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STATUS AND TRENDS

Zooplankton Monitoring 2011

April Hennessy and Tina Enderlein (DFW), April.Hennessy@wildlife.ca.gov

Introduction

The Zooplankton Study has estimated the abundance of zooplankton taxa in the upper San Francisco Estuary since 1972 to assess trends in fish food resources. The study also detects and monitors zooplankton recently introduced to the estuary and determines their effects on native species. Three gear types are used: 1) a pump for sampling microzooplankton < 1.0 mm long, including rotifers, copepod nauplii, and adult copepods of the genus *Limnoithona*; 2) a modified Clarke-Bumpus (CB) net for sampling mesozooplankton 0.5-3.0 mm long, including cladocerans, copepodids (immature copepods), and adult copepods; and 3) a macrozooplankton net for sampling zooplankton 1-20 mm long, which targets mysid shrimp. Here seasonal abundance indices are presented from 1974 through 2011 for a select group of the most common copepods, cladocerans, rotifers, and mysids.

Methods

During 2011, sampling occurred monthly from January through December at 22 stations, including 12 core stations (i.e., stations sampled consistently since study inception in 1972) and 2 floating entrapment zone (EZ) stations located at bottom electrical conductivity of 2 and 6 mS/cm (approximately 1 and 3‰). The study area extends from eastern San Pablo Bay through the delta and the station map can be viewed at www.dfg.ca.gov/delta/data/zooplankton/stations.asp. Seasonal indices presented here were calculated using 16 stations: the 12 core stations, the 2 EZ stations, and 2 additional stations sampled consistently since 1974 (Suisun Slough station S42 and Disappointment Slough station MD10). Reports published prior to 2007 used data from 1972 that included only the 12 core and 2 EZ stations. Since this report utilized data from 2 additional stations, indices started in 1974 and may be slightly different from those reported prior to 2007. However, overall trends remained the same.

Data were grouped into 3 seasons: 1) spring, March through May, 2) summer, June through August, and 3) fall, September through November. January, February, and December were not always sampled historically and therefore not used for long-term trend analyses. Abundance indices were calculated as the mean number of each taxon per cubic meter of water (reported as catch-per-unit effort, CPUE) by gear, season, and year for the 16 stations. Relative calanoid copepod abundance for each season of 2011, including winter (December 2010 through February 2011), used data from all stations sampled. Similar to 2004 through 2011 Status and Trends reports, indices were separated by gear type and taxon, whereas pre-2004 reports combined CB and pump data for each taxon into a single index.

Copepods

Both congeners of the cyclopoid copepod genus *Limnoithona* inhabit the upper estuary: *L. sinensis*, first recorded in 1979, and *L. tetraspina*, first recorded in 1993. In 1993, *L. tetraspina* mostly supplanted the historically common and slightly larger *L. sinensis*, and numerically became the dominant copepod in the upper estuary. *L. tetraspina* is common in both brackish and freshwater. As an ambush predator that feeds on motile prey (Bouley and Kimmerer 2006), *L. tetraspina* may have benefited from the phytoplankton species composition change (described by Brown 2009) from non-motile diatoms to motile flagellates. Despite high densities of *L. tetraspina* in the estuary, it may not be a readily available food source for visual predators, like delta smelt, due to its small size and relatively motionless behavior in the water column (Bouley and Kimmerer 2006). Both pump and CB net indices are presented here because *L. tetraspina* is not completely retained by the CB net, especially in summer and fall when adults are smaller. Pump *L. tetraspina* abundance decreased again in 2011 in all seasons, whereas CB abundance increased in all seasons (Figure 1). In 2011, spring pump abundance was the lowest since 1994, summer pump abundance was the lowest since 1993, and fall pump abundance was the lowest since 1998 (Figures 1A, 1B, and 1C). In contrast, *L. tetraspina* 2011 spring CB abundance was the highest since 2008 and summer and fall abundance the highest since 2006 (Figures 1A, 1B, and 1C). Lower 2011 pump abundance and higher CB abundance indicated that *L. tetraspina* individuals were larger and therefore retained better by the CB net. *L. tetraspina* was most abundant during early fall 2011 in Grizzly Bay and Montezuma Slough, with peak densities in September in Montezuma Slough (74,448 m^{-3}). *L. sinensis* continued to be collected in very low numbers in 2011.

Eurytemora affinis, a calanoid copepod introduced to the estuary before monitoring began, was once a major food source for larval and juvenile fishes of many species, as well as adult planktivores such as delta smelt and threadfin shad. It is found throughout the upper estuary in every season and is most abundant in salinities less than 6‰. *E. affinis* abundance declined in all seasons since monitoring began, with the sharpest downturns during summer and fall of the late-1980s (Figure 2), subsequent to the introductions of the overbite clam, *Potamocorbula amurensis*, and the calanoid copepod *Pseudodiaptomus forbesi*. Prior to these introductions, *E. affinis* abundance was usually highest during summer; however, since 1987 abundance has been highest in spring and dropped abruptly in summer, when both *P. forbesi* abundance and *P. amurensis* grazing rates increase. Again in 2011, *E. affinis* was the fifth most abundant calanoid copepod in the study area. Abundance was highest in spring, when it accounted for 35% of the total calanoid copepod CPUE and was the most abundant calanoid copepod (Figure 3). *E. affinis* abundance increased in spring and summer 2011 from 2010, but decreased slightly in fall. Spring abundance increased sharply in 2011, from the lowest abundance on record, and was the third highest in the last decade (Figure 2A). Summer *E. affinis* abundance was the highest since 2006 (Figure 2B). Although fall abundance decreased slightly in 2011 (Figure 2C), it was still higher than the 1990 through 2010 mean. *E. affinis* was common in Suisun Marsh from January through May, and in western Suisun Bay in the entrapment zone from April through June. In the eastern delta, densities were low most of the

