IEP Environmental Monitoring Program
Zooplankton Study Metadata

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I. Contact Information

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II. Study Mandate and Objectives

The State Water Resources Control Board (SWRCB) sets water quality objectives to protect beneficial uses of water in the Sacramento-San Joaquin Delta and Suisun and San Pablo bays. These objectives are met by establishing standards mandated in water right permits issued to the Department of Water Resources (DWR) and U.S. Bureau of Reclamation (USBR) by the SWRCB. The standards include minimum Delta outflows, limits to Delta water export by the State Water Project (SWP) and the Central Valley Project (CVP), and maximum allowable salinity levels.

In 1971, the State Water Resources Control Board (SWRCB) established Water Right Decision 1379 (D-1379). This Decision contained new water quality requirements for the San Francisco Bay-Delta Estuary. D-1379 was also the first water right decision to provide terms and conditions for a comprehensive monitoring program to routinely determine water quality conditions and changes in environmental conditions within the estuary. The monitoring program described in D-1379 was developed by the Stanford Research Institute through a contract with the SWRCB. Implementation of the monitoring program began in 1972, as SWRCB, DWR, and USBR met to define their individual responsibilities for various elements of the monitoring program. In 1978, amendments to water quality standards were implemented and resulted in Water Right Decision 1485 (D-1485). These standards were again amended under the 1995 Water Quality Control Plan and Water Right Decision 1641 (D-1641) established in 1999. The SWP and CVP are currently operated to comply with the monitoring and reporting requirements described in D-1641. D-1641 requires DWR and USBR to conduct a comprehensive environmental monitoring program to determine compliance with the water quality standards and submit an annual report to the SWRCB discussing data collected.

The Zooplankton Study is one element of the Environmental Monitoring Program (EMP) conducted under the Interagency Ecological Program (IEP) umbrella. The EMP also includes monitoring of water quality, benthos, and phytoplankton. The Zooplankton Study monitors abundance and distribution of mysid shrimp and zooplankton; which are important food organisms for larval, juvenile, and small fishes, including delta smelt, juvenile salmon, striped bass, and small splittail. Initiated to investigate the population trends of pelagic organisms consumed by young striped bass, the original Neomysis-Zooplankton Project sought to determine the annual and seasonal population levels of *Neomysis mercedis*, other mysids, and

various zooplankton taxa in order to assess the size of the food resource for fishes. The study also seeks to detect the presence of exotic species recently introduced to the estuary, to monitor the distribution and abundance of these exotics, and to determine their impacts on native species.

III. Study Area and Sample Sites

A. General Information

Geographic coverage of the sampling sites ranges from San Pablo Bay east through the upper estuary including Suisun Bay, Suisun Marsh, the lower Sacramento River upstream to Rio Vista, the San Joaquin River upstream to Stockton, and the southern Delta to Old River. A total of 90 sites have been sampled at various times during the life of the project. However, on no survey were all stations sampled. Currently, 17 fixed stations are sampled monthly (Figure 1). Three additional fixed stations are sampled monthly when outflow is high and therefore surface specific conductance is less than 20,000 microSiemens per centimeter at these stations. Between 2 and 4 non-fixed entrapment zone stations (where bottom specific conductance is 2,000 and 6,000 microSiemens per centimeter) are also sampled monthly.

B. Name and Location Information for Zooplankton Sampling Sites

1. Currently Sampled Stations (Table 1)
2. Historically Sampled Stations (Table 2)

IV. Period of Record

Zooplankton monitoring began in 1968 with the mysid *Neomysis mercedis*. In 1972 monitoring expanded to include copepods, cladocerans, and rotifers.

V. Sampling Frequency

Sampling was conducted at least monthly during most months, except historically not in January, February, and December. Some years sampling was conducted twice a month during some months, usually March through October. Currently, sampling is conducted once a month during all months in conjunction with the Department of Water Resources EMP discrete water quality sampling.

- Sampling frequency by month and year (Table 3)

VI. Data availability in EMP's zooplankton database through 2018

A. Sampling events

- Number of sampling events per station per year: all conducted sampling events (Table 4)

B. Samples

- Number of valid samples per year by gear (Table 5): mysid samples with valid data, including those without mysids (Table 5, Column B); CB samples with valid data (Table 5, Column C); pump samples with valid data (Table 5, Column D).

