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Of Interest to Managers

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This issue's Quarterly Highlights includes updates on water project operations in the Delta as well as abundance and distribution trends of calanoid copepods in the upper San Francisco Estuary. This section also includes estimates of fall-run Chinook salmon smolt production in the San Joaquin River Basin, an update on the CDFG's midwater trawl mouth geometry evaluation and a review of California halibut in the estuary.

Kate Le (DWR) summarizes Central Valley Project (CVP) and State Water Project (SWP) operations in the Delta during April – September 2008. Extremely dry conditions during the reporting period resulted in very low flows in the Sacramento and San Joaquin Rivers. Pumping operations were typical for this time of year including actions to accommodate the Vernalis Adaptive Management Plan (VAMP) which took place from April 22 to May 22.

Jihyen (Anna) Lee (DFG) describes the abundance and distribution trends of several calanoid copepods during spring and early summer 1995 – 2005. Data from CDFG's 20mm survey were summarized and 4 important prey items were the focus of the discussion: *Pseudodiaptomus forbesi, Eurytemora affinis, Sinocalanus doerrii, and Acartia* spp. Lee found that the overall abundance of these copepods has decreased since the study began, and the main drivers of their distribution appear to be salinity and temperature.

Steve Tsao (DFG) reports on monitoring the fall-run Chinook salmon smolt outmigration from the San Joaquin drainage during April 1 – June 30. Kodiak trawling (10, 20 minute tows) was conducted at Mossdale 5 days a week from April 1 to June 6 and 3 days a week between June 9 and June 30. A total of 1,696 unmarked Chinook salmon smolts were collected during the study period with the majority of the catch coinciding with the VAMP study period. Preliminary smolt production estimates based on this work are the lowest since 2001.

Jennifer Messineo (DFG) provides an update on the midwater trawl mouth geometry evaluation they are conducting using a wired acoustic system developed by Desert Star Systems of Marina, CA. The purpose of the study is to determine the area of the net mouth opening under various towing conditions. To date, DFG has assessed 2 vessels and hopes to expand their evaluations to the rest of their fleet. Preliminary results indicate that the observed measurements are close to the estimates already used in volume calculations by DFG surveys.

Finally, Maxfield Fish (DFG) investigates the surprisingly strong recreational fishery for California halibut in the San Francisco Estuary during 2008. Data from the DFG Bay Study shows that strong year classes of halibut coincide with warm water events off the coast. The latest strong year class reached harvestable size prior to the 2008 season resulting in a banner year for anglers. The fishing community remains positive about the outlook for a healthy halibut population within the estuary, and DFG will continue to collect valuable data and evaluate fishing regulations.

IEP QUARTERLY HIGHLIGHTS

DELTA WATER PROJECT OPERATIONS

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During the April through September 2008 reporting period, both the Sacramento River and San Joaquin River flows were very low due to extremely dry conditions with only one day of precipitation. (Figure 1). Sacramento flows ranged between 200 cms and 380 cms, and San Joaquin flows ranged between 17 cms and 100 cms. Net Delta Outflow Index (NDOI) flows ranged between 70 cms and 360 cms. Sacramento and NDOI flow patterns were similar until the later part of May when NDOI declined and Sacramento flows remained above 250 cms to support increased pumping. The drop in NDOI was due to a drop in outflow standard from 201 cms in June to 113 cms in July, thus more in line with standard operating procedure during this time of year than a court ordered standard.

April through September 2008 export actions at the SWP and CVP were typical during the April through June period to meet demands and for Vernalis Adaptive Management Plan (VAMP), which occurred from April 22 to May 22, 2008. Thereafter, both water projects had similar pumping patterns until the early week of July 2008, when SWP pumping went into conservation mode because all of the SWP water supply had been moved to storage facilities south of the delta. Pumping for CVP increased for the remainder of the period but was no higher than 125 cms (Figure 2). During the April through September 2008 period, SWP pumping ranged between zero and 90 cms whereas CVP was between 12 cms and 125 cms (Figure 2).

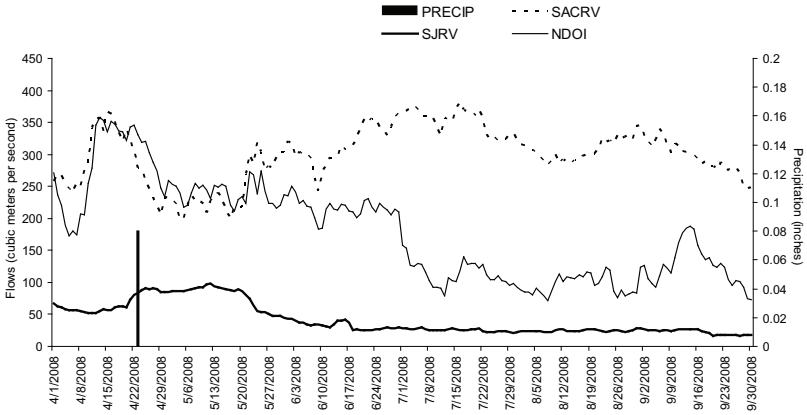

Figure 1 Sacramento River, San Joaquin River, Net Delta Outflow Index, and Precipitation, April through September 2008