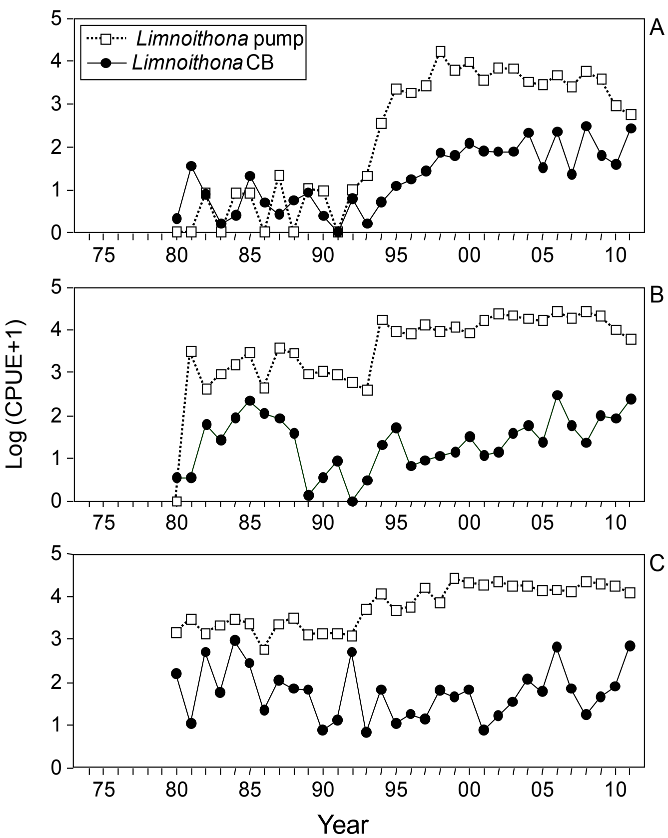

Figure 1 Abundance of *Limnoithona tetraspina* and *L. sinensis* combined (Log of mean catch*m^{-3}+1) from the pump and CB net in spring (A), summer (B), and fall (C), 1974 – 2011

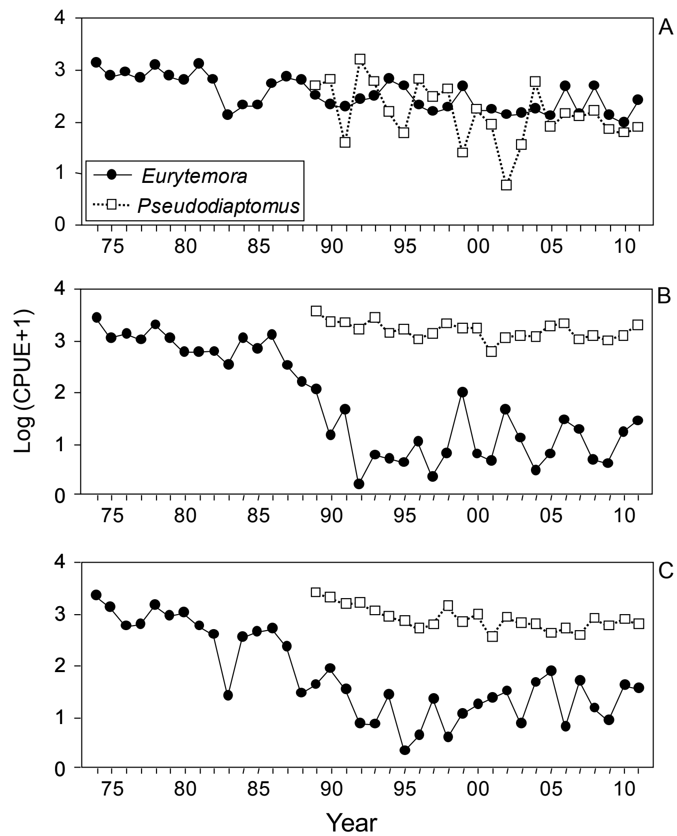

Figure 2 Abundance of *Eurytemora affinis* and *Pseudodiaptomus forbesi* (Log of mean catch*m^{-3}+1) from the CB net in spring (A), summer (B), and fall (C), 1974 – 2011