VII. Field Collection Methods

Three types of sampling gear are used by the project to target different sizes of zooplankton; a mysid net, a Clarke-Bumpus net (CB net, targets adult and juvenile copepods, and cladocerans), and a pump (targets adult and juvenile cyclopoid copepods of the genera *Limnoithona* and *Oithona*, copepod nauplii, and rotifers). The CB and mysid nets are mounted on a sampling sled with the CB net mounted directly above the mysid net (Figure 2). The sampling sled is made of a tubular steel frame (Figure 3), with diving plates (Figure 4), and a plexiglass CB housing (Figure 5). The sled is towed through the water column in a stepwise oblique fashion, according to the tow schedule (Table 6), to sample the entire water column. Start meter readings are recorded on the datasheet (Figure 6) before the tow begins, and end meter readings recorded immediately upon sled retrieval.

Samples are preserved in 10% formalin with Rose Bengal dye to aid in separating organisms from detritus and algae. One quart glass sample jars are taken into the field with 100mL of full-strength formaldehyde in each. The lid of each sample jar is labeled with the gear, survey, and year. Samples are rinsed using a wash-down hose with ambient water from the outside of the net into the cod-end, paying special attention to carefully rinse all seams where organisms get caught. After the sample is thoroughly rinsed into the cod-end, the cod-end is unscrewed and the sample swirled to suspend all organisms before the sample is poured into the appropriately-labeled sample jar with formaldehyde. The cod-end is dipped halfway into a bucket with ambient water (be sure mouth of cod-end is not submerged), swirled gently and the contents of the cod-end is poured into the sample jar until the sample jar is full. A tag with the gear, survey, and year are also placed into the sample jar.

A. Mysid net

The mysid net, from 1968 through 1970, was made of 1 mm silk bolting cloth, was 1 m long and had a mouth area of 0.1 m^2. From 1971 through 1973 the Neomysis net was made of 0.93 mm mesh nylon cloth, had a 30 cm mouth diameter, and was 0.7 m long. From 1994 to the present, the mesh size has been 0.505 mm, the outer mouth diameter 30 cm (interior mouth diameter 28 cm) and the length 1.48 m (Figure 7). All mysid nets tapered to 76 mm at the cod end where a polyethylene jar screened with 0.503 mm mesh wire cloth captured the mysids. Until 1973, Pygmy flow meters were used to estimate water volumes filtered by the mysid net. From 1974 to present General Oceanics model 2030 flow meters have been used.

B. Clarke-Bumpus net

The Clarke-Bumpus net (CB net), from 1971 through October 2004, was made of 0.160 mm mesh nylon cloth (No. 10 mesh), had an outer mouth diameter of 12.5 cm (interior mouth diameter of 12.4 cm), and a length of 76 cm. It tapered to 45 mm at the cod-end where a polyethylene jar screened with 0.140 mm mesh wire cloth collected organisms. The original brass CB net-frame possessed an integrated flow meter. Beginning November 2004, the study began using a new CB frame design,

because the manufacturer discontinued production of the historically used brass CB frames. The new frame consisted of an acrylic cylinder 12.5 cm outer diameter (interior mouth diameter of 12.0 cm, due to new acrylic frame being thicker than previous metal frame) by 19.0 cm long (Figure 5) with a General Oceanics model 2030 flow meter bracketed inside. The new net was made of 0.160 mm mesh nylon cloth (No. 10 mesh), had an inner mouth diameter of 13 cm, and a length of 73 cm (84.75 cm including the canvas mouth and end) (Figure 8). It tapered to 50mm at the cod-end where a polyethylene bottle screened with 0.140mm mesh wire cloth collected organisms.

C. Pump

The siphon pump for microzooplankton collection was a Teel 12 volt self-priming marine utility pump with a capacity of 14.7 L/min connected to a 15 m-long hose, which had a weighted nozzle at the lower end (Figure 9). From 1972 through January 2008, pumped water was collected in a 19 L carboy, which was then shaken to homogenize the sample, and the entire contents poured off while a 1.5-1.9 L sample was decanted into a half-gallon jug containing 100 mL of full-strength formaldehyde and Rose Bengal Dye. The volume of the retained sample was measured in the laboratory. Beginning February 2008, a larger sample volume was collected by the same pump and concentrated. A GPI in-line flow meter measured the volume of water sampled as the water was discharged into a plankton net of 35 micron mesh fitted with a cod end for sample collection. The pump was lowered to the bottom and retrieved in a step-wise fashion according to a tow schedule (Table 7) to sample the entire water column as evenly as possible. The pump was turned off and sampling ceased when an approximately 19.8 gallon sample had been collected and the sample volume recorded on the datasheet.

