CONTRIBUTED PAPERS

LIST OF FISHES FOUND IN SAN FRANCISCO BAY-DELTA SHALLOW WATER HABITATS

Mike Chotkowski, DFG

I examined several historical San Francisco Bay-Delta shallow water monitoring databases to determine what fishes have been taken. Not surprisingly, habitat with characteristics that permit use of a minnow seine have been most heavily sampled, while sites featuring rip-rap or supporting thick growths of aquatic vegetation have been more sparsely sampled. However, enough sampling has been conducted to compile a preliminary list of the fishes that occur in Delta, near-shore, shallow water habitat featuring various substrata and categories of vegetation, and along bare, seinable shores in San Francisco Bay.

This article presents a table of fishes that have been collected during nearshore shallow water monitoring, and a brief statement of the dominant taxa in recent years, including an overall breakdown into native and nonindigenous species categories. Collecting gears clearly bias the apparent proportional representation of taxa, but insufficient local information is presently available to quantify these biases. Habitat categories are as described by the original investigators. Four especially useful sources—the US Fish and Wildlife Service (USFWS) Beach Seine database, the IEP Delta Outflow/ San Francisco Bay Study Beach Seine database, the DFG Resident Fishes Monitoring Survey database, and the University of California, Davis, (UCD) Suisun Marsh Study fishes database—appear to have been sufficient to construct the list. A more detailed treatment of these data will be presented in a forthcoming Interagency Ecological Program technical report.

1. DATA SOURCES

USFWS Beach Seine (1976 to 1999) and IEP Delta Outflow/San Francisco Bay Study Beach Seine (1980 to 1986)

The IEP USFWS beach seine study, which is part of the USFWS Juvenile Salmon Migration Study, has been in annual operation since 1976, though the core panel of stations was not settled upon until a few years into the program. The geographic scope of monitoring has historically included the Delta and the lower Sacramento and San Joaquin rivers, but has expanded very recently to include San Francisco Bay, partially replacing the discontinued IEP Delta Outflow/San Francisco Bay Study beach seine monitoring (see below). The number of stations sampled has varied in most years of the study, but a widely distributed core of 26 stations has been sampled in each year since 1981. During most of the 1980s, the program focused on sampling in late fall, winter, and early spring. The program permanently expanded in the 1990s to include year-round sampling and more stations. Samples are collected with a minnow seine (usually 15.4 m long), and all fishes are identified to species or assigned to "unknown" categories. When more than fifty individuals of any species except salmon are caught, specimens of that species are enumerated and released; otherwise, each specimen is measured for fork length. All salmon are measured for fork length.

The IEP Delta Outflow/San Francisco Bay Study beach seine was a year-round study that included collection of seine samples at 27 stations distributed throughout San Francisco Bay and as far upstream as Sherman Island. For the six years of the study's existence, two seine hauls per month were routinely taken year-round at each station. The collecting gear, field protocol, and sample-processing protocol were similar to the USFWS beach seine.

Between 8 March 1976 and 29 March 1999, the USFWS beach seine database includes records of 17,789 seine hauls from 125 different stations, yielding 684,686 fishes. Proportional abundance calculations were based upon data collected between January 1994 and 29 March 1999, a period in which 9,707 seine hauls at 74 different stations yielded 462,878 fishes. Between August 1980 and December 1986, the IEP Delta Outflow/San Francisco Bay Study recorded 3,251 seine hauls at 27 stations, yielding 70,462 fishes. In all, about 61 species have been recorded by USFWS beach seine, while 63 were recorded by the IEP Delta Outflow/San Francisco Bay Study beach seine.

UCD Suisun Marsh Study (1979 to 1997)

The fish monitoring portion of the Suisun Marsh project has been extensively reported by Moyle and his colleagues. Its purposes include measurement of long-term trends in species abundances, monitoring of seasonal distribution of certain species, detection and monitoring of non-indigenous species, and assessment of the effects of the Suisun Marsh Salinity Control Gates on fish populations.

The otter trawl portion of the database has been reviewed here because of its extensive coverage of shallow sloughs. A four-seam otter trawl, with a 1 x 2.5 m opening and 5.3 m length, is used and operated to ensure that the trawl reaches the bottom. Fishes and invertebrates are identified to species, and fishes are measured for standard length.

