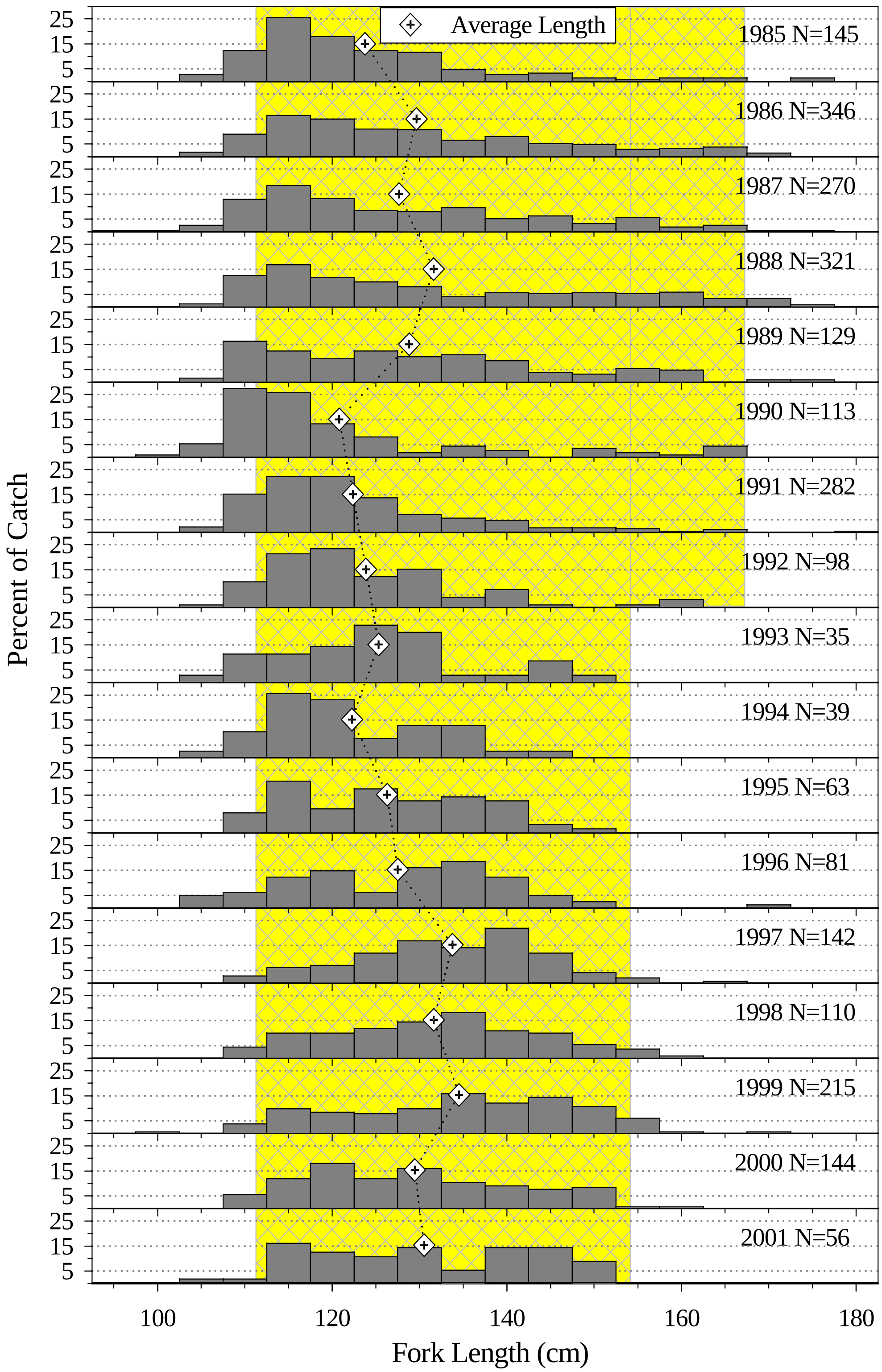


Figure 8. Length frequency and mean length of green sturgeon sampled in Lower Columbia River commercial fisheries, 1985-2001. Legal slot limit, based on conversion from total length (FL = TL/1.09), is indicated by background shading. (This is an updated figure based on Appendix Figure C-2 in Rien et al. 2001.)