VIII. Lab Processing Methods

A. Mysids and amphipods

Mysids and amphipods are identified and enumerated from macro-zooplankton net samples. Mysids are identified to species level, see mysid lookup table (Table 8) for a brief description of each taxon identified and enumerated. Amphipods were only identified as Gammarus or Corophium type from March 1996 through May 2014. From June 2014 to present, amphipods were identified to species where possible, otherwise to genus (Table 8). Identification references for these taxa include: 1) Tattersal 1932, 2) Tattersal 1951, 3) Mecum 2007, and 4) Ward and others 1959.

Samples are concentrated in the laboratory by pouring them through a 0.5 mm sieve. Subsampling is conducted when samples appear to contain more than 400 organisms. Samples are spread evenly, using a stirring motion to distribute specimens randomly, in a square tray equipped with removable partitions for subsampling. Samples that appear to have more than 400 mysids are divided into 4, 16, or 64 subsamples (Figure 10). The first subsample selected for counting is always the lower right corner of the tray followed by the subsample directly diagonal to the lower right corner (Figure 11); this is random but systematic because the specimens are randomly distributed in the tray.

All mysids in a selected subsample are identified and counted, and additional subsamples are counted until a minimum number of total organisms are reached.

Prior to 1984 a minimum count of 220 was required. This was increased to 400 in 1984 through the present. The first 100 mysids counted are also measured in millimeters from the tip of the eye to the base of the telson (Figure 12). Measurements are rounded up to the nearest millimeter. Beginning in 1976, mysids measured are identified as being juvenile, gravid female, non-gravid female, or male. Gravid females had their eggs and embryos counted starting in 1976. In 1979 staging of eggs and embryos began where eggs were recorded as embryo stage "1", eyed embryos were recorded as embryo stage "2", and comma-shaped embryos were recorded as embryo stage "3". Gravid females with partial egg sacs were not counted until 2001 with "p" standing for partial.

All amphipods in a selected subsample are identified and counted, and additional subsamples are counted until a minimum count of 400 was reached. The threshold number to trigger subsampling was reduced to 100 in 2014 when many more taxa were added for identification and enumeration. The first 50 amphipods are also measured to the nearest 0.5mm from the tip of the rostrum to the base of the telson (Figure 13).

For each station the total number of each macro-zooplankton taxon per cubic meter of water sampled is calculated using the following equation:

N = ((C/S)/V)

Where:

N = the number of a taxon per cubic meter of water filtered
C = the cumulative number of a taxon counted in tray segment(s) (sub-samples) examined
S = fraction of total sample examined (1/number of tray segment(s) examined)
V = the volume of water filtered through the net (m^3) (where Volume filtered is estimated by: VolFiltered = (end meter reading – start meter reading) * calibration factor * mouth area)

B. Clarke-Bumpus

CB samples are concentrated in the laboratory by pouring them through a sieve screened with 0.154 mm mesh wire. Excess formalin is rinsed off sample using tap water. The concentrated sample is rinsed from the sieve into a beaker where the sample is reconstituted to organism densities of 200-400 per milliliter; this volume is recorded as dilution volume. The sample is stirred to distribute the animals homogeneously and a 1 milliliter subsample is extracted with an automatic pipette and placed in a Sedgewick-Rafter cell (slide). All animals on a slide are identified and counted under a compound microscope, see CB and Pump taxon lookup table (Table 9) for a brief description of each taxon identified and enumerated from the CB and pump samples. Identification references for these taxa include: 1) Abiahy and others 2006, 2) Brooks 1957, 3) Davis 1955, 4) Ferrari and Orsi 1984, 5) Light and others 1954, 6) Pennak 1989, 7) Sars 1918, and 8) Ward and others 1959.

Historical Procedure (Samples Collected January 1972- December 2003): Additional 1 milliliter subsamples (cells) were examined until at least 200 animals had been counted.

Procedure (January 2004- December 2005): Targeted examining 6% of dilution volume with no minimum or maximum number of cells required to be examined. Example: Dilution volume of 100 milliliters, 6 Sedgewick-Rafter cells examined (6 ml).

Current Procedure (January 2006- present): In 2006 this protocol was changed to include examination of a minimum of 5 cells and a maximum of 20 cells, while continuing to target examination of 6% of the dilution volume.