Fish species in collections taken at 11 otter trawl stations in Boynton, Cutoff, Denverton, Goodyear, and Peytonia Sloughs between 16 May 1979 and 16 December 1997 were reviewed. Sampling was conducted in most months during that period; sampling frequency varied by station and year. In all, 2,150 trawl samples yielded 138,838 fishes representing 46 species. Proportional abundances were calculated for 35 species occurring among 38,004 fishes collected in 510 samples between 1 January 1994 and 16 December 1997.

DFG Resident Fishes Monitoring Survey (1995, 1997, and 1999)

This electrofishing database consists of two segments: a randomized survey conducted during 1980 through 1984 (now inactive) and a survey of 20 fixed sites begun in 1995 and continuing at present in odd-numbered years. Data from 1995, 1997, and 1999 (through 1 March) were used here. The purpose of the study is to monitor the abundance and species composition of Delta resident fish species. A boat-mounted electroshocker is used to conduct transects along fixed sections of shoreline. Samples consist of results of a single transect. All fishes are identified to species and up to 50 individuals of each species in each sample are measured to the nearest millimeter fork length. Although sampling is scheduled for February, April, June, and August, survey data for 1995 and 1997 include data for most months from January through August because of boat breakdowns and inclement weather during nominal sampling months.

This study is unique among historical shallow water databases in that multiple shore habitat categories have been described and separately sampled. Habitat descriptions include separate substratum and vegetation categories. Substratum types include mud bank, mud flat, riprap, and sand beach; vegetation categories include bare, submergent vegetation, emergent vegetation, floating vegetation, riparian vegetation (may include aquatic vegetation), and mixed vegetation. Some habitat category combinations have been more heavily sampled than others.

A total of 17 combinations of substratum and vegetation type were sampled in data from 1995, 1997, and January through 1 March 1999. In all, 253 samples yielded 25,547 fishes representing 39 species.

2. SPECIES LIST

Species prevalences have been expressed using an ordinal proportional (or relative) abundance scale that includes an "absent" category and numbered categories from I (relatively unusual: accounting for less than 1% of fishes taken) to V (relatively very abundant: accounting for 25% or more of all fishes taken) (Table 1). USFWS beach seine and UCD Suisun Marsh study lists include some species that have not been observed since before 1994; these are marked as "absent" on the table, but asterisks indicate an earlier observation.

The 17 substrate/vegetation categories reported by the Resident Fishes Monitoring Survey were reduced to 12 table columns by two summarization steps intended to consolidate similar categories. First, although the study reports sampling of four discrete substratum types (mud bank, mud flat, sand beach, and rip-rap), vegetated habitat with any of the mud or sand substrata yielded fairly similar assemblages of fishes within vegetation category. Therefore, the vegetated habitats were reported using two substratum categories: rip-rap, and a pooled mud bank-mud flat-sand beach category. However, proportional representation of relatively abundant fishes clearly differed among nonvegetated mud bank, mud flat, and sand beach substrata. Bare mud flat was substantially different from bare mud bank and bare sand beach; the latter two were apparently homogeneous. Therefore, bare substratum was reported in two categories: mud flat, and a pooled mud bank plus sand beach category.

3. Prevalent Fish Species, By Gear and Region

Minnow Seine: San Francisco Bay (1980 to 1986)

Overall, topsmelt, northern anchovy, and jacksmelt dominated the seine assemblage, accounting for 59.3% of all fishes taken. Pacific staghorn sculpin, arrow goby, striped bass, yellowfin goby, shiner surfperch, and dwarf surfperch accounted for approximately another 30%. The 40 least commonly caught species together accounted for about 1% of the overall catch. More than half of the recorded species (36 of 63 species) are marine species indigenous to the Northeastern Pacific. Nine nonindigenous euryhaline species accounted for about 11.8% of all individuals taken.

Minnow Seine: Sacramento-San Joaquin Delta, Lower Sacramento and San Joaquin Rivers (1994 to 1999)

Seine stations were dominated by inland silverside and chinook salmon, which account for about 59.5% of fishes caught. Threadfin shad, red shiner, Sacramento sucker, Sacramento pikeminnow, western mosquitofish, and striped bass are also relatively abundant: the eight most relatively abundant species account for a total of 90.9% of fishes taken. At present red shiner is seined in large numbers only in the San Joaquin River system, and is the only abundant species in the Delta seine assemblage that is not widely distributed. Thirty of 61 species were non-indigenous, accounting for about 59.3% of all fishes taken.