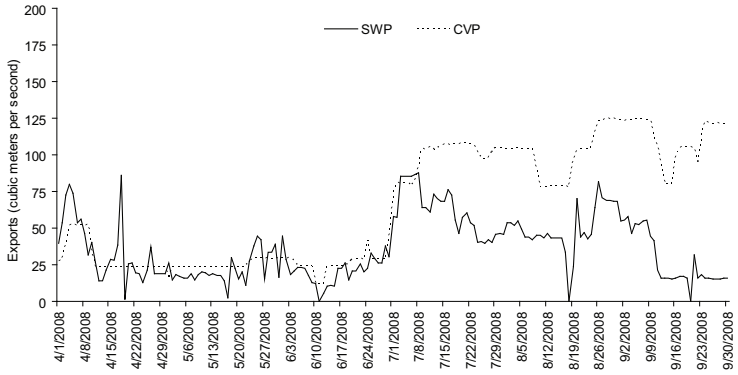

Figure 2 State Water Project and Central Valley Project Pumpings, April through September 2008

Abundance and Distribution Trends of Calanoid Copepods of the Upper San Francisco Estuary

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Introduction

Zooplankton are planktonic invertebrate animals that feed on phytoplankton, bacterioplankton, and other zooplankton. Zooplankton play a key role as a secondary component of the aquatic food web by providing nutrients and energy sources to higher level organisms such as fish, birds and ultimately humans. Zooplankton also help us assess the health of the aquatic ecosystem, since they respond to various environmental stressors including changes in salinity, phytoplankton abundance, water quality, temperature, and freshwater inflow.

This summary describes abundance and distribution of several calanoid copepods during spring and early summer in the upper San Francisco Estuary using data collected by the California Department of Fish and Game's (CDFG) 20mm Survey. This project has been collecting larval fish and zooplankton since 1995, and was designed to "provide recent information on the distribution and relative abundance of delta smelt throughout the delta and estuary" (CDFG 2007). The success of larval and juvenile striped bass, and planktivorous delta smelt throughout their lives, is closely related to prey densities (Boynton et al. 1981, Nobriga 2002, Bryant and Arnold 2007, Slater 2007). Therefore, it is critical to monitor and analyze the abundance and distribution of zooplankton in the upper esturay.

The 4 calanoid copepods discussed are *Pseudodiaptomus forbesi*, *Eurytemora affinis*, *Sinocalanus doerrii*, and *Acartia* spp. Adults of these taxa were selected because they are the most common calanoid copepods in the upper estuary and are important prey items for delta smelt. Annual abundance trends, distribution by salinity zone, and species composition by salinity zone are presented.

Methods

Zooplankton samples were collected twice monthly by CDFG's 20mm Survey from April through June, 1995 to 2005; occasionally, sampling began in March and extended into August. Sampling was conducted at 52 stations throughout the upper estuary (Figure 1). Zooplankton were collected concurrently with fish at all stations in order to analyze food resources for the fish caught. Areas sampled included San Pablo Bay, Napa River, Suisun Bay, the confluence of the Sacramento and San Joaquin rivers, and upstream into the lower Sacramento River, the lower San Joaquin River, and the south and central delta. A modified Clarke-Bumpus (CB) net with a 160 µ mesh was obliquely towed at each station to obtain zooplankton samples. All valid samples were included in the data analysis, and most stations were sampled consistently throughout the time period. However, some stations in San Pablo Bay and the Napa River were sampled only during high river flow years, and a few stations were discontinued since 1995.

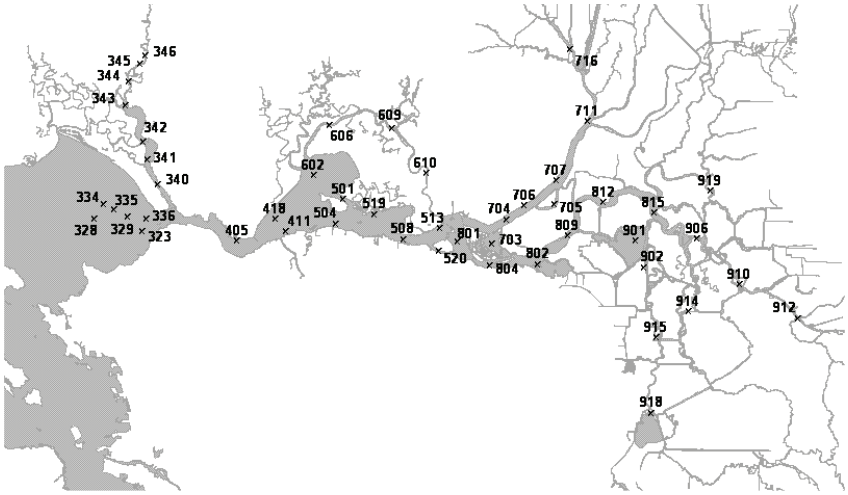

Figure 1 Map of the 20mm Survey sampling stations in the upper San Francisco Estuary

A YSI® Model 85 meter (YSI Corporation, Yellow Springs, Ohio) was used to measure and standardize the bottom electrical conductivity (EC) to 25°C at each station. Each sampling event was then classified into 1 of 4 salinity zones based on the Venice System (Anonymous 1958) according to EC (Table 1). The number of sampling events in the limnetic zone was about 4 times greater than in the oligohaline or mesohaline zones, and only a few samples were from the polyhaline zone (Table 2). Furthermore, no sample was taken in 1995, 1998, and 2005 in the polyhaline zone. The 20mm Survey procedures (CDFG 2007) were followed to obtain zooplankton abundance or catch-per-unit-effort (CPUE), reported as number per cubic meter (number/m^3) of water sampled. To calculate CPUE, the sub-sample count for each taxon was expanded for the entire dilution volume, which was then divided by sample volume.