The number per cubic meter for each zooplankton taxon taken in the Clarke-Bumpus net was calculated using the following equation:

N = ((C/S)*L)/V

Where:

N = the number of a taxon per cubic meter of water filtered
C = the cumulative number of a taxon counted for the sample
L = the reconstituted sample volume (dilution volume) in milliliters
S = the number of Sedgewick-Rafter cells examined (1 ml ea)
V = the volume of water filtered through the net (m^3) (where Volume filtered is estimated by: VolFiltered = (end meter reading – start meter reading) * calibration factor * mouth area)

C. Pump

Pump samples are processed by measuring and recording the sample volume, then concentrating the sample by pouring through a sieve screened with 0.154 mm mesh (to remove organisms more efficiently sampled by the CB net) followed by one with 0.043 mm mesh. Excess formalin is rinsed off sample using tap water. The concentrated sample is rinsed from the sieve into a beaker where the sample is reconstituted to organism densities of 200-400 per milliliter. The sample is stirred to distribute the animals homogeneously and a 1 milliliter subsample is extracted with an automatic pipette and placed in a Sedgewick-Rafter cell. All animals are identified and counted under a compound microscope, see CB and Pump taxon lookup table (Table 10) for a brief description of each taxon identified and enumerated from the meso-zooplankton and micro-zooplankton samples. Identification references for these taxa include: 1) Abiahy and others 2006, 2) Davis 1955, 3) Donner 1966, 4) Ferrari and Orsi 1984, 5) Light and others 1954, 6) Pennak 1989, and 7) Ward and others 1959.

Historical procedure (Samples collected January 1972- January 2008): All organisms retained by the 0.043 mm mesh were reconstituted in a beaker of water to a density of 200-400 per milliliter, and identified and counted from one or more Sedgewick-Rafter cells.

Procedure for samples collected February 2008 through December 2015: Organisms retained by both sieve sizes (0.043 mm and 0.154 mm) are processed and recorded separately. The portion of the sample retained by the 0.043 mm mesh is recorded as size fraction 1 and the portion of the sample retained by the 0.154 mm mesh is recorded as size fraction 2. Each size fraction is reconstituted in a separate beaker of water to a density of 200-400 per milliliter, and the sample volume of each

recorded as dilution volume. Each size fraction is processed separately by stirring to distribute the animals homogeneously, then a 1 milliliter subsample is extracted with an automatic pipette and placed in a Sedgewick-Rafter cell. Subsequent 1 milliliter subsamples (cells) are examined until approximately 6% of each size fraction is processed with a minimum of 5 cells and a maximum of 20 cells examined for each size fraction. When a small number of organisms were present in the larger size fraction, the entire sample was placed in a counting wheel and counted. To maintain consistency with historical procedure, only smaller size fraction,1, is used to calculate catch-per-unit-effort for matrix.

Procedure for samples collected January 2016 through present: Organisms retained by both sieve sizes (0.043mm and 0.154mm) are retained, but only the organisms in the small size fraction are processed and recorded. The portion of the sample retained by the 0.043 mm mesh is recorded as size fraction 1. The sample is reconstituted in a separate beaker of water to a density of 200-400 per milliliter, and the reconstituted sample volume recorded as dilution volume. The sample is stirred to distribute the animals homogeneously, then a 1 milliliter subsample extracted with an automatic pipette and placed in a Sedgewick-Rafter cell. Subsequent 1 milliliter subsamples (cells) are examined until approximately 6% of each size fraction is processed with a minimum of 5 cells and a maximum of 20 cells examined.

The number per cubic meter for each zooplankton taxon taken in the pump was calculated using the following equation:

N = ((C/S)*L)/V

Where:

N = the number of a taxon per cubic meter of water sampled
C = the cumulative number of a taxon counted for the sample
L = the reconstituted sample volume (dilution volume) in milliliters
S = the number of Sedgewick-Rafter cells examined (1 ml ea)
V = the volume of water sampled (m^3)

Note: Samples collected between January 1972 and January 2008 had the entire sample volume (~1700-1900 ml) examined, counts cumulative not recorded by cell so L=1 and S=1. Samples collected from February 2008 to present were a higher volume (~19.8 gallons), approximately 6% of sample processed with a minimum of 5 cells examined and a maximum of 20.