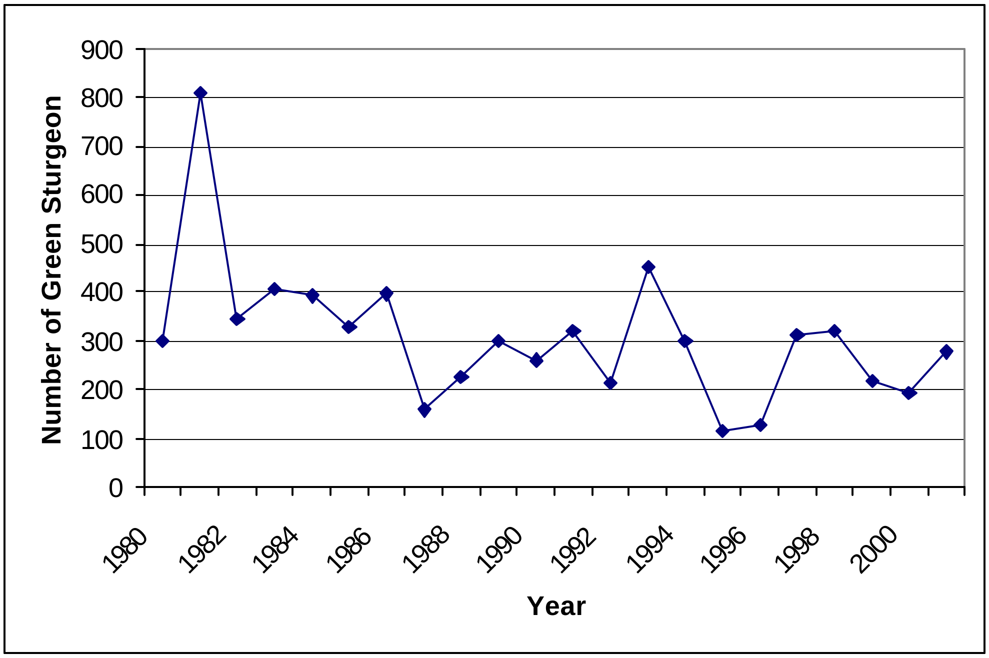


Figure 9. California Tribal harvest of green sturgeon from the salmon gill net fishery from 1980 to 2001. (Data from USFWS 1993-1998 and Hillemeyer pers. comm.)

