A Survey of Non-indigenous Aquatic Species in San Francisco Bay

Updated July 2009

California Department of Fish and Game/
Office of Spill Prevention and Response

San Jose State University Foundation/
Moss Landing Marine Laboratories

AUTHOR

Stephen Foss
California Department of Fish and Game

This report should be cited as:
California Dept. Fish and Game. 2009. A Survey of Non-native Aquatic Species in San Francisco Bay. Final Report. Sacramento, CA.

INTRODUCTION

Under California's 1999 Ballast Water Management for Control of Non-indigenous Species Act, the California Department of Fish and Game (CDFG) was required to conduct a study to determine the location and geographic range of non-indigenous species (NIS) in California estuaries and coastal areas. In 2000, CDFG's Office of Spill Prevention and Response (OSPR) undertook a large-scale biological assessment to determine the current location of non-indigenous aquatic species in the estuarine and coastal waters of the state (Foss et al. 2007).

The study focused on areas where species introduced from ballast water were most likely to occur. Biological sampling took place in multiple habitats, focusing on soft bottom benthic, epifaunal (hard substrate fouling), zooplankton, and fish communities. Data from comparable concurrent studies being conducted independently by other organizations and from a comprehensive literature review were used to supplement the DFG surveys. Data collected during this study provided the basis for a comprehensive analysis of impacts from NIS and served as a baseline to determine effectiveness of future management efforts to control species introductions (Foss et al. 2007).

Results of the initial study showed that all areas of the California coast have experienced some level of invasion by NIS (Foss et al. 2007). Data analysis explored several aspects of California NIS: total number of taxa, potential pathways of introduction, regions of origin of introduced species, and harbor specific results. The study also indicated that San Francisco Bay continued to be the most invaded estuary, with other ports and harbors not far behind in terms of numbers of NIS. Many species introductions were associated with ballast in ships, but the data suggested that hull fouling, aquaculture, and intentional introductions are important pathways as well. Ongoing biological surveys to monitor new introductions of NIS to determine the effectiveness of ballast control measures were recommended.

In 2003, after sunset of the 1999 Act, the Marine Invasive Species Act (AB 433) was passed, revising and widening the scope of the program. Under the 2003 legislation, ballast water control measures were expanded to include coastwise traffic. As such, it was determined that the initial baseline survey conducted by CDFG of ports and harbors would have to be expanded to include outer coastal habitats. In addition, the new legislation required a monitoring program to determine if new introductions had occurred since the original baselines were established.

The survey of San Francisco Bay described in this report, conducted during the summer and fall of 2005, is part of a long-term monitoring effort that also will include surveys in each of the previously sampled ports, harbors, and estuaries and a re-sampling of the outer coast. OSPR contracted with Moss Landing Marine Laboratories as the principal investigator for the biological survey.

San Francisco Bay has been described as one of the most invaded aquatic ecosystems in the world (Cohen and Carlton 1998), but it has also been one of the most intensively sampled. Nichols and Thompson (1985) noted that cumulative results of numerous studies of the benthos of San Francisco Bay found a macroinvertebrate community composed largely of

introduced species. Rapid Assessment surveys for exotic species were conducted in San Francisco Bay in 1993, 1994, 1996, 1997, and in 2004-2005 (Cohen et al. 2005). In addition to targeted NIS surveys, State agencies monitor fish and macroinvertebrate populations, documenting the presence of new NIS in the process.

The survey described in this report does not include sites in the low salinity area of the estuary (the Sacramento-San Joaquin Delta), which were also surveyed in 2005 and discussed in a previous report (Maloney et al. 2007).