IX. Data Management and Reporting

A. Field Data

Field data is collected and recorded onto datasheets by DWR personnel. These data are then entered monthly by Department of Fish and Wildlife (DFW) personnel into an Access database that stores the current year's data. Field data is reviewed monthly for accuracy and completeness. Annually, after all samples are processed for the year and lab data are reviewed for accuracy and completeness, the annual data is appended into a larger Access database that stores all of the data from 1972 through the previous year. Field environmental data is entered by DWR staff and

provided to DFW monthly. This data is QC'd by CDFW and appended into the historical database. Chlorophyll-a data is provided by DWR to CDFW 1-2 times per year upon request, QC'd by DFW, and appended into the historical database. A local copy of this database resides on the scientists computer, the server, and a thumb drive, as well as a SQL server on DFW's tier 3 server.

B. Lab Data

Organism identification and enumeration data is directly entered into the current year's Access database by DFW laboratory personnel as the sample is processed. Annually, all lab data are reviewed for accuracy and completeness and the annual data appended into the historical Access database that stores all of the data from 1972 through the previous year. Amphipod length and plus count data resides in a separate database that is linked to the historical database.

C. Data Reporting

An annual status and trends report is produced that summarize the data (https://water.ca.gov/Programs/Environmental-Services/Interagency-Ecological-Program). Annual data summary reports and data are also posted on the California Estuaries Portal at http://californiaestuaryportal.com/.

Catch-per-unit effort data, in number per cubic meter of water sampled, for each valid sample for each gear type are available in Excel with the associated field data through the ftp site (ftp://ftp.wildlife.ca.gov/IEP_Zooplankton/). Associated metadata, including field descriptions, are in each CPUE matrix.

Bubbleplot maps showing densities of organisms at each station and survey are available on the internet at http://www.dfg.ca.gov/delta/data/Zooplankton/CPUE_zoomap.asp.

X. Reference

*A. **Taxonomic References***

Abiahy, Bernardo Barroso do, Carlos Eduardo Falavigna da Rocha, and Frank D. Ferrari. 2006. Redescription of *Limnoithona tetraspina* Zhang et Li, 1976 (Copepoda, Cyclopoida) with a discussion of character states shared with the Oithonidae and older cyclopoids. Invertebrate Zoology 3(2): 115-135.

Brooks, John Langdon. 1957. The systematics of North American Daphnia. Memoirs of the Connecticut of Arts & Sciences Vol. XIII.

Davis, Charles C. 1955. The Marine and Fresh-water Plankton. Michigan State University Press. Michigan.

Donner, Josef. 1966. Rotifers. Trans. by H. G. S. Wright. Fredick Warne & Co. Ltd. New York.

Ferrari, Frank D., and James Orsi. 1984. *Oithona davisae*, new species, and *Limnoithona sinensis* (Burckhardt, 1912) (Copepoda: Oithonidae) from the

Sacramento-San Joaquin Estuary, California. Journal of Crustacean Biology 4(1): 106-126.

Light, S.F., Ralph I. Smith, Frank A. Pitelka, Donald P. Abbot, and Frances M. Weesner. 1954. Intertidal invertebrates of the Central California coast. University of California Press.

Mecum, W. Lee. 2007. A Key to the Mysidacea of the Upper San Francisco Estuary. IEP Technical Report 75. 13pp.

Pennak, Robert W. 1989. Fresh-water Invertebrates of the United States: Protozoa to Mollusca 3rd ed. John Wiley and Sons. New York.

Sars, Georg Ossian. 1918. An account of the Crustacea of Norway : with short descriptions and figures of all the species.: Vol.VI,-Copepoda. Bergen Museum. Bergen.

Tattersall, W. M. 1932. Contribution to a knowledge of the Mysidacea of California. II. The Mysidacea collected during the survey of San Francisco Bay by the U.S.S. Albatross in 1914. University of California Publications in Zoology, 37:301-314.

Tattersall, W. M. 1951. A review of the Mysidacea of the United States National Museum. Bulletin of the US National Museum, 201:1-292.

Ward, Henry Baldwin, George Chandler Whipple and W. T. Edmondson. 1959. Fresh-water Biology 2nd ed. John Wiley and Sons. New York.