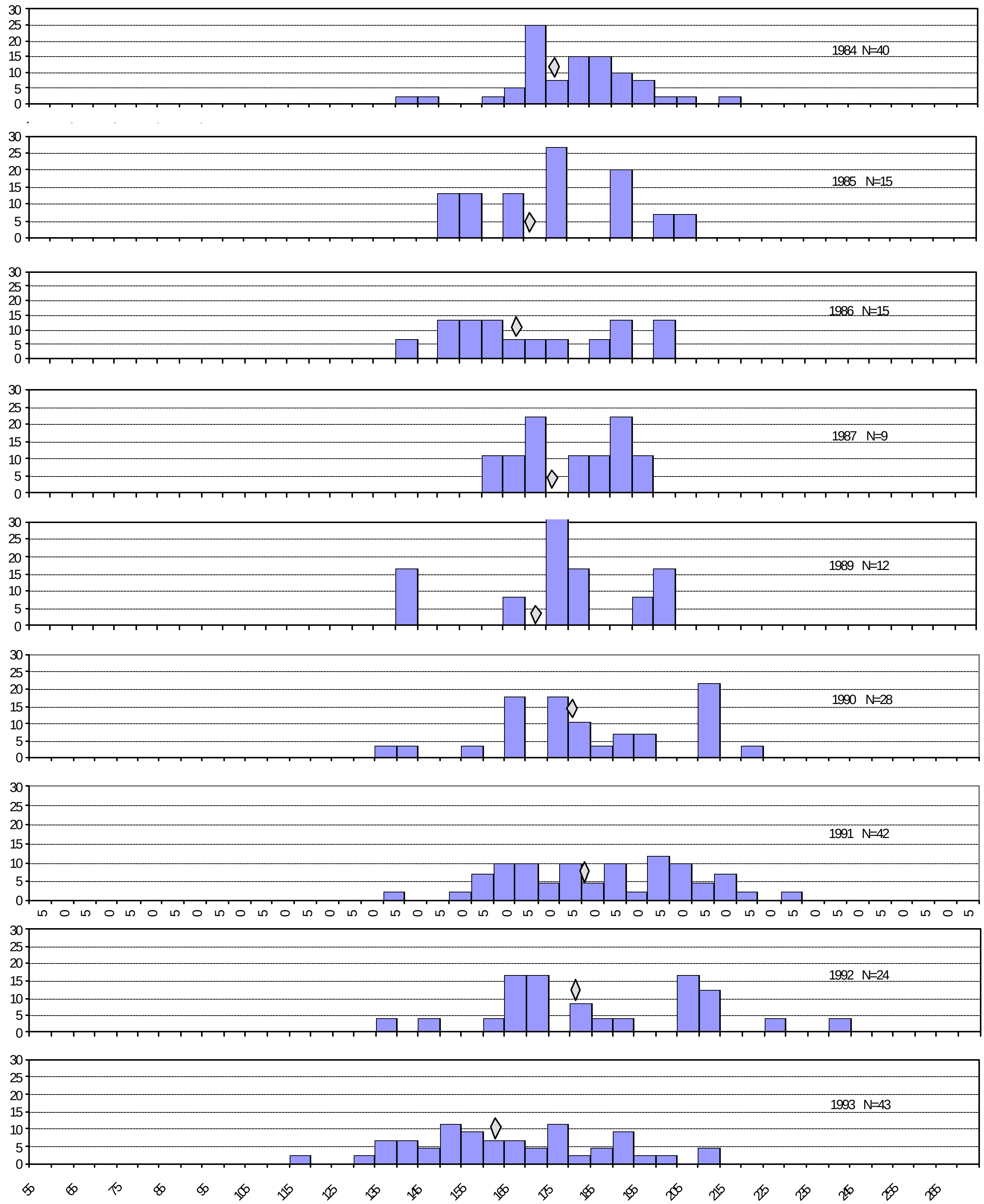


Figure 10. Fork lengths of Klamath Yurok Tribal green sturgeon catch from mid and upper river from April 1, until July 31. The diamonds indicates average size.

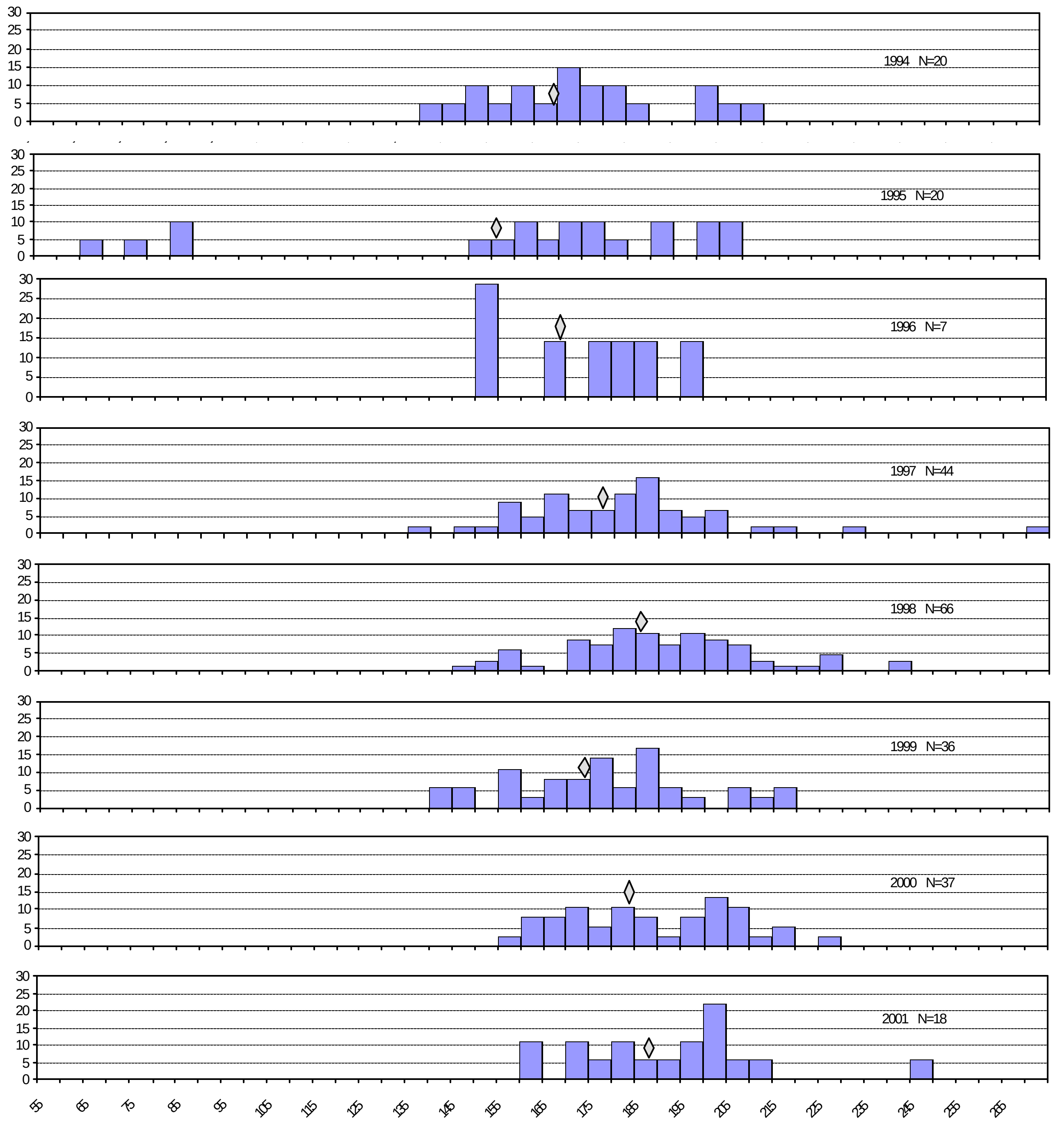


Figure 10. Continued.