Table 1 The salinity ranges of the Venice system and EC conversion

Salinity zone	*Salinity (ppt)*	*Standardized bottom EC (mS/cm)*[a]
Limnetic	< 0.5	< 1
Oligohaline	0.5- 5	1- 9
Mesohaline	5-18	9- 29
Polyhaline	18- 30	29- 46.25
Euhaline	≥ 30	≥ 46.25

[a] indicates milli-Siemens per centimeter

Table 2 Number of sampling events by year and salinity zone

Year	Limnetic	Oligohaline	Mesohaline	Polyhaline	All zones
1995	247	19	27	N/S[a]	293
1996	211	41	51	3	306
1997	179	72	68	9	328
1998	267	43	16	N/S	326
1999	204	56	38	1	299
2000	224	79	57	2	362
2001	178	66	79	7	330
2002	158	80	70	5	313
2003	208	62	46	1	317
2004	165	62	74	6	307
2005	271	52	22	N/S	345
1995-2005	2312	632	548	34	3526

[a] indicates "not sampled"

Results

By Species

Pseudodiaptomus forbesi is an introduced calanoid copepod first detected in the upper San Francisco Estuary in 1987 that is most common from fresh to low salinity water (Orsi and Ohtsuka 1999). *P. forbesi* has been one of the most abundant calanoid copepods in the upper estuary since 1989 (Hennessy 2008), where it is an important food item for delta smelt and young striped bass (Nobriga 2002, Bryant and Arnold 2007). *P. forbesi* abundance usually peaks in June and July, with major concentrations found in the lower San Joaquin River, and abundance has decreased slightly since its introduction (Hennessy 2008). The annual abundance has decreased slightly since its introduction. The 20mm zooplankton data also observed a gradual decline in abundance of *P. forbesi* from 1995 to 2005 within the study area (Table 3).

P. forbesi was mainly found in the limnetic and oligohaline zones of the estuary (Table 3). From 1995 to 2000, the higher outflow years of the study, *P. forbesi* was usually most abundant in the oligohaline zone (Table 3), with major concentrations in the lower Napa River, Suisun Marsh, and the confluence of the Sacramento and San Joaquin rivers from June through August. During the lower outflow years of the study, 2001 through 2005, *P.*

forbesi was generally most abundant in the limnetic zone, which was further upstream in the delta.

An unusually high *P. forbesi* CPUE of 11,575/m^3 occurred in 1998 in the oligohaline zone (Table 3). This was mainly attributable to very high densities in Napa River in June and July. Throughout the estuary, *P. forbesi* abundance is low until late spring or early summer when water temperatures increase; abundance remains high through the summer and fall before declining again in winter (Hennessy 2008). Usually, the lower Napa River is mesohaline by late spring or early summer, when water temperatures are optimum for *P. forbesi.* However, higher outflow later in 1998 kept the area oligohaline through July, creating the right combination of higher temperatures and low salinity water where *P. forbesi* thrives. Similarly, high abundance of *P. forbesi* occurred in the oligohaline zone in 2000 and 2003 due to the combination of low salinity water and higher temperatures in June in the Napa River.

Eurytemora affinis was introduced to California around 1879 (Orsi 1995). Historically, *E. affinis* was the most abundant calanoid copepod in the upper estuary, where it was a favored food for delta smelt and larval striped bass (Nobriga 2002, Bryant and Arnold 2007). However, its abundance has declined consistently since the late-1980s, when the Asian clam, *Corbula amurensis*, and the calanoid copepod, *P. forbesi*, were introduced to the estuary (Hennessy 2008). The average annual CPUE of *E. affinis* in all salinity zones continued to decline after a peak in 1999 and 2000, and annual CPUE was below 100/m^3 from 2003 to 2005 (Table 4).

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Table 3 Abundance (number/m^3) of *Pseudodiaptomus forbesi* by year and salinity zone

Year	Limnetic	Oligohaline	Mesohaline	Polyhaline	All zones
1995	2,258	2,147	405	N/S	2,080
1996	1,433	1,458	231	0	1,222
1997	1,428	1,079	150	30	1,048
1998	1,728	11,575	2,644	N/S	3,072
1999	2,305	1,443	184	0	1,866
2000	1,856	2,263	428	0	1,710
2001	1,428	936	35	694	981
2002	542	186	36	0	329
2003	506	2,426	76	0	817
2004	777	433	26	4	511
2005	701	337	4	N/S	602
1995-2005	1,395	1,910	214	152	1,292

Table 4 Abundance (number/m^3) of *Eurytemora affinis* by year and salinity zone

Year	Limnetic	Oligohaline	Mesohaline	Polyhaline	All zones
1995	169	1,732	257	N/S	278
1996	165	54	10	0	123
1997	196	35	3	0	115
1998	117	706	2	N/S	189
1999	551	269	56	0	434
2000	112	1,261	87	0	358
2001	213	95	51	1	146
2002	161	70	43	0	109
2003	93	77	25	0	80
2004	100	45	8	0	65
2005	61	112	21	N/S	66
1995-2005	171	329	44	0	178

E. affinis was most abundant in the oligohaline zone in high outflow years and in the limnetic zone in low outflow years (Table 4). In the high outflow years, especially 1995, 1998, and 2000, abundance was highest in the lower Napa River in April and May. From 2001 through 2005, the lower outflow years, the center of abundance shifted upstream to the central and southern delta, with the highest CPUE occurring from March through May.