B. Program Reports, Publications, and Other Pertinent Literature.

1. Knutson, A. C. and J. J. Orsi. 1983. Factors regulating abundance and distribution of the shrimp *Neomysis mercedis* in the Sacramento-San Joaquin Estuary. Transactions of the American Fisheries Society 112: 476-485.
2. Orsi, J. J., T. E. Bowman, et al. 1983. Recent introduction of the planktonic calanoid copepod *Sinocalanus doerrii* (Centropagidae) from mainland China to the Sacramento-San Joaquin estuary of California. Journal of Plankton Research 5(3): 357-375.
3. Ferrari, Frank D., and James Orsi. 1984. *Oithona davisae*, new species, and *Limnoithona sinensis* (Burckhardt, 1912) (Copepoda: Oithonidae) from the Sacramento-San Joaquin Estuary, California. Journal of Crustacean Biology 4(1): 106-126.
4. Orsi, J. 1986. Interaction between diel vertical migration of a mysidacean shrimp and two-layered estuarine flow. Hydrobiologia 137: 79-87.
5. Orsi, J. J. and W. L. Mecum. 1986. Zooplankton distribution and abundance in the Sacramento-San Joaquin Delta in relation to certain environmental factors. Estuaries 9(4B): 326-339.
6. Orsi, J. 1989. A report on the vertical migration of *Eurytemora affinis* and *Sinocalanus doerrii* in the Sacramento-San Joaquin Estuary. Stockton, CA: California Department of Fish and Game**:** 8p.

7. Meng, L. and J. J. Orsi. 1991. Selective Predation by Larval Striped Bass on Native and Introduced Copepods. Transactions of the American Fisheries Society 120: 187-192.
8. Orsi, J. 1991. Trophic interactions between copepods and microplankton: A question about the role of diatoms. Limnology and Oceanography 36(1): 172-178.
9. Orsi, J. and T. C. Walter. 1991. *Pseudodiaptomus forbesi* and *P. marinus* (Copepoda: Calanoida), the latest copeopod immigrants to California's Sacramento-San Joaquin Estuary. Proceedings of the Fourth International Conference on Copepoda; Bull. Plankton Soc. Japan. Spec. Vol. 1991: 553-562.
10. Obrebski, S., J. J. Orsi, W. Kimmerer. 1992. Long-term trends in zooplankton distribution and abundance in the Sacramento-San Joaquin Estuary. IEP Technical Report 32. 42p.
11. Orsi, J. 1992. The dance of the copepods or can vertical migration explain the horizontal separation of *Eurytemora* and *Sinocalanus*? Stockton, CA**:** California Department of Fish and Game:1992 Apr 29. Food Chain Committee Draft Working Paper. 13p.
12. Kimmerer, W. J., E. Gartside, and J. J. Orsi. 1994. Predation by an introduced clam as the likely cause of substantial declines in zooplankton of San Francisco Bay. Marine Ecology Progress Series 113:81-93.
13. Orsi, J. J. 1995. Food Habits of Several Abundant Zooplankton Species in the Sacramento-San Joaquin Estuary. IEP Technical Report 41. 22pp.
14. Orsi, J. J. 1995. Radical changes in the Estuary's zooplankton caused by introductions from ballast water. IEP Newsletter 8(3): 16-17.
15. Orsi, J. J. and W.L. Mecum. 1996. Food limitation as the probable cause of a long-term decline in the abundance of *Neomysis mercedis* the opossum shrimp in the Sacramento-San Joaquin Estuary. In: J. T. Hollibaugh, ed. San Francisco Bay: the Ecosystem. Pacific Division of the American Association for the Advancement of Science, San Francisco, California. Pages 375-401.
16. Kimmerer, W. J. and J. J. Orsi. 1996. Changes in the zooplankton of the San Francisco Bay estuary since the introduction of the clam *Potamocorbula amurensis*. In: J. T. Hollibaugh, ed. San Francisco Bay: the Ecosystem. Pacific Division of the American Association for the Advancement of Science, San Francisco, California. Pages 403-424.
17. Modlin, R. F. and J. J. Orsi. 1997. *Acanthomysis bowmani*, a new species, and *A. aspera* Ii, Mysidacea newly reported from the Sacramento-San Joaquin Estuary, California (Crustacea: Mysidae). Proceedings of the Biological Society of Washington 110(3): 439-446.
18. Orsi, J. J. and S. Ohtsuka. 1999. Introduction of the Asian copepods *Acartiella sinensis*, *Tortanus dextrilobatus* (Copepoda: Calanoida), and *Limnoithona tetraspina* (Copepoda: Cyclopoida) to the San Francisco Estuary, California, USA. Plankton Biology and Ecology 46(2): 128-131.
19. Mecum, W. Lee. 2007. A Key to the Mysidacea of the Upper San Francisco Estuary. IEP Technical Report 75. 13p.