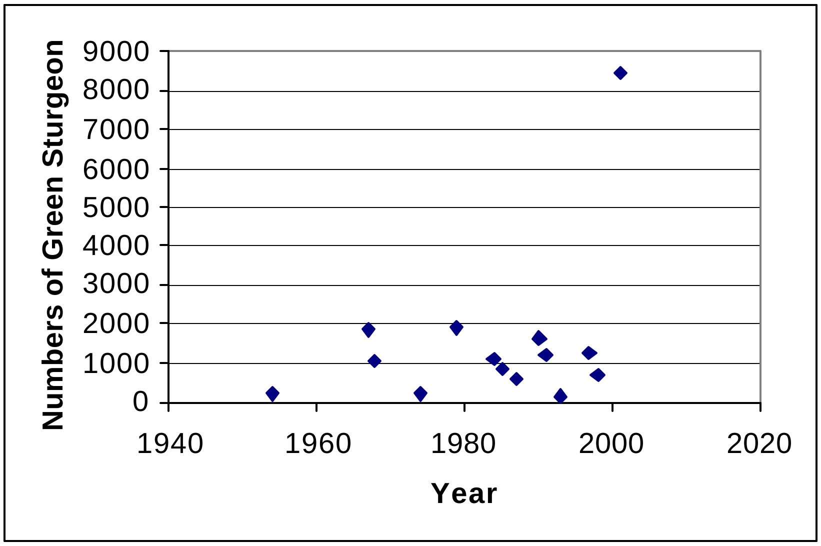


Figure 11. Legal-size (<102 cm) green sturgeon abundance estimates from CDFG white sturgeon tagging program. Green sturgeon abundances are estimated using the white sturgeon abundance and ratios of green to white sturgeon caught in tagging (Data from CDFG 2002).

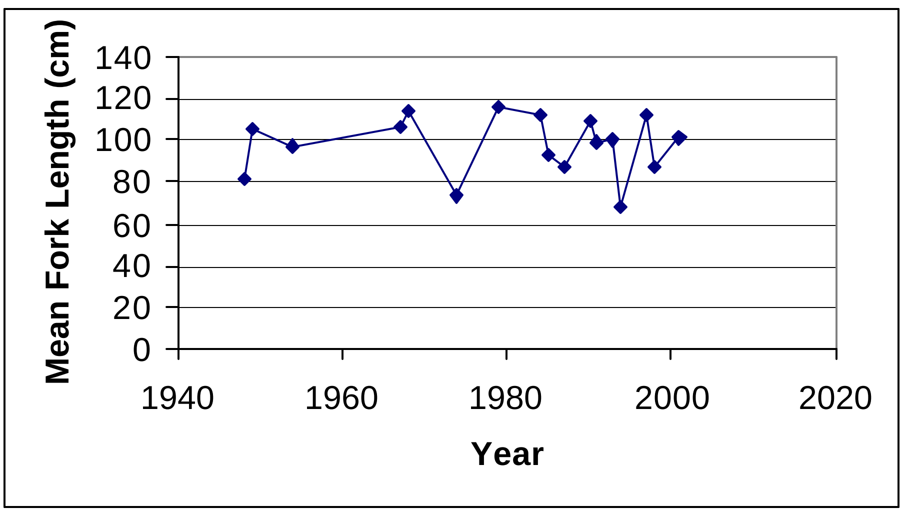


Figure 12. Green sturgeon mean fork length measured from San Pablo Bay tagging program. (n = 640, Data from CDFG 2002, TL converted to Fl using conversion from Rien et al. 2001).

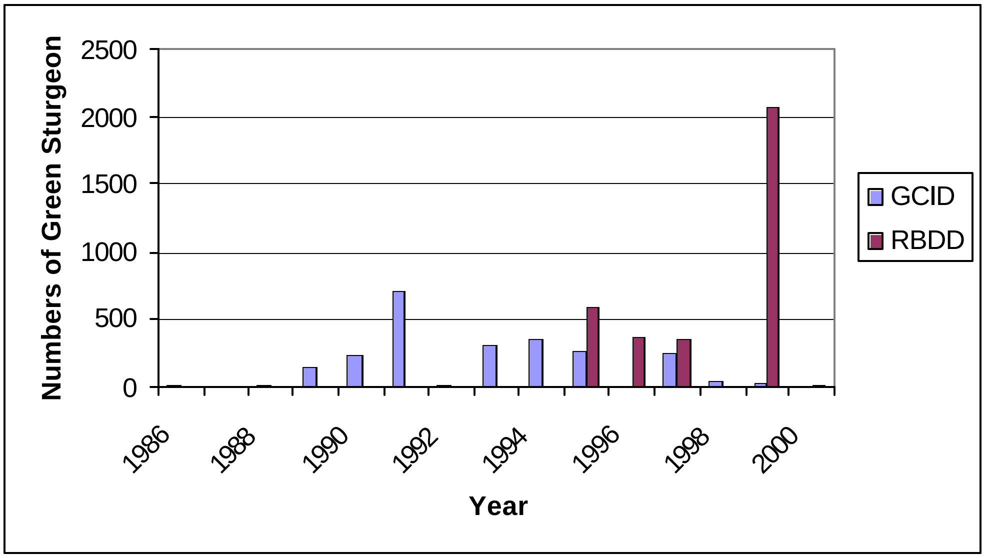


Figure 13. Annual Numbers of juvenile green sturgeon taking in trapping at the Red Bluff Division Dam (rkm 391) and the Glenn-Colusa Irrigation District (rkm 330). (Data from CDFG 2002.)