Sinocalanus doerrii is an introduced calanoid copepod first observed in the estuary in 1978 that is most common in fresh and low salinity waters (Orsi et al. 1983). Like *E. affinis* and *P. forbesi*, *S. doerrii* is a favored food for larval and young striped bass (Bryant and Arnold 2007). The mean annual abundance of *S. doerrii* decreased between the mid-1980s and the mid-1990s, but increased moderately since the late-1990s in the estuary (Hennessy 2008). Unlike *E. affinis* and *P. forbesi*, which usually peak around the same time each year, *S. doerrii* abundance peaks at different times in different parts of the estuary (Hennessy 2008). In the 20mm zooplankton data, the mean annual abundance of *S. doerrii* was relatively low in the high outflow years of 1995, 1996 and 1998 across all salinity zones (Table 5). Abundance recovered from 1999 to 2003, but decreased again in 2004 and 2005, all lower outflow years. The effect of outflow on the abundance of *S. doerrii* was more variable than for the other calanoid copepods discussed in this summary.

S. doerrii mainly occurred in the limnetic and oligohaline zones (Table 5), with major concentrations in Suisun Marsh and the confluence in May and June. *S. doerrii* distribution was also less predictable based on outflow than the other species discussed. CPUE was high in the limnetic zone in 1999, 2001, 2002, and 2003, years with vastly different outflow.

The genus *Acartia* includes several species of calanoid copepods that are native to the San Francisco Estuary. It is the most abundant calanoid in the higher salinity areas of the estuary (Kimmerer and Orsi 1996). The abundance of *Acartia* spp. is strongly affected by river outflow (Baxter and Hieb 2005). The mean annual abundance of *Acartia* spp. sharply decreased in the mid-1990s but gradually recovered since then as outflow decreased (Hennessy 2008). In the 20mm data, the mean annual abundance of *Acartia* spp. was very low between 1995 and 1998 in all salinity zones, but increased from 1999 to 2001 (Table 6). The abundance peaked in 2001, the lowest outflow year of the study period, and continuously decreased since 2002 across all salinity zones. However, low or no sampling events in the polyhaline zone probably contributed the low average CPUE of *Acartia* spp. in several low outflow years.

Table 5 Abundance (number/m^3) of *Sinocalanus doerrii* by year and salinity zone

Year	Limnetic	Oligohaline	Mesohaline	Polyhaline	All zones
1995	87	97	11	N/S	81
1996	73	53	2	0	58
1997	347	135	2	0	220
1998	69	259	3	N/S	91
1999	406	240	8	0	323
2000	382	506	20	0	350
2001	575	477	20	135	413
2002	441	432	15	0	337
2003	502	423	13	0	414
2004	289	199	6	0	197
2005	123	184	9	N/S	125
1995-2005	278	305	11	28	239

Table 6 Abundance (number/m^3) of *Acartia* spp. by year and salinity zone

Year	Limnetic	Oligohaline	Mesohaline	Polyhaline	All zones
1995	0	0	71	N/S	7
1996	0	0	20	97	4
1997	0	0	0	2	0
1998	0	1	3	N/S	0
1999	0	231	764	2,716	149
2000	0	3	1,045	739	169
2001	0	16	1,720	9,786	623
2002	0	10	605	2,147	172
2003	0	94	993	373	164
2004	0	100	477	177	139
2005	0	2	357	N/S	23
1995-2005	0	43	654	2,505	134

Acartia spp. was consistently most abundant in the mesohaline and polyhaline zones (Table 6), although abundance was relatively low in the high outflow years of 1995 through 1998. During the low outflow years, 2001 through 2005, *Acartia* spp. was most abundant in San Pablo Bay, but was also abundant in Carquinez Strait and western Suisun Bay. The relatively low abundance in mesohaline and polyhaline zones between 1995 and 1998 was probably due to high outflows keeping *Acartia* seaward of the sampling area.

Between Species

In the limnetic zone, *P. forbesi* was the most dominant calanoid copepod, but its abundance gradually decreased during the study period (Figure 2A). The decline was possibly caused by an explosive increase of the cyclopoid copepod *Limnoithona tetraspina* beginning in 1993 (Bouley and Kimmerer 2006). In 1995, 1996, 1998, and 1999, *E. affinis* was the second most common calanoid in the limnetic zone. However, *S. doerrii* has replaced *E. affinis* as the second most abundant calanoid copepod in this zone since 2000. This coincided with the lower outflows that occurred 2001 through 2005, possibly indicating that *S. doerrii* is more successful than *E. affinis* during low

outflow periods. The annual abundance trends of *P. forbesi* and *E. affinis* were proportional to each other, but *S. doerrii* abundance was often inversely proportionate to *P. forbesi* and *E. affinis*.