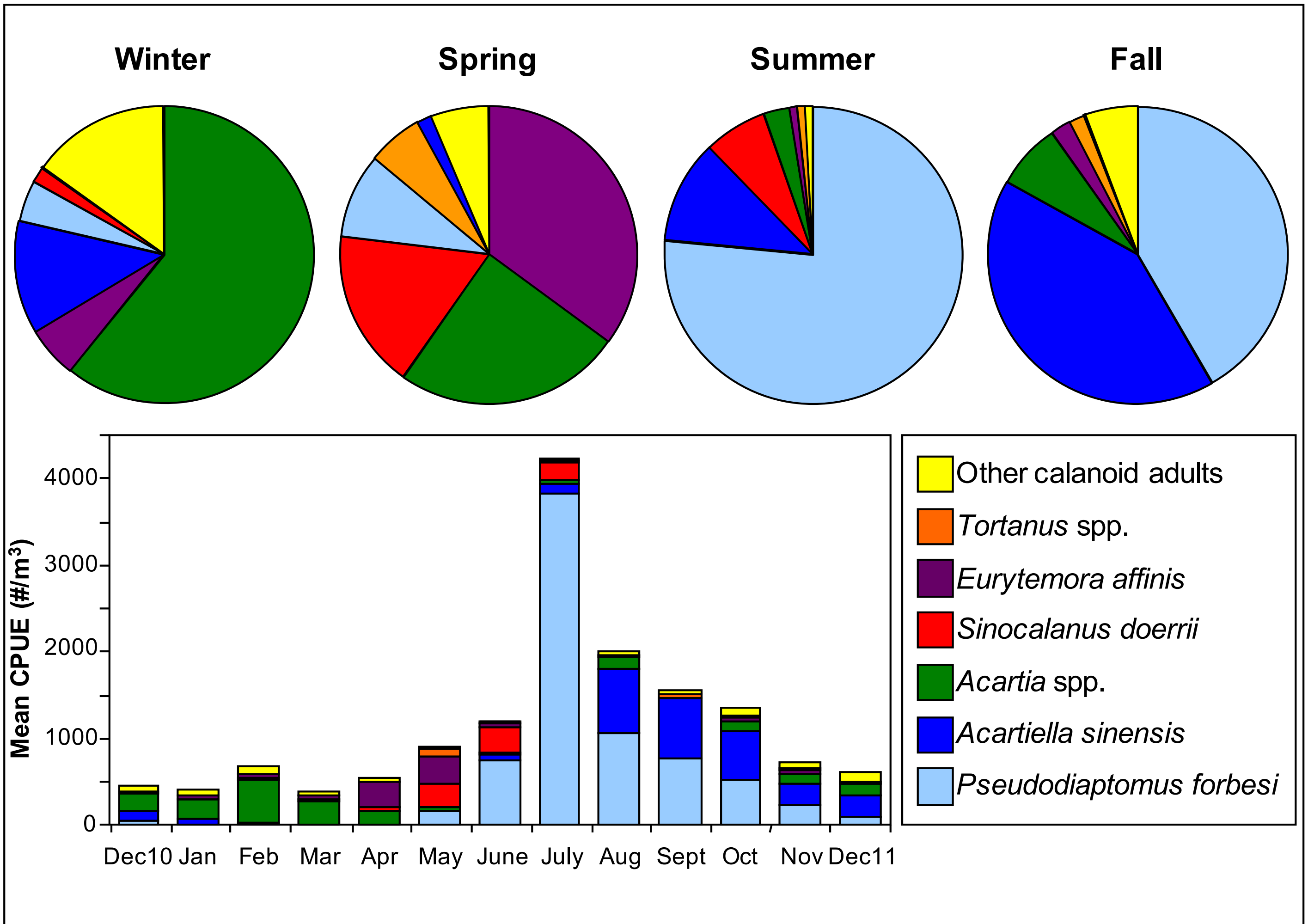

Figure 3 Relative abundance of the most common calanoid copepods (percent mean catch*m^{-3}) from the CB net from all stations by seasons and by months in 2011. Seasonal pie charts include winter (December 2010-February 2011), spring (March-May 2011), summer (June-August 2011), and fall (September-November 2011). Bar graph shows average monthly CPUE of the most common calanoid copepods.

year before increasing in late fall. In 2011, *E. affinis* abundance peaked in April in western Suisun Bay (2,521 m^{-3}) and in May in Suisun Slough (1,569 m^{-3}) and Old River in the South Delta (1,132 m^{-3}).

P. forbesi is an introduced freshwater calanoid copepod first detected in the upper estuary in 1988. By 1989, *P. forbesi* summer and fall abundance was comparable to *E. affinis* before its decline (Figure 2). Although *P. forbesi* abundance declined slightly since its introduction, it remained relatively abundant in summer and fall compared to other copepods. In both 2010 and 2011, *P. forbesi* was the most abundant calanoid copepod in the study area. In 2011, relative abundance peaked in summer, when it accounted for 76% of the total calanoid copepod CPUE (Figure 3). Spring abundance has always been highly variable and increased slightly in 2011 from 2010 (Figure 2A). Summer abundance also increased, whereas fall abundance decreased slightly from 2010 (Figures 2B and 2C). During summer and fall 2011, *P. forbesi* was common in all regions upstream of Suisun Bay, and most abundant in Suisun Marsh, the San Joaquin River, and the delta. The highest density was in July in Frank's Tract in the South Delta, where CPUE was 23,284 m^{-3}.