Boat-mounted Electrofishing Gear: Sacramento-San Joaquin Delta (1995, 1997, and early 1999)

Mud and Sand Substrata

Bare mud bank and bare sand beach were dominated by Pacific lamprey (probably ammocoetes) and chinook salmon, which accounted for 62% and 69% of fishes taken, respectively. Twelve of 24 species taken on mud bank or sand beach were nonindigenous; these accounted for 22.6% of fishes taken. Bare mud flats were dominated by redear sunfish and bluegill, accounting for 57% of fishes taken. Twelve of 17 species were nonindigenous; these accounted for 94.9% of fishes taken.

Three categories of vegetated habitat (emergent vegetation, submergent vegetation, mixed aquatic vegetation) and shore with riparian vegetation all were dominated by centrarchids, especially bluegill, redear sunfish, and largemouth bass, with lesser numbers of golden shiner, threadfin shad, and others. Twenty-four of 36 species taken were nonindigenous. In all, nonindigenous species accounted for 94.2% of fishes taken.

Rip-rap Substratum

Bare rip-rap was dominated by bluegill and largemouth bass, which accounted for 54.5% of fishes taken; the most relatively abundant indigenous fish was tule perch at about 3% of all collected fishes. Twenty-three of 35 species were nonindigenous; these accounted for 88.4% of fishes taken overall.

Four categories of vegetated rip-rap (emergent vegetation, submergent vegetation, mixed aquatic vegetation, floating vegetation) and rip-rapped shore with riparian vegetation were dominated by bluegill and largemouth bass, accounting for 56.9% of fishes taken. As with bare rip-rap, the most relatively abundant indigenous species taken was tule perch (2.1%). Twenty-three of 36 species were nonindigenous; these accounted for 94.7% of fishes taken. One shore category, accounting for only a small fraction of effort, rip-rap with floating vegetation, yielded only nonindigenous fishes.

Otter Trawl: Shallow Slough Channels, Suisun Marsh (1994 to 1997)

Otter trawl hauls taken in shallow sloughs yielded large numbers of striped bass, shimofuri goby, and yellowfin goby, which together accounted for 56.3% of fishes taken. The most abundant indigenous fishes were prickly sculpin, splittail, and threespine stickleback. Because the trawl is drawn along the substratum, benthic fishes (gobies and sculpins here) are expected to be particularly efficiently collected by this gear. Nineteen of 35 species were nonindigenous; these accounted for about 63% of fishes taken.

References

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Table 1 Fishes observed during routine monitoring in Bay-Delta near-shore shallow water habitat. Sources: Bay minnow seine data from the IEP Delta Outflow/San Francisco Bay beach seine study, 1980 to 1986; Suisun Marsh otter trawl data from UCD Suisun Marsh study, 1979 to 1997; Delta minnow seine data from USFWS Beach Seine Study, 1976 to 1999; Delta electrofishing data from DFG Resident Fishes Monitoring Survey, 1995, 1997, and early 1999. Proportional abundances computed from recent data for UCD Suisun Marsh Study (1994 to 1997) and USFWS Beach Seine Study (1994 to 1999), or from all data otherwise. For completeness, fish species occurring in USFWS Beach Seine and UCD Suisun Marsh databases only before 1994 are also given, with asterisks indicating earlier observations. Parenthetical dates next to nonindigenous species names indicate latest plausible year of introduction given by Cohen and Carlton (1995) or L. R. Brown (personal communication). Classification follows Nelson (1994).