In the oligohaline zone, *P. forbesi* was the most abundant calanoid copepod during most years, except 2002 when *S. doerrii* was most abundant (Figure 2B). During the high outflow years of the study, *E. affinis* was the second most abundant species, whereas *S. doerrii* was the second most abundant copepod in this zone from 2001 to 2005. *S. doerrii*, which maintained a relatively high abundance throughout the study years, may be one of the reasons that recovery of *E. affinis* was suppressed in the oligohaline and limnetic zones.

In the mesohaline zone, *P. forbesi* was the most abundant calanoid species from 1995 to 1998, the high outflow years (Figure 2C). However, *Acartia* spp. replaced *P. forbesi* in 1999 as the most dominant species, probably because low outflow allowed *Acartia* to again occupy the upper estuary. In 2001 and 2002, *P. forbesi* was the third most common copepod in this zone, with a lower average annual CPUE than *E. affinis*. In 2005, the average CPUE of *P. forbesi* was even lower than that of *S. doerrii* and became a rare species in the mesohaline zone.

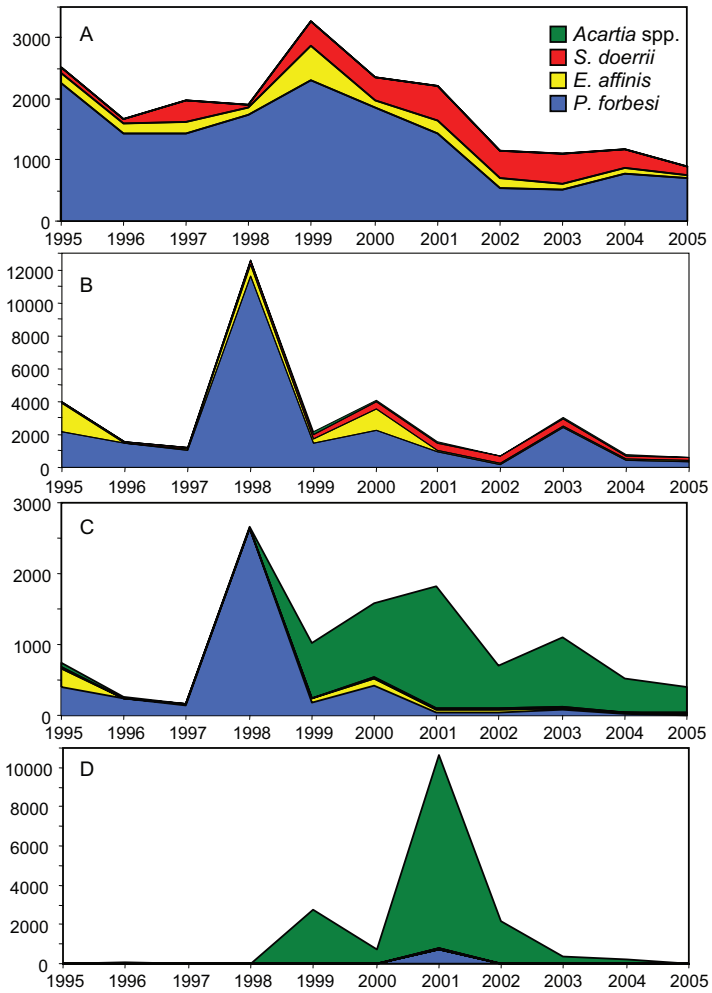

Figure 2 Abundance (number/m^3) of 4 major calanoid copepods, 1995-2005, in the limnetic (A), oligohaline (B), mesohaline (C), and polyhaline zones (D)

In the polyhaline zone, *Acartia* spp. was the most dominant calanoid copepod for all years sampled (Figure 2D). The highest abundance of *Acartia* spp. was in 1999, 2001 and 2002, years with moderate or low outflow. However, the low abundance of *Acartia* in 2000, 2003, and 2004, years that also had relatively low freshwater outflow, may be due to low sample size. In 2001 when the abundance of *Acartia* peaked, a relatively high abundance

of *P. forbesi* and *S. doerrii* was also observed in the polyhaline zone.

In conclusion, the overall abundance of the major calanoid copepods has gradually decreased in the upper San Francisco Estuary since the inception of the 20mm Survey in 1995. In the Zooplankton Study data, the abundance trends of these calanoid copepods were similar (Hennessy 2008). Both studies support the conclusion that the availability of calanoid copepods as a food source for larval and young fish has decreased.

Salinity was the major factor controlling distribution, but in high outflow years, the center of distribution of several species shifted to a higher salinity zone. For example, E. *affinis* was usually most abundant in the oligohaline zone in high outflow years and in the limnetic zone in low outflow years. Temperature was also an important factor, as evidenced by the high *P. forbesi* CPUE in the Napa River in several years. It is likely that abundance and distribution of calanoid copepods are affected by many different factors, including freshwater outflow, salinity, temperature, food supply, and competition with or predation by introduced species.