Several species of the native calanoid copepod genus *Acartia* are abundant in San Pablo Bay, and expand their range into Suisun Bay and the western delta as salinity increases seasonally and annually. Conversely, their affinity for higher salinities is sufficiently strong that their distribution shifts seaward of the sampling area during high-outflow events, resulting in low seasonal and annual abundance. In 2011, *Acartia* was the third most abundant calanoid copepod in the study area. Relative abundance peaked in winter, when *Acartia* accounted for 61% of the total calanoid copepod CPUE (Figure 3). *Acartia* abundance declined in spring and fall of 2011, but increased slightly in summer (Figure 4). Higher spring outflow in 2011 resulted in the lowest *Acartia* abundance since 1996 (Figure 4A). Lower summer abundances generally corresponded with the highest outflow years, so the slight increase in summer 2011 was unexpected (Figure 4B). By fall 2011 outflow decreased, which allowed abundance to increase from summer levels (Figure 4C). However, fall 2011 outflow was higher than recent years, which caused *Acartia* to be further downstream and resulted in lower fall abundance when compared to 2010 (Figure 4C). *Acartia* was common throughout the year in San Pablo Bay, where the highest densities occurred from January through March with a peak in February (3,406 m^{-3}). *Acartia* was also found in Carquinez Strait during every month of 2011 except May, with a peak in February (2,339 m^{-3}).

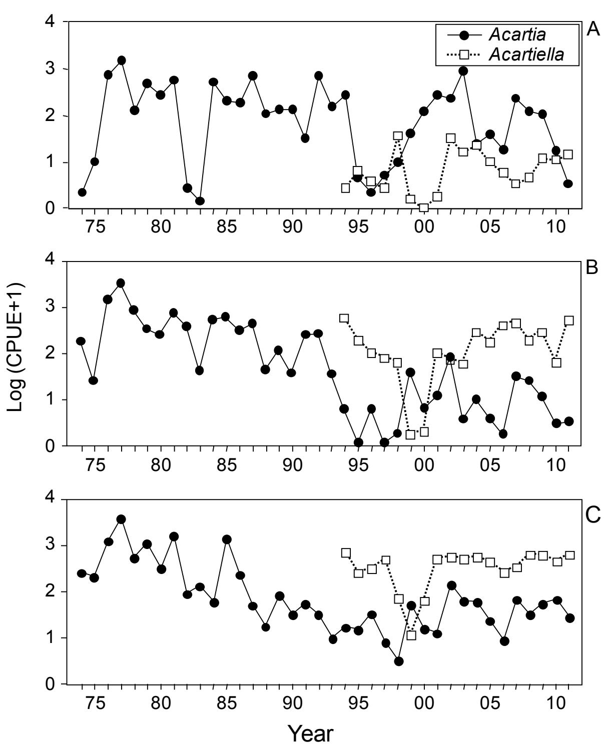

Figure 4 Abundance of *Acartia* spp. and *Acartiella sinensis* (Log of mean catch*m^{-3}+1) from the CB net in spring (A), summer (B), and fall (C), 1974 – 2011

Acartiella sinensis is an introduced calanoid copepod, first recorded in spring 1994, that is most abundant in the entrapment zone during summer and fall. In 2011, *A. sinensis* was the second most abundant calanoid copepod in the study area. Relative abundance was highest in fall, when it accounted for 41% of the total calanoid copepod CPUE (Figure 3). In 2011, *A. sinensis* abundance increased in spring, summer, and fall from 2010 (Figure 4). Spring abundance has always been highly variable; after declining steadily from 2004 through 2007 abundance increased from 2008 to 2011 (Figure 4A). Summer *A. sinensis* abundance steadily increased from the record lows of 1999 and 2000, and 2011 had the second highest abundance since its introduction (Figure 4B). Fall abundance has been relatively stable since 2001 and increased in 2011 to the third highest on record (Figure 4C). In 2011, *A. sinensis* abundance was highest August through October in Suisun Bay and the lower Sacramento River, with a peak in eastern Suisun Bay in the entrapment zone (3,151 m^{-3}) in August.

The introduced freshwater calanoid copepod *Sinocalanus doerrii* was first recorded in spring 1979. Initially most abundant in summer, *S. doerrii* abundance began to decline during summer and fall in the mid-1980s (Figure 5). This downward trend continued through the mid-1990s, followed by modest increases recently. In 2011, *S. doerrii* was the fourth most abundant calanoid copepod in the study area. Relative abundance peaked in spring, when it accounted for 17% of the total calanoid copepod CPUE (Figure 3). *S. doerrii* abundance decreased sharply in 2011 from 2010 in all seasons (Figure 5). Spring abundance, historically more variable than summer or fall abundance, declined in 2011 to densities similar to 2005 through 2007 (Figure 5A). Although summer and fall 2011 abundance declined, the overall trend was of increasing abundance since 2004 for summer and 2005 for fall (Figures 5B and 5C). In 2011, *S. doerrii* was most abundant May and June in Suisun Bay and Suisun Marsh, peak abundance occurred in June in Montezuma Slough (1,979 m^{-3}).