Taxon	Nat. Hist.[a]	SB	TSM	SD	EMS	EMF	EMS EMGT	EMS MIXED	EMS RIPAR	EMS SUBM	ER	ER EMGT	ER FLOAT	ER MIXED	ER RIPAR	ER SUBM
Class Cephalaspidomorphi																
Order Petromyzontiformes																
Petromyzontidae																
Lampetra ayresi	A	–	–	I	–	–	–	–	–	–	I	–	–	–	–	–
Lampetra tridentata	A	–	I	I	V	–	I	–	I	–	I	I	–	–	I	–
Class Chondrichthyes																
Order Carcharhiniformes																
Triakidae																
Triakis semifasciata	M	I	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Order Rajiformes																
Myliobatidae																
Myliobatis californica	M	I	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Class Osteichthyes																
Order Acipenseriformes																
Acipenseridae																
Acipenser transmontanus	E	–	I	–	–	–	–	–	–	–	–	–	–	–	–	–
Order Clupeiformes																
Engraulidae																
Engraulis mordax	M	IV	–*	I		–	–	–	–	–	–	–	–	–	–	–
Clupeidae																
Alosa sapidissima (1871)	E	I	I	I	I	–	–	I	–	I	I	–	–	I	–	I
Clupea pallasi	M	–	I	I	–	–	–	–	–	–	–	–	–	–	–	–
Dorosoma petenense (1961)	E	I	I	IV	I	I	II	II	IV	II	II	II	I	II	III	II
Sardinops sagax	M	I	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Order Cypriniformes																
Cyprinidae																
Carassius auratus (1963)	F	–	I	I	–	–	I	I	I	I	I	I	I	I	I	I
Cyprinella lutrensis (1980)	F	–	–	IV	–	–	I	–	I	–	II	I	–	–	I	–
Cyprinus carpio (1917)	F	I	II	I	II	II	II	II	II	III	II	II	–	II	II	II
Gila bicolor	F	–	–	–*	–	–	–	–	–	–	–	–	–	–	–	–
Hesperoleucus symmetricus	F	–	–	I	I	–	–	–	–	–	–	–	–	–	–	–
Lavinia exilicauda	F	I	I	I	I	–	–	–	–	I	–	–	–	–	–	–
Mylopharodon conocephalus	F	–	–	I	–	–	–	–	–	–	–	–	–	–	–	–

[a] "Natural History" Codes: A = anadromous; E = euryhaline; F = freshwater; M = marine.

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Notemigonus crysoleucas (1964)	F	–	–*	I	I	II	III	IV	III	IV	II	II	I	II	III	III
Orthodon microlepidotus	F	I	–*	I	–	I	–	I	I	I	I	I	–	–	I	I
Pimephales promelas (1950s)	F	–	I	II	–	–	–	–	–	–	–	–	–	–	–	–
Pogonichthys macrolepidotus	F	I	IV	II	I	–	II	–	I	II	II	II	–	–	–	I
Ptychocheilus grandis	F	I	I	II	III	–	II	I	I	–	I	I	–	–	I	I
Catostomidae																
Catostomus occidentalis	F	–	II	III	II	II	–	I	II	II	II	I	–	I	I	I
Order Siluriformes																
Ictaluridae																
Ameiurus catus (1874)	F	–	II	I	–	II	I	I	II	II	III	II	II	II	I	III
Ameiurus melas (1874)	F	–	I	I	–	–	–	–	–	–	–	–	–	–	–	–
Ameiurus natalis (1874)	F	–	–	I	–	–	–	–	–	–	–	–	–	–	–	–
Ameiurus nebulosus (1874)	F	–	I	I	–	I	I	II	I	II	I	I	I	II	I	II
Ictalurus punctatus (1940s)	F	–	I	I	–	I	I	I	I	–	I	I	–	I	I	I
Order Osmeriformes																
Osmeridae																
Hypomesus nipponensis (>1972)	F	–	–	I	–	–	–	–	–	–	–	–	–	–	–	–
Hypomesus pretiosus	E	I	–*	I	–	–	–	–	–	–	–	–	–	–	–	–
Hypomesus transpacificus	E	I	I	I	I	–	I	–	I	–	I	I	–	–	I	–
Spirinchus starksi	M	I	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Spirinchus thaleichthys	E	I	I	I	–	–	–	–	–	–	–	–	–	–	–	–
Order Salmoniformes																
Salmonidae																
Oncorhynchus mykiss	A	I	–*	I	I	I	I	–	I	I	I	I	–	–	I	–
Oncorhynchus tshawytscha	A	I	–*	IV	IV	–	II	I	II	–	II	II	–	I	II	I
Order Batrachoidiformes																
Batrachoididae																
Porichthys notatus	M	I	I	–	–	–	–	–	–	–	–	–	–	–	–	–
Order Mugiliformes																
Mugilidae																
Mugil cephalus	E	I	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Order Atheriniformes																
Atherinidae																
Atherinops affinis	M	V	–	I	–	–	–	–	–	–	–	–	–	–	–	–
Atherinopsis californiensis	M	IV	–	I	–	–	–	–	–	–	–	–	–	–	–	–
Menidia beryllina (1971)	E	I	I	V	II	IV	II	I	I	–	II	I	–	I	I	I
Order Cyprinodontiformes																
Poeciliidae																