Acknowledgements

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2007 Fall-Run Chinook Salmon Smolt Production in the San Joaquin River Basin: Kodiak Trawl at Mossdale

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Monitoring of the fall-run Chinook salmon smolt outmigrant population, from the San Joaquin drainage, is conducted by California Department of Fish and Game (CDFG). This essential measurement of timing and production of fall-run Chinook salmon smolts has been performed since 1988 at this location in order to:

- Determine annual salmon smolt production in the San Joaquin Basin
- Develop smolt production trend information
- Determine timing and magnitude of smolt outmigration into the Delta from the San Joaquin tributaries
- Document the occurrences of other species including listed species such as steelhead and delta smelt

Department of Fish Game conducted the Kodiak Trawl at Mossdale from April 1 to June 30, 2008. The sampling intensity was 5 days a week between April 1, 2008 to June 6, 2008, and 3 days a week between June 9, 2008 and June 30, 2008. There were 59 sampling days out of the study period of 91 days. A normal sample day would consist of 10 tows, 20 minutes each. Sampling is performed with a 6 by 25 foot (1.87m x 7.6m) Kodiak trawl net that uses two boats to pull a net equipped with spreader bars. The cod end of the trawl net is secured using a rope.

All fish were identified to species and enumerated. The first 30 individuals per tow of all species were measured, and only enumerated after the first 30 measurements. All Chinook salmon were measured and checked for any marking. During 2008 study period, we caught 13,472 fish representing 24 species, and 7 fish were unable to be identified due to advance decomposition or damage by net (Table 1). There were 4 steelhead/rainbow trout (*Oncorhynchus mykiss)* caught during this study period, which was one of the lowest years since 1998 (Figure 1).

Between April 1 and June 30, 2008, 1,696 unmarked Chinook salmon smolts were captured in the Mossdale trawl (Figure 2). Average forklength of non-marked Chinook was 88.3 millimeters (mm) and ranged from 58 to 129 mm. Preliminary Chinook smolt production estimate for 2008 in the San Joaquin basin is 188,652 using the smolt per acre feet estimate, and 285,887 using the population ratio estimate. This is the lowest Chinook smolt production estimate since 2001.

Table 1 Total number of species caught at Mossdale from April 1 to June 30, 2008

Species	Number Caught
American Shad	16
Bass (Unknown Species)	6596
Bluegill	22
Black Crappie	1
Common Carp	8
Channel Catfish	18
Chinook	1696
Chinook Dye Marked	1249
Chinook CWT	0
Goldfish	3
Golden Shiner	44
Largemouth Bass	13
Inland Silverside	593
Pacific Lamprey	5
Rainbow Trout	4
Redear Sunfish	3
Red Shiner	76
Sacramento Pikeminnow	2
Sacramento Sucker	14
Sacramento Blackfish	1
Smallmouth Bass	1
Splittail	521
Striped Bass	55
Threadfin Shad	2443
Tule Perch	2
Unidentified Fish	7
White Catfish	70