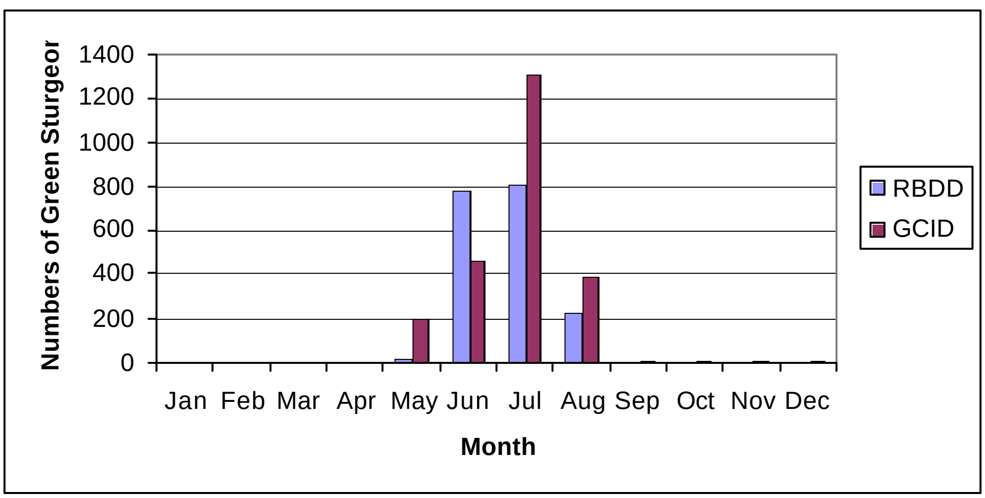


Figure 14. Juvenile green sturgeon seasonal trend from trapping at the Red Bluff Division Dam (rkm 391) and the Glenn-Colusa Irrigation District (rkm 330). (Data from CDFG 2002.)

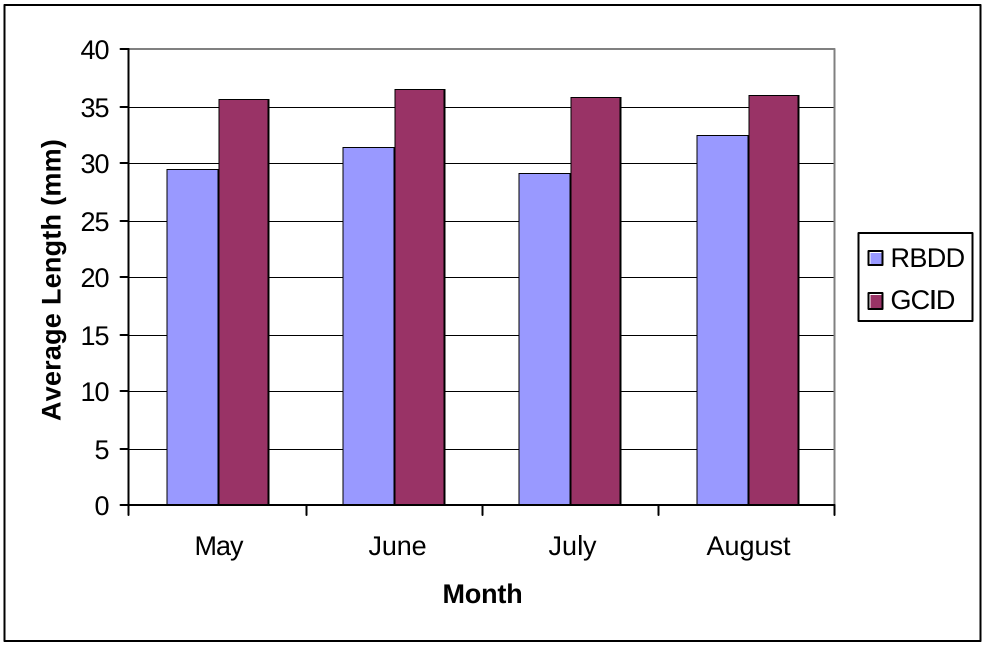


Figure 15. Average length of green sturgeon by month taken in trapping from the Red Bluff Division Dam (rkm 391) and from the Glenn-Colusa Irrigation District (rkm 330). (Data from CDFG 2002.)