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Gambusia affinis (1965)	E	I	I	II	–	–	–	I	I	–	I	–	–	I	I	–
Cyprinodontidae																
Lucania parva (1958)	E	I	–*	I	–	–	–	I	–	–	–	–	–	–	–	–
Order Gasterosteiformes																
Gasterosteidae																
Gasterosteus aculeatus	E	II	III	I	–	–	I	–	–	–	–	I	–	–	–	–
Syngnathidae																
Syngnathus leptorhynchus	E	II	I	I	–	–	–	–	–	–	–	–	–	–	–	–
Order Scorpaeniformes																
Scorpaenidae																
Sebastes auriculatus	M	I	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Hexagrammidae																
Hexagrammos decagrammus	M	I	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Cottidae																
Cottus asper	E	I	IV	I	I	–	I	I	–	–	II	I	–	I	I	I
Cottus gulosus	F	–	–	I	–	–	–	–	–	–	I	–	–	–	–	I
Leptocottus armatus	E	III	II	I	–	–	–	–	–	–	–	–	–	–	–	–
Oligocottus snyderi	M	I	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Scorpaenichthys marmoratus	M	I	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Order Perciformes																
Percichthyidae																
Morone saxatilis (1879)	E	III	V	I	I	–	II	I	I	I	I	I	–	–	I	I
Centrarchidae																
Archoplites interruptus	F	–	–	–*	I	–	–	–	–	–	–	–	–	–	–	–
Lepomis cyanellus (1964)	F	–	I	I	I	–	–	–	I	–	I	I	–	I	I	I
Lepomis gulosus (>1921)	F	–	–*	I	–	I	II	I	I	I	II	II	IV	II	II	II
Lepomis macrochirus (1908)	F	–	I	I	I	IV	IV	V	V	IV	V	V	V	V	V	V
Lepomis microlophus (>1949)	F	–	I	I	II	V	IV	IV	IV	IV	III	IV	V	IV	IV	IV
Micropterus dolomieu (=1948)	F	–	–	I	III	–	–	–	I	–	II	–	–	–	II	I
Miicropterus salmoides (=1948)	F	–	–	I	I	IV	IV	IV	IV	IV	IV	IV	IV	IV	IV	IV
Pomoxis annularis (1951)	F	–	I	I	–	–	–	–	I	–	I	–	–	I	–	–
Pomoxis nigromaculatus (1908)	F	–	I	I	–	III	I	II	II	II	I	I	I	I	I	II
Percidae																
Percina macrolepida (1973)	F	I	–*	I	–	I	I	I	I	I	I	I	–	I	I	I
Sciaenidae																
Genyonemus lineatus	M	I	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Embiotocidae																

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Amphistichus argenteus	M	I	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Amphistichus koelzi	M	I	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Cymatogaster aggregata	E	III	–*	I	–	–	–	–	–	–	–	–	–	–	–	–
Embiotoca jacksoni	M	I	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Hyperprosopon argenteum	M	I	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Hyperprosopon ellipticum	M	I	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Hysterocarpus traski	F	I	II	I	I	II	III	I	I	I	II	III	–	–	I	I
Micrometrus minimus	M	III	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Phanerodon furcatus	M	I	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Rhacochilus toxotes	M	I	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Rhacochilus vacca	M	I	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Pholidae																
Apodichthys flavidus	M	I	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Pholis ornata	M	I	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Ammodytidae																
Ammodytes hexapterus	M	I	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Clinidae																
Gibbonsia metzi	M	I	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Blenniidae																
Hypsoblennius gilberti	M	I	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Gobiidae																
Acanthogobius flavimanus (1963)	E	III	IV	I	III	–	II	–	I	I	I	I	–	I	I	I
Clevelandia ios	E	III	–	I	–	–	–	–	–	–	–	–	–	–	–	–
Gillichthys mirabilis	E	I	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Ilypnus gilberti	M	I	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Lepidogobius lepidus	M	I	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Tridentiger bifasciatus (1985)	E	–	IV	I	–	–	–	–	–	–	I	–	–	I	–	I
Tridentiger trigonocephalus (1962)	M	I	–	I	–	–	–	–	–	–	–	–	–	–	–	–
Order Pleuronectiformes																
Paralichthyidae																
Citharichthys stigmaeus	M	I	–	I	–	–	–	–	–	–	–	–	–	–	–	–
Paralichthys californicus	M	I	–*	–	–	–	–	–	–	–	–	–	–	–	–	–
Hypsopsetta guttulata	M	I	–	I	–	–	–	–	–	–	–	–	–	–	–	–
Platichthys stellatus	E	I	I	I	–	–	–	–	–	–	–	–	–	–	–	–
Pleuronectes vetulus	M	I	–	I	–	–	–	–	–	–	–	–	–	–	–	–
Psettichthys melanostictus	M	I	–	–	–	–	–	–	–	–	–	–	–	–	–	–