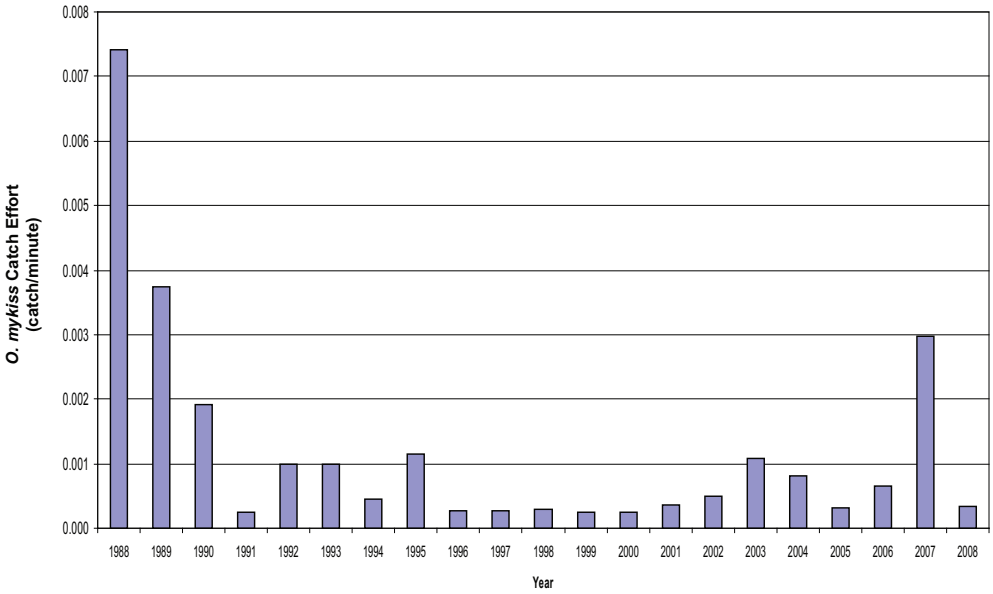

Figure 1 Catch effort of *O. mykiss* caught since 1988

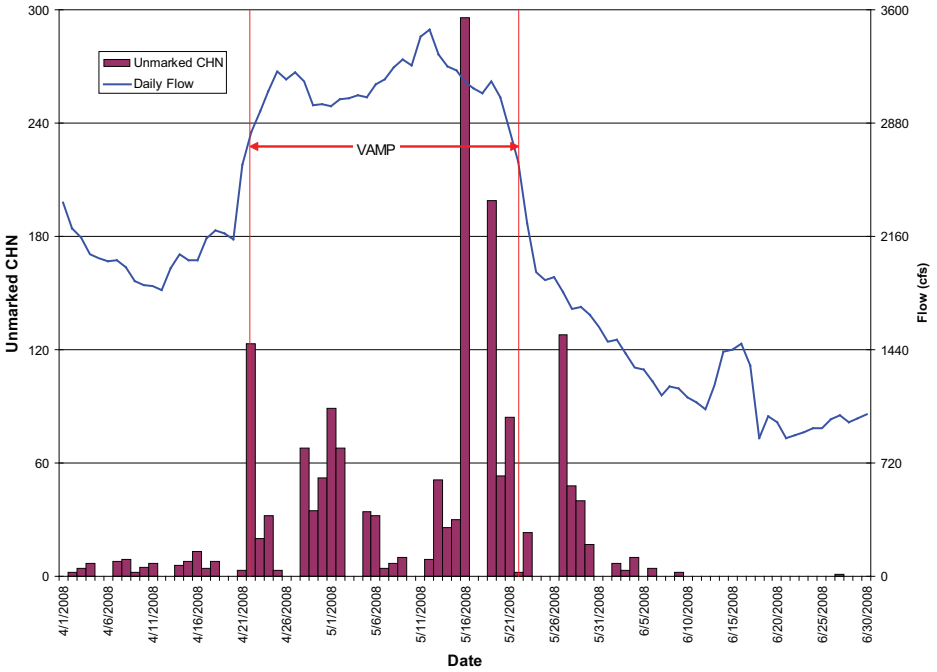

Figure 2 Number of unmarked CHN caught from April 1 to June 30, 2008

Update on the Midwater Trawl Mouth Geometry Evaluation

Jennifer Messineo (DFG), jmessineo@dfg.ca.gov

In order to calculate fish abundance estimates from midwater trawl catch data, it's necessary to first determine the volume of water sampled by the gear. The amount of water "fished" by a net depends upon the size and variation in size of the mouth opening while it's under tow. Currently, the Department of Fish and Games's (DFG) Fall Midwater Trawl (FMWT) and San Francisco Bay Study (Bay Study) surveys sample with a midwater trawl net. The netmouth is 12 ft by 12 ft with a metal "door" attached to each corner that connects to the bridles; top and bottom bridle cables connect together at a swivel 100 ft ahead of the net mouth and the swivel in turn is connected to the main warp (cable attached to winch) (Figure 1). The two bottom doors are weighted, the top doors possess a float and all are designed to act like hydrofoils and spread ropes forming the net mouth while under tow. Mouth geometry is likely to be influenced by numerous factors including vessel speed, length and material of warp deployed, current strength, and gear depth. To date, there has been little research on midwater trawl net mouth geometry.

The goal of this project is to document mouth geometry under the range of tow conditions experienced while trawling in the delta. Specifically, we'd like to explore the effects of: 1) tow direction with respect to water current, 2) warp material (steel cable vs. Kevlar spectra) and length of warp deployed, and 3) top and bottom door contact with the surface and bottom, respectively.

To address our questions, we have worked with Desert Star Systems (Marina, CA) in the development of a wired acoustic system, to determine the area of the net mouth opening while it's fishing. We're using a custom designed acoustic system that relays real-time net mouth area data to a laptop where it is recorded. The electronic system includes four small "responders", one attached to each corner of the net mouth, which are individually connected via 30 ft cables to a junction box that connects 300 ft of cable to the surface station aboard the research vessel. Via synchronization signals, the software calculates the distances between the responders and the area of the midwater trawl mouth opening every 4 seconds.

To date, we have successfully conducted 32 tows with the midwater trawl: 16 on the R/V *Scrutiny* using Kevlar spectra warp and 16 on the R/V *Longfin* using steel cable warp. We are currently examining the data and preliminary results show an average net mouth area close to the 10.7 m^2 used in the Bay Study's midwater trawl volume calculations during the majority of the tow. However, it appears that the mouth area contracts during the last one-third of the tow when retrieving the bridles. At this point, the top doors of the net are at the surface and no longer strongly planing away from the bottom doors. We also tested the system accuracy by hanging transponders from the dock at fixed measured locations and have found less than 1% difference in the actual versus calculated areas.

We plan to use this system to investigate the midwater trawl mouth area and its variation from each vessel currently used for survey trawling. Since the midwater trawl net is used by both the Fall Midwater Trawl and San Francisco Bay Study (Bay Study) surveys, we will be towing with the vessels and equipment used by each. Eventually, we hope to expand our efforts to include the mouth area of other types of gear such as the Spring Kodiak Trawl and Bay Study's otter trawl.

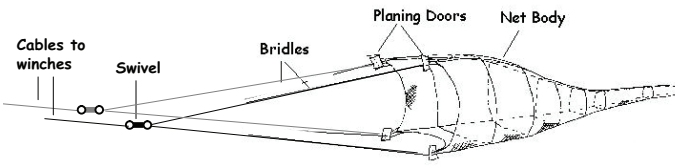

Figure 1 Midwater trawl diagram showing net, planing doors, bridles and cables as it might look when being towed

California Halibut in the San Francisco Estuary

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In 2008, anglers pursuing California halibut, *Paralichthys californicus*, in the San Francisco Estuary had unprecedented success. Anglers have found success with almost every type of bait and lure and full bag limits have been common since May 2008. Although fish weighing up to 40 lbs have been landed, the vast majority of retained fish were in the 22-25 inch (559-635 mm) range (Fraser, personal communication, see Notes). Many party boat skippers have been quoted as saying that this year's

success is an obvious indicator of the health of the halibut population, but whether this is true is a case for debate.