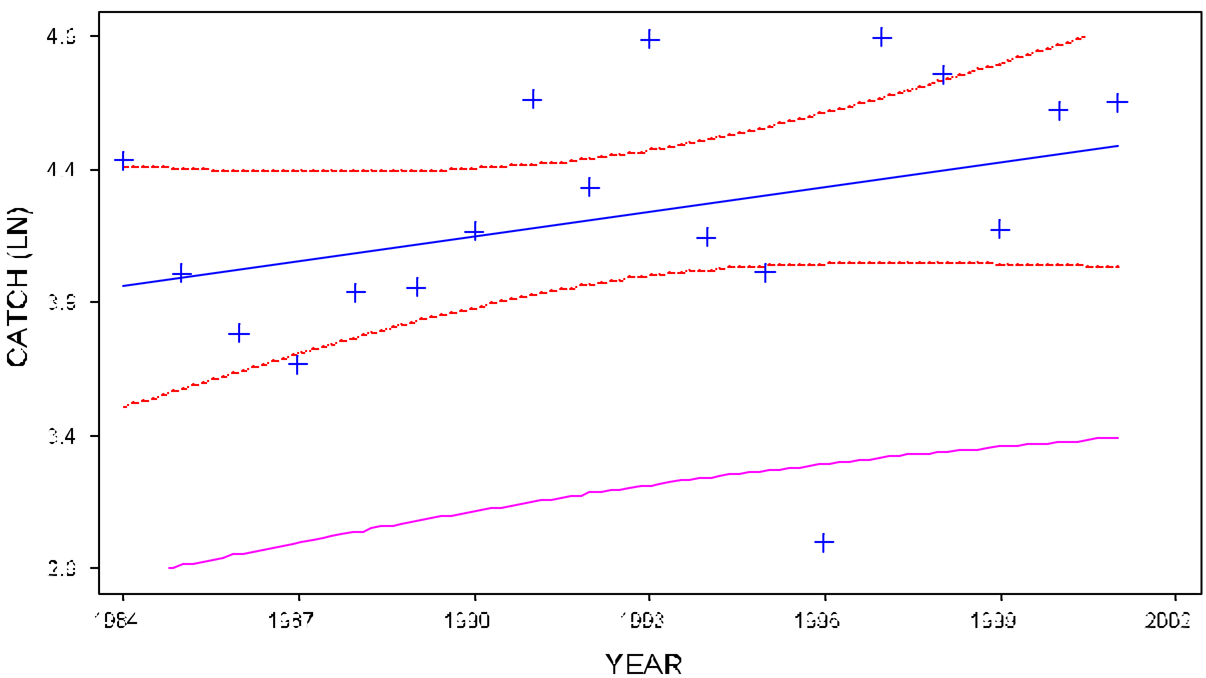


Figure 16. Yurok Tribal green sturgeon catch (Ln transformed) during April and May 1984 to 2001 regressed against year.

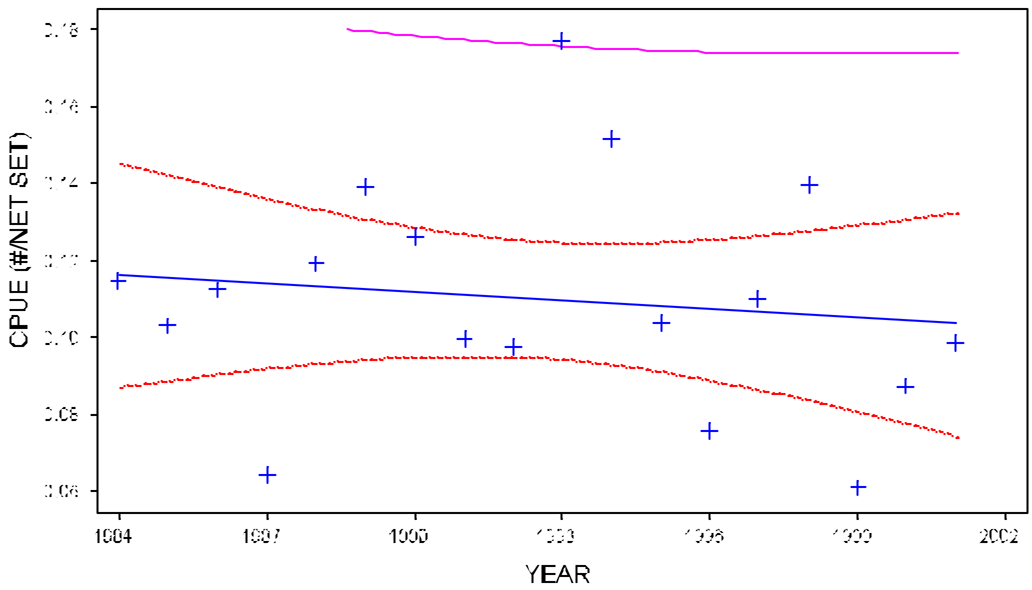


Figure 17. Yurok Tribal green sturgeon three-year running sum CPUE (numbers/gill net set) for April and May 1984 to 2001 regressed against year.