[a] "Natural History" Codes: A = anadromous; E = euryhaline; F = freshwater; M = marine.

Effects of Wetlands Restoration on the Production of Methyl Mercury in the San Francisco Bay-Delta System: Preliminary Results

Thomas H. Suchanek[1], Darell G. Slotton[2], Brenda S. Johnson[1], Shaun Ayers[2], and Douglas C. Nelson[3]

[1]Department of Wildlife, Fish & Conservation Biology, UC Davis

[2]Department of Environmental Science & Policy, UC Davis

[3]Section of Microbiology, Division of Biological Sciences, UC Davis

Background

Mercury pollution and, particularly, the bioaccumulation of toxic methyl mercury in food webs, is a global problem impacting aquatic ecosystems and all consumers of aquatic organisms. The toxicity of mercury to higher order consumers of aquatic organisms is well documented, although its effects on reproduction, development, and juveniles of aquatic and aquatic-feeding species is only poorly understood. Mercury constitutes a significant potential human health hazard through consumption of fish caught from the San Francisco Bay-Delta (hereafter: Bay-Delta) and it has been identified by most California state agencies as an aquatic pollutant of great concern. Because of the widespread nature of mining-related bulk mercury contamination in California (see below), virtually every sub-region of the Bay-Delta and its watershed is affected. All of the named CALFED priority habitats and priority species (in addition to numerous others) are exposed to this ecosystem stressor.

During the past 150 years, large amounts of mercury coming from mines in the California Coast Range, as well as residual mercury from gold and silver mining in the Sierra Nevada, have been, and continue to be, deposited in Bay-Delta sediments (see Figure 1 for distribution of mines). The extensive Sacramento-San Joaquin Delta levee system that originated in the 1860s effectively isolated and converted ("reclaimed") wetlands for the production of agricultural crops and other uses, and in doing so dramatically altered the natural functioning of these wetlands. Many levees were likely constructed in locations which already contained considerable mercury deposits, and some of these historic, mercury-laden diked wetlands have long been isolated from normal tidal inundation. Upstream, mercury is still being released from contaminated watersheds and it continues to be transported to Delta environments by way of sediments, water, and organisms.

It is well known that newly flooded wetlands typically produce elevated levels of methyl mercury (Cox and others 1977; Bodaly and others 1984; Slotton 1991). This phenomenon occurs even under conditions in which *in situ* mercury concentrations are relatively low. In addition to the "new flooding" phenomenon of initially enhanced mercury methylation, wetland habitats have been found to promote mercury methylation at enhanced rates on an ongoing basis as well. Because some of the projected restoration projects for the San Francisco Bay-Delta system involve the intentional breaching of existing dikes and levees, with subsequent flooding or re-inundation of adjacent areas to create "restored" (reflooded) wetlands, there is a tangible risk that these restoration activities will increase levels of toxic methyl mercury entering the Bay-Delta ecosystem. Indeed, with natural breaching of some of the Bay-Delta levees (from storm and flooding events), there have likely been notable, but unquantified, increases in the level of methyl mercury production from these tracts. In addition, some source watersheds, depending on the distribution, nature, and magnitude of mining, likely contribute disproportionately to regional mercury loading, resulting in locally high concentrations of mercury. Environmental gradients in salinity, organic matter, and other toxic contaminants such as selenium, are known to affect mercury cycling and may also influence production of methyl mercury in the Bay-Delta.

Future restoration projects involving deliberate breaching of existing dikes and levees will likely result in a similar production of methyl mercury as a result of new flooding. Thus it is important that we quantify the potential risks of any future restoration project to the ecological health of the Bay-Delta system.