Tortanus dextrilobatus is an introduced brackish-water calanoid copepod first recorded in spring 1994. *T. dextrilobatus* is a large carnivorous copepod whose abundance increases in the sampling area as flows decrease and salinities increase during summer and fall. In 2011, *T. dextrilobatus* was the least abundant of the common calanoid copepods in the study area; relative abundance peaked in spring when it accounted for 6% of the total calanoid copepod CPUE (Figure 3). *T. dextrilobatus* abundance decreased in all seasons of 2011 from 2010 (Figure 5). Spring abundance rose steadily from the low in 2006, caused by the extremely high flows, and reached the fifth highest abundance in 2009 before dropping sharply in 2010 and 2011 (Figure 5A). In 2008 and 2009, summer abundance was the highest since *T. dextrilobatus* was introduced, before declining in 2010 and 2011 (Figure 5B). Fall 2011 abundance decreased slightly, but remained above the fall mean (Figure 5C). In 2011, *T. dextrilobatus* was found throughout the year in San Pablo Bay and Carquinez Strait. Abundance peaked in May in San Pablo Bay (630 m^{-3}) and in September in Carquinez Strait (429 m^{-3}).

Cladocerans

Bosmina, *Daphnia*, and *Diaphanosoma* are the most abundant cladoceran genera in the upper estuary. Combined, these native freshwater cladocerans had an overall downward trend since the early 1970s, especially in fall (Figure 6). From 2010 to 2011, abundance decreased in all seasons and was below the seasonal means, probably due to higher flows in 2011 resulting in lower residence time. In 2011, cladocerans were common throughout the estuary upstream of the entrapment zone and were most abundant in the East Delta from April through October. Peak densities occurred in Disappointment Slough in September (13,748 m^{-3}).

Rotifers

Synchaeta bicornis is a native brackish-water rotifer that is usually most abundant in the upper estuary in summer and fall, when salinity increases. However, long-term abundance has declined since the 1970s (Figure 7). *S. bicornis* abundance increased in all seasons of 2011. From 2002 through 2007 there was no spring catch at any core stations, followed by an increase in 2008 and 2009. Higher spring outflow in 2010 resulted in no catch at any stations sampled, and although 2011 spring abundance increased slightly, it remained very low (Figure 7A). After dropping to 0 in 2010, for the first time since monitor-

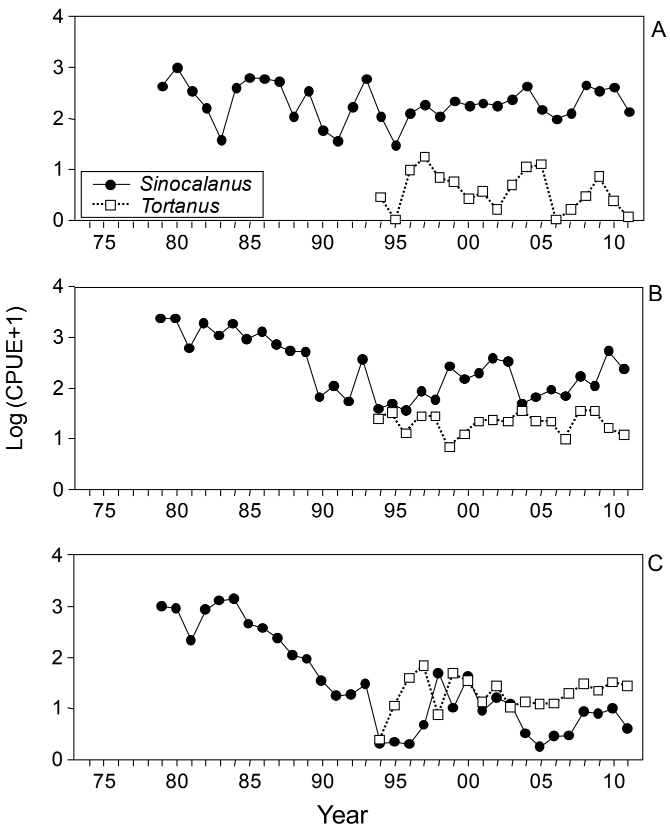

Figure 5 Abundance of *Sinocalanus doerrii* and *Tortanus dextrilobatus* (Log of mean catch*m^{-3}+1) from the CB net in spring (A), summer (B), and fall (C), 1974 – 2011