California halibut is an opportunistic predator and a wide range of prey items have been documented among stomach contents. During the first 3 years of life (up to 300 mm TL) the diet is dominated by crustaceans, a large portion of which is mysids and caridean shrimp (Wertz and Domeier 1997). In southern California, gobies represented a significant part of the diet for juveniles (Drawbridge 1990); this is likely true for San Francisco Bay as well. California halibut over 300 mm TL are predominately piscivorous and feed primarily on northern anchovy *Engraulis mordax,* Pacific sardine, *Sardinops sagax,* white croaker, *Genyonemus lineatus*, and other flatfishes (Wertz and Domeier 1997).

Both the eggs and larvae of California halibut are pelagic. Once they settle, juveniles spend the early part of their life foraging in shallow bays, estuaries and sheltered portions of the open coast. Estuaries and other embayments are an extremely important nursery habitat for juvenile halibut. In southern California, over a 2-year period, elemental fingerprinting showed that although only 15% of potential nursery habitat occurred within embayments, 58% of juvenile halibut were determined to have embayment origins (Fodrie and Levin 2008).

California halibut is a subtropical species and requires warm water for successful reproduction. Laboratory experiments have shown that almost no larvae survived at day 17 in water temperatures less than or equal to 12°C, and highest larval survival occurred in water temperatures between 16 and 24°C (Gadomski et. al. 1991). In the northern part of its range, San Francisco Estuary included, ocean temperatures fluctuate seasonally, but rarely remain warm for an extended period of time, and therefore successful spawning events are infrequent.

Over the entire study period (1980 to present), the San Francisco Bay Study (CDFG) data set showed only 4 strong year classes of California halibut in the estuary (Figure 1). These cohorts were concurrent with warm water events associated with the early 1980s, early 1990s, late 1990s, and most recently late 2004 and early 2005 (Figure 2). Only 2 age-0 California halibut have been collected since early 2006. The largest individuals from this most recent year class reached legal size (22 inches or 559 mm) in fall 2007, which illustrates why the fishing was so productive in spring 2008.

Halibut fishing inside the estuary has remained strong since May 2008, but because there has not been successful spawning since 2005, this trend may not last. There is concern that with the increased fishing pressure on California halibut due to salmon and groundfish closures and increased public awareness, the spawning stock for this valuable fishery may be over harvested before we see another warm-water event suitable for strong halibut recruitment.

California Department of Fish and Game continues to collect data and assess the current regulations through a variety of research projects. The San Francisco Bay Study continues to provide valuable information on recruitment and age-class structure. The halibut tagging program provides data on growth rates and movement patterns. California Department of Fish and Games's Marine Region has also recently implemented a special study which addresses mortality of released fish based on hook type and wound location and is also collecting otoliths and fin clips to determine natal origins of halibut within the San Francisco Estuary.

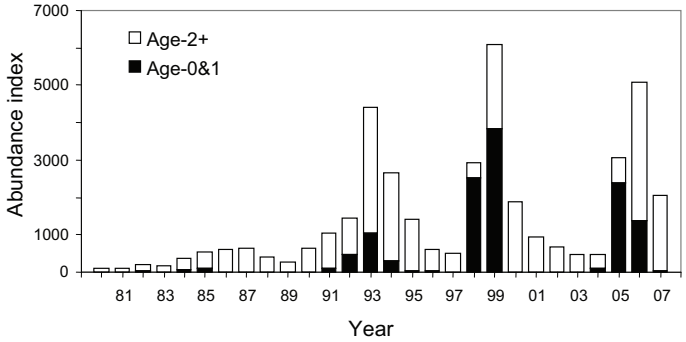

Figure 1 Annual abundance of juvenile (age-0 and age-1) and age-2+ California halibut, Bay Study otter trawl, February-October

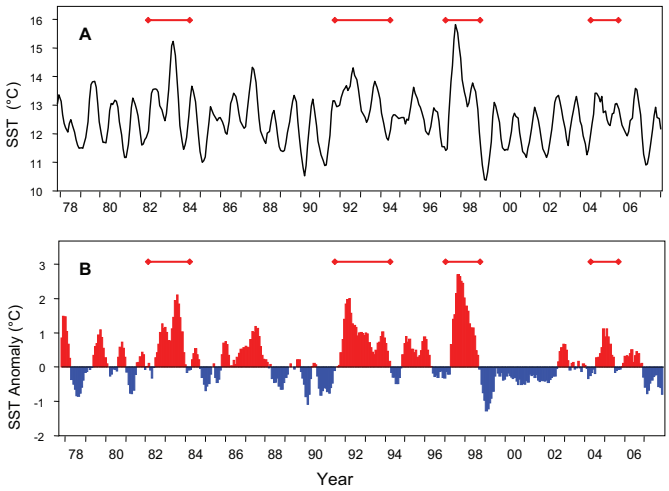

Figure 2 Sea surface temperatures (A) and anomalies (B) at Southeast Farallon Island, with periods of strong California halibut recruitment indicated by the red horizontal bars. PRBO unpublished data

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Notes

Fraser, Keith. Operator of Loch Lomond Live Bait and Tackle shop**.** Personal communication, phone conversation 14 July, 2008

Point Reyes Bird Observatory Conservation Science (PRBO). Sea surface temperatures, unpublished data

■ Interagency Ecological Program for the San Francisco Estuary ■

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