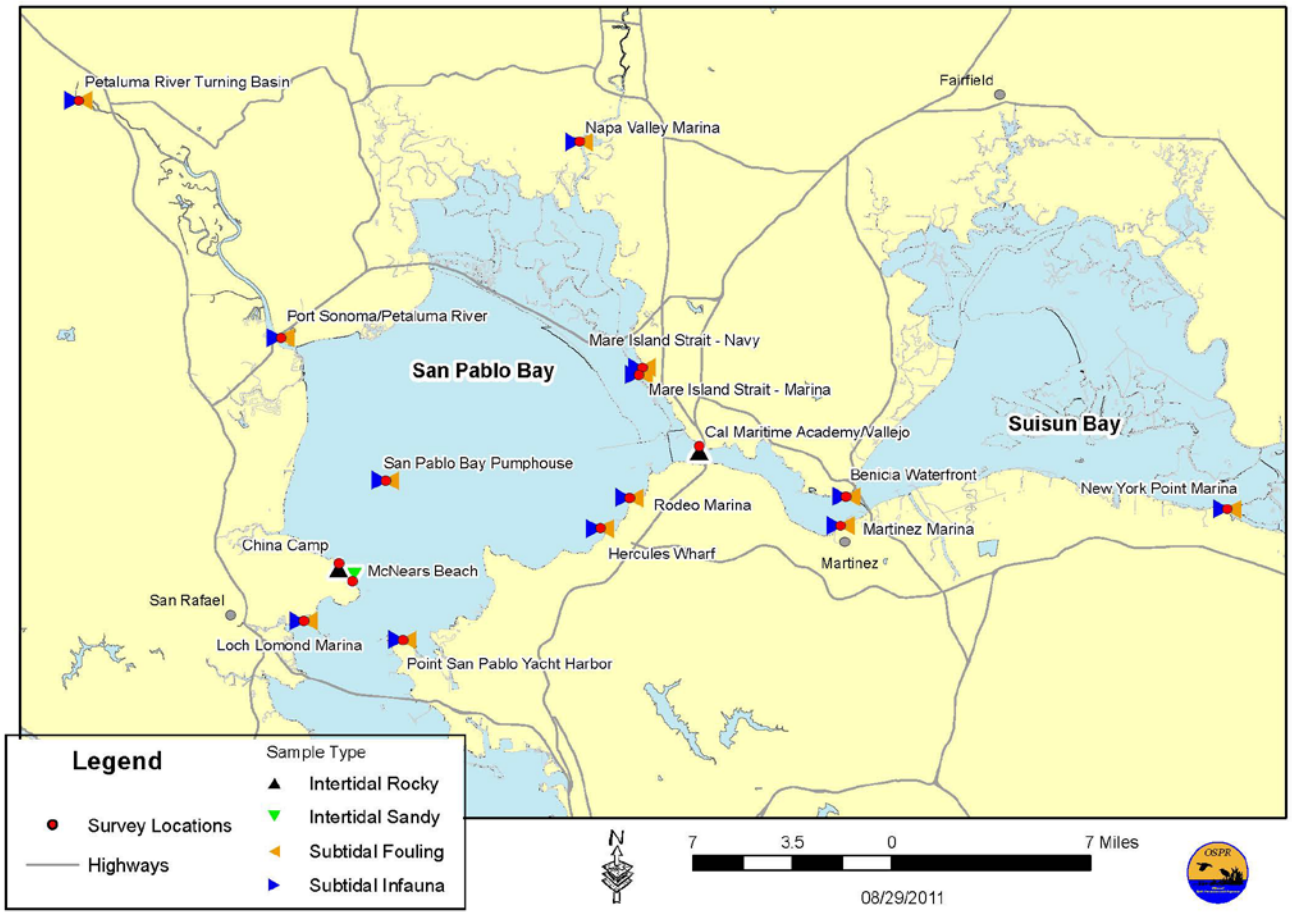

Figure 1. Sampling sites for 2005 San Francisco Bay field survey in sub-regions San Pablo Bay and Suisun Bay.

Figure 2. Sampling sites for 2005 San Francisco Bay field survey in sub-region Central San Francisco Bay.