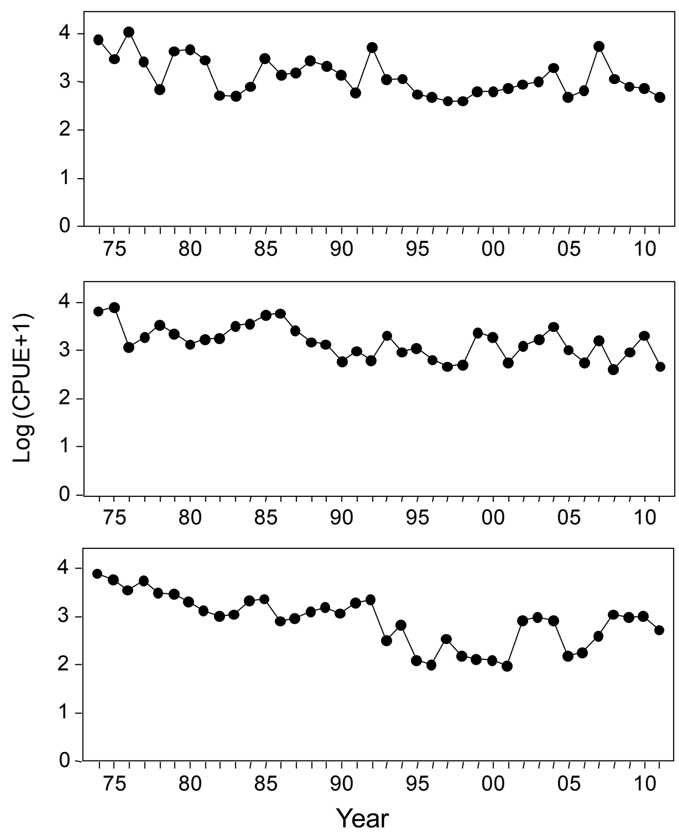

Figure 6 Abundance of Cladocera (Log of mean catch*m^{-3}+1) from the CB net in spring (A), summer (B), and fall (C), 1974 – 2011

ing began, summer 2011 abundance increased sharply and was the highest since 1992 (Figure 7B). Fall 2011 abundance also increased sharply from 2010 and reached the third highest fall abundance recorded (Figure 7C). In 2010, *S. bicornis* was most abundant August through October in Carquinez Strait, Suisun Bay, and Suisun Marsh. Peak densities occurred in Montezuma Slough in Suisun Marsh in September (1,308,452 m^{-3}).

Abundance of all other rotifers, without *S. bicornis*, declined from the early 1970s through the 1980s, but stabilized since the early 1990s (Figure 7). In 2011, rotifer abundance increased in all seasons. After decreasing to the lowest spring abundance in 2009, abundance increased in 2010 and 2011 to the highest since 1978 (Figure 7A). Summer abundance increased slightly in 2011 for the third year in a row (Figure 7B). Fall abundance increased in 2011 from the lowest abundance since the study began (Figure 7C). Rotifers were common throughout the study area in 2011, with the highest density in Suisun Slough, where mean CPUE for the year was 97,951 m^{-3} and peaked at 1,054,909 m^{-3} in April.

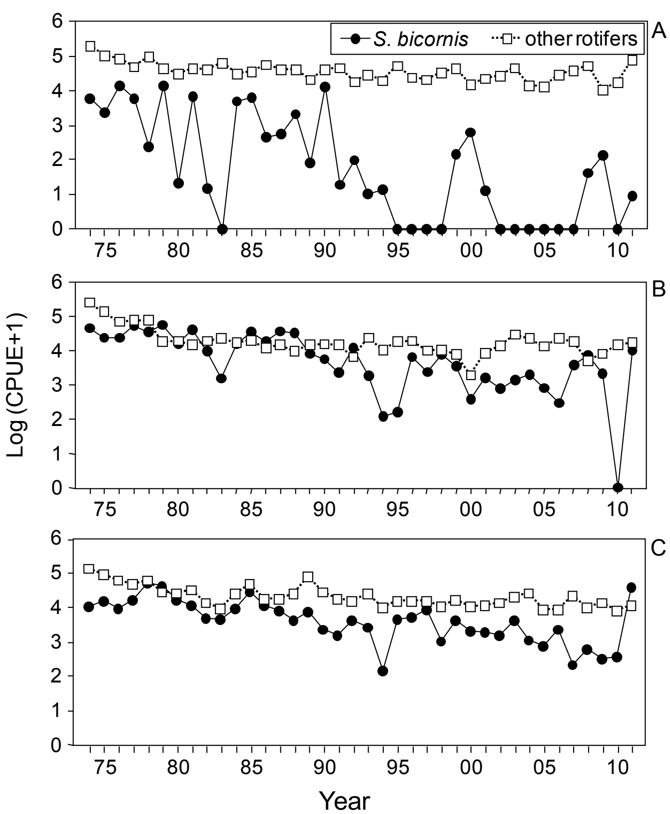

Figure 7 Abundance of *Synchaeta bicornis* and rotifers excluding *S. bicornis* (Log of mean catch*m^{-3}+1) from the pump in spring (A), summer (B), and fall (C), 1974 – 2011

Mysids

Hyperacanthomysis longirostris (formerly *Acanthomysis bowmani*), an introduced mysid first collected by the study in summer 1993, has been the most abundant mysid in the upper estuary since summer 1995 (Table 1). *H. longirostris* is commonly found in densities of more than 10 m^{-3}, and occasionally in densities of more than 100 m^{-3}. Spring *H. longirostris* abundance increased from 1995 to 1998 and fluctuated thereafter, decreasing in 2011 to the second lowest abundance on record. Summer abundance had a downward trend from 2003 to 2009, increased in 2010, then decreased sharply in 2011 to the lowest since its introduction. *H. longirostris* fall abundance declined consistently since 2004, resulting in record low abundances from 2007 through 2009 of less than 1 m^{-3}. Although abundance increased in fall 2010 and 2011, it remained below the study-period mean. In 2011, *H. longirostris* was most abundant in the entrapment zone from June through August in Suisun Bay, and from September and December in the lower Sacramento River. Densities were also high during July in Carquinez Strait, and from August through October in Montezuma Slough in Suisun Marsh. The highest 2011 density occurred during June in the entrapment zone in Suisun Bay (48 m^{-3}).