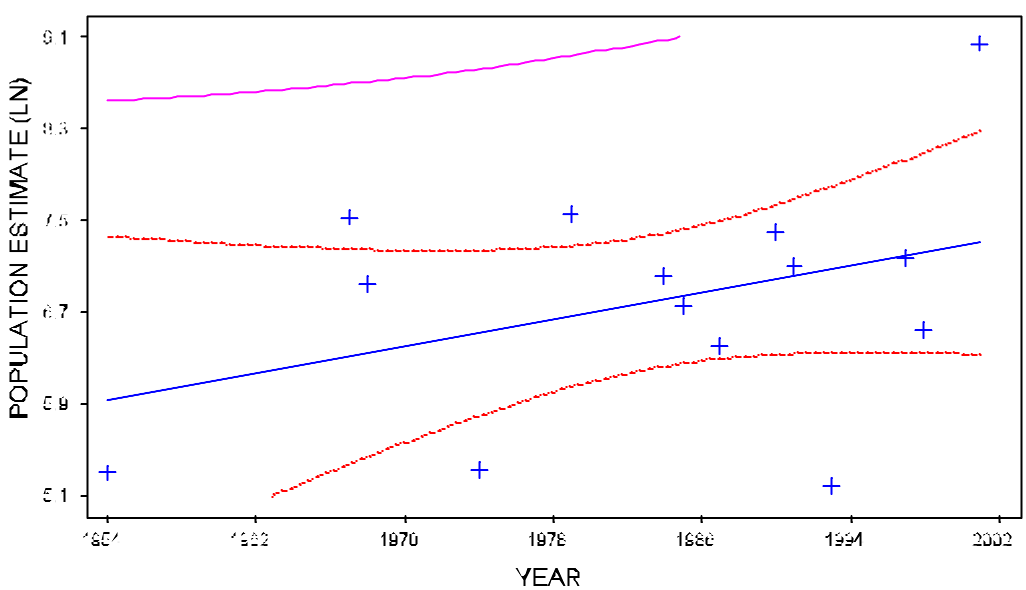


Figure 18. CDFG San Pablo Bay green sturgeon (<102 cm) population estimates (Ln transformed) from mark and recapture white sturgeon estimates (see text) conducted intermittently from 1954 to 2001.

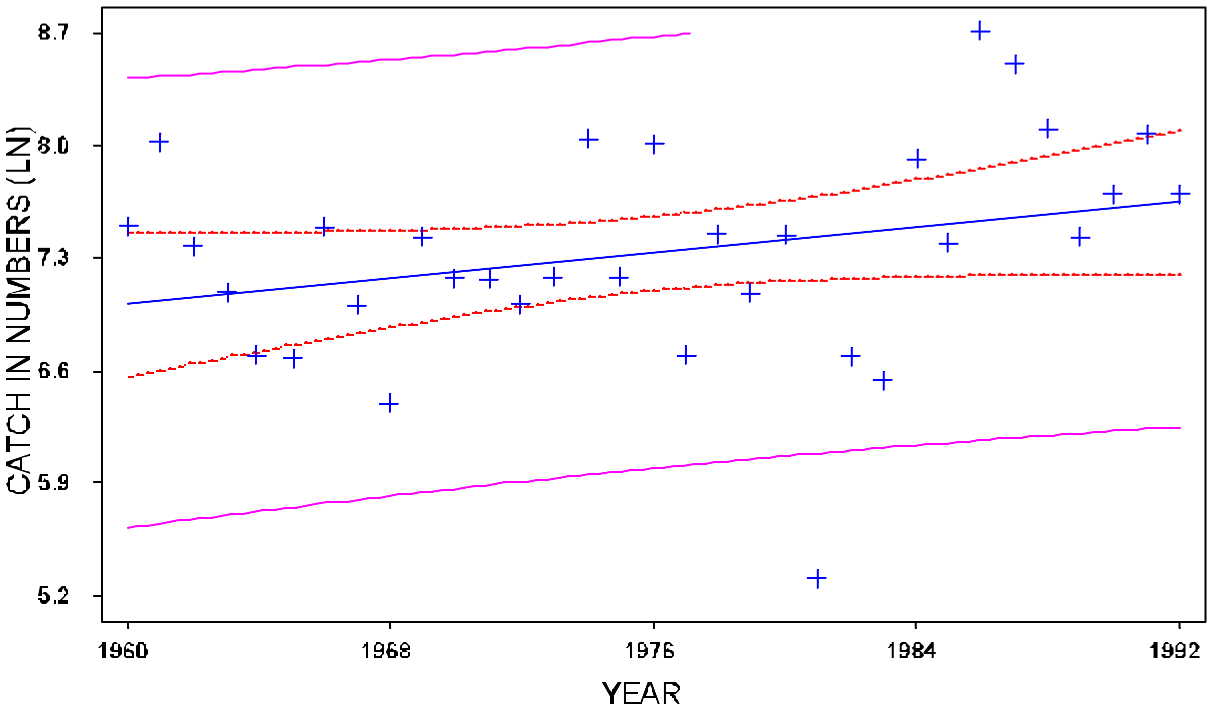


Figure 19. Columbia River green sturgeon catch (Ln transformed) in numbers (see text) regressed against year. The time period is 1960 to 1992 due to regulation changes in 1993.

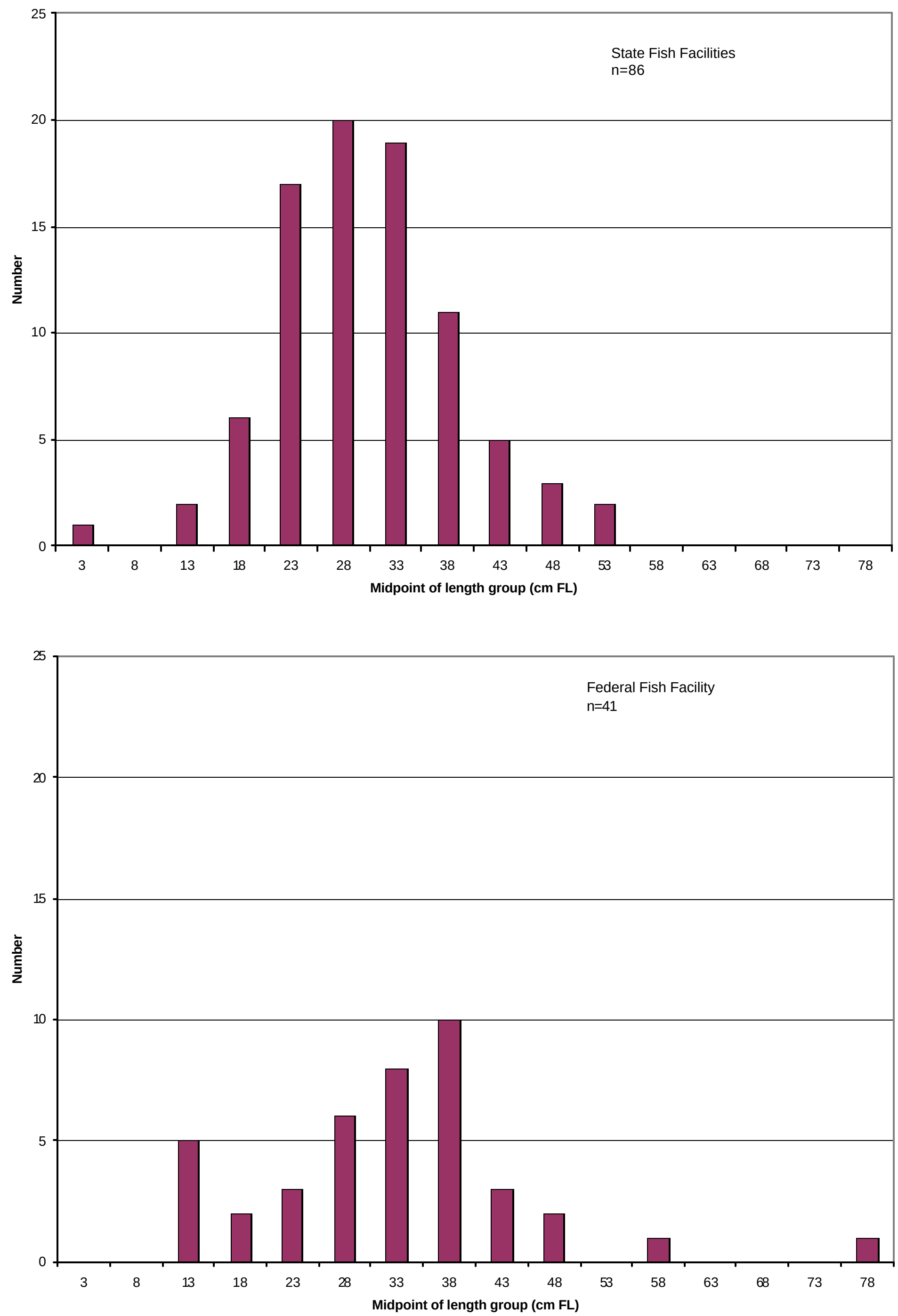


Figure 20. Length frequency distribution of green sturgeon collected in the State and Federal fish facilities in the South Sacramento-San Joaquin Delta from 1968 to 2001 (Data from CDFG 2002).