Neomysis mercedis, historically the only common mysid in the upper estuary, suffered a severe population crash in the early 1990s. In 2011, it was the least abundant mysid species of those shown in Table 1, for the second year in a row. *N. mercedis* is most abundant in spring and summer, and prior to the population crash mean spring and summer densities were more than 50 m^{-3} (Table 1). Since 1994, mean spring abundance has been less than 1 m^{-3}, rendering *N. mercedis* inconsequential as a food source in most open-water areas of the upper estuary. After some of the lowest spring densities on record from 2007 through 2010, abundance increased in 2011 and was the highest since 2006, but remained very low relative to the 1970s and 1980s. Summer abundance has been extremely low, less than 1 m^{-3}, since 1997. After decreasing to the lowest summer abundance on record in 2009, summer abundance increased slightly in 2010, and again in 2011 to the highest since 1996. No *N. mercedis* were caught during fall at any stations sampled from 2005 through 2008. From 2009 through 2011, only 1 *N. mercedis* was caught during fall of each year. Since June 2006, *N. mercedis* has been uncommon throughout the study area with densities less

Table 1 Seasonal abundance of the most common mysid species (mean catch*m^{-3}) from the macrozooplankton net

Year	*H. longirostris*			*N. mercedis*			*N. kadiakensis*			*A. macropsis*		
	Spring	*Summer*	*Fall*	*Spring*	*Summer*	*Fall*	*Spring*	*Summer*	*Fall*	*Spring*	*Summer*	*Fall*
1974-1989				54.506	87.293	18.154						
1990				23.458	7.612	0.436						
1991				32.058	18.331	0.489						
1992				4.223	1.989	0.076						
1993			2.470	7.850	22.503	0.008						
1994	0.932	21.604	2.063	0.449	0.733	0.004						
1995	0.437	7.180	4.407	0.590	0.370	0.000				0.000	0.000	0.004
1996	1.636	11.693	4.432	0.541	1.432	0.001	0.032	0.001	0.017	< 0.001	0.000	0.003
1997	6.939	27.630	7.714	0.565	0.063	0.000	0.011	0.011	0.385	0.006	0.000	0.004
1998	18.136	6.015	18.691	0.181	0.238	0.025	0.108	0.041	0.006	0.005	0.000	0.008
1999	3.888	34.697	14.329	0.264	0.288	0.001	0.037	0.007	0.075	0.014	0.000	0.001
2000	23.580	38.453	9.958	0.880	0.136	0.001	0.074	0.165	0.465	0.003	0.000	0.001
2001	4.767	13.441	8.956	0.422	0.052	0.001	0.285	0.351	0.143	0.013	0.001	0.001
2002	10.121	21.224	7.516	0.022	0.069	0.001	0.209	0.254	0.753	0.005	0.000	0.002
2003	4.342	21.307	4.555	0.022	0.046	< 0.001	0.314	0.209	0.166	0.038	0.000	0.003
2004	9.915	13.725	5.044	0.150	0.016	0.002	0.129	0.106	0.170	0.001	0.000	0.001
2005	4.010	16.281	3.265	0.092	0.141	0.000	0.173	0.104	0.077	0.003	0.000	0.004
2006	7.186	14.143	1.967	0.321	0.137	0.000	0.071	0.727	0.051	0.001	0.000	0.001
2007	0.969	8.997	0.575	0.005	0.023	0.000	0.176	0.306	0.122	0.004	< 0.001	0.025
2008	17.696	14.574	0.715	0.063	0.108	0.000	1.359	0.820	0.154	0.027	< 0.001	0.155
2009	0.729	6.303	0.681	0.016	0.013	< 0.001	0.418	0.240	0.128	0.064	0.003	0.096
2010	2.887	25.975	2.045	0.013	0.174	< 0.001	0.177	0.280	0.081	0.090	0.002	0.183
2011	0.584	4.350	2.815	0.161	0.313	< 0.001	0.142	0.322	0.235	0.040	0.002	0.079
Average:	**6.597**	**17.088**	**5.379**	**24.854**	**38.196**	**7.671**	**0.232**	**0.246**	**0.189**	**0.018**	**0.001**	**0.034**

than 1 m^{-3} at most stations. Peak 2011 densities occurred in May and June in Suisun Slough (3 m^{-3} and 4 m^{-3}, respectively) and in July in the lower Sacramento River near Decker Island (3 m^{-3}). These were the highest densities seen since May 2006, but still very low relative to earlier years.

Neomysis kadiakensis is a native brackish-water mysid that regularly appeared in mysid samples beginning in 1996, but was not common until recently (Table 1). From 2001 through 2008, *N. kadiakensis* was the second most abundant mysid in the study area, but from 2009 through 2011 fell to the third most abundant. In 2011, *N. kadiakensis* abundance decreased in spring, but increased in summer and fall from 2010. After reaching a record high in spring 2008, abundance decreased from 2009 through 2011. In 2011, summer abundance increased for the second year in a row, and was above the summer mean for all years. Fall abundance increased sharply in 2011 to the highest level since 2002, and was above the fall mean. In 2011, peak densities occurred in April (4.5 m^{-3}) and May (10.5 m^{-3}) in Carquinez Strait near Benicia. Since the late 1990s, *N. kadiakensis* has extended its range into lower salinity water at the confluence of the Sacramento and San Joaquin rivers, leading to the hypothesis that some of the upper-estuary specimens may be a second species, *N. japonica*. To date no physical characteristics have been published to separate these 2 species.

Alienacanthomysis macropsis is a native brackish-water mysid usually found in San Pablo Bay and Carquinez Strait that was first consistently enumerated by the study in 1995. *A. macropsis* has never been common in the sampling area, and therefore indices were not reported until 2007. Since 2009, *A. macropsis* abundance surpassed *N. kadiakensis* and became the second most abundant mysid in the upper estuary across all stations and surveys, although it remained a minor component of the mysid community due to high *H. longirostris* abundance. After increasing each year from 2007 through

2010, spring abundance decreased in 2011, but remained above the study-period mean (Table 1). After reaching the highest summer abundance on record in 2009, abundance decreased slightly in 2010 and remained steady in 2011. Although fall 2011 abundance decreased from 2010, the highest fall abundance recorded, it remained above the study-period mean. In 2011, *A. macropsis* was most abundant from January through May and again in December in San Pablo Bay, Carquinez Strait, and Suisun Bay. The highest density occurred in January in Carquinez Strait near Benicia (20 m^{-3}).

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2011 Bay Study Fishes Annual Status and Trends Report for the San Francisco Estuary

Maxfield Fish, Jennifer Messineo, and Kathryn Hieb (CDFW),[1] Kathy.Hieb@wildlife.ca.gov

Introduction

The 2011 San Francisco Bay Study (Bay Study) Status and Trends fishes report includes demersal species from the entire estuary and pelagic species from the lower estuary. Results for the upper estuary pelagic species collected by the Townet Survey, the Fall Midwater Trawl, and the Delta Smelt 20-mm Survey were reported in the Spring 2012 IEP Newsletter (Contreras et al. 2012). The most recent abundance indices, long-term abundance trends, and distributional information are presented here for common fishes and some less-common species of interest, such as the surfperches. Presented first are the upper estuary demersal fishes, followed by the marine pelagic fishes, surfperches, and marine demersal fishes. Within each section, species are presented phylogenetically.

Methods

The Bay Study has sampled from South San Francisco Bay to the western delta monthly with an otter trawl and midwater trawl since 1980. There are some data gaps, most significantly: limited midwater trawl sampling in 1994, no winter sampling from 1989 to 1997, and limited sampling at stations in and near the confluence of the Sacramento and San Joaquin rivers in 2007 and 2008 to reduce delta smelt take. Abundance indices are routinely calculated for 35+ fishes and several species of crabs and caridean shrimp. Only the fishes are included in this report; the crabs and shrimp are subjects of separate annual reports, to be published in an IEP Newsletter issue later this year. Bay Study midwater trawl data was used to describe abundance trends and distribution of the pelagic fishes while otter trawl data was used for demersal fishes. Catch-per-unit-effort (CPUE), as average catch per tow, was consistently used to analyze and report distribution.

Of the 52 stations currently sampled, 35 have been consistently sampled since 1980 ("core" stations) and are used to calculate the annual abundance indices. Stations are fairly evenly distributed between channels and shoals in most regions, although depths < 3 meters are not sampled. Most stations have a soft substrate, such as mud, sand, or a mix of shells – we intentionally avoid rocky areas and eelgrass beds. Additional information about study methods, including index calculation, can be found in IEP Technical Report 63 (Baxter et al. 1999).

Several physical data sets were used to describe the oceanic and estuarine environmental conditions that were then related to abundance trends and distributional patterns. Daily outflow at Chipps Island was from Dayflow (DWR); the 1979-2011 daily values were averaged to monthly values and plotted. Monthly Pacific Decadal Oscillation (PDO) indices, from Nathan Mantua (University of Washington), and North Pacific Gyre Oscillation (NPGO) indices, from Emanuele Di Lorenzo (Georgia Institute of Technology), were plotted for 1950-2011. Monthly ocean upwelling anomalies (base period 1946-2011, 39 °N), from the NMFS Pacific Fisheries Environ-

1 Authorship: Introduction, Methods, and Physical Setting, K. Hieb (Kathy.Hieb@wildlife.ca.gov); the gobies, flatfishes, plainfin midshipman, and Pacific staghorn sculpin, M. Fish (Max.Fish@wildlife.ca.gov); Pacific herring, northern anchovy, jacksmelt, the surfperches, leopard shark, brown rockfish, and white croaker, J. Messineo (Jennifer.Messineo@wildlife.ca.gov).