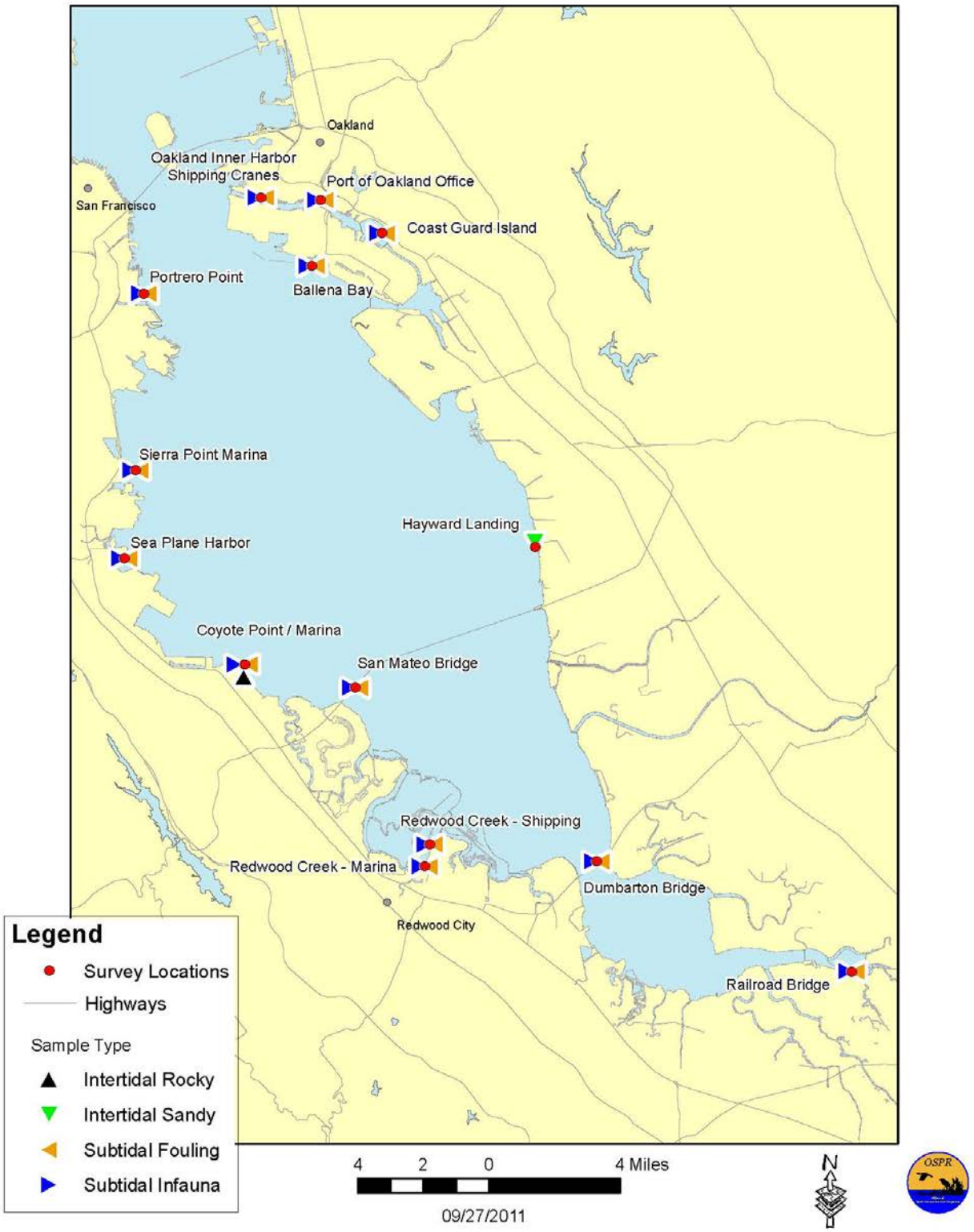

Figure 3. Sampling sites for 2005 San Francisco Bay field survey in sub-region South San Francisco Bay.

METHODS

Literature and data reviews were complimented by field and laboratory studies jointly conducted by CDFG/OSPR and San Jose State University Foundation's Moss Landing Marine Laboratories (MLML). Additional universities and specialized laboratories provided taxonomic expertise in identification of marine species.

The sampling design was adapted from the design used in previous DFG/MLML NIS surveys conducted in California bays and harbors (Foss et al. 2007, Maloney et al. 2007) and outer coast habitats (CDFG 2006), and focused on whole community structure rather than singling out any one species or habitat. Multiple habitats were surveyed at each of 70 San Francisco Bay sites (Figures 1, 2, and 3). Site selection and general descriptions are detailed below.

Introduction Status Determinations

Status determinations made by taxonomists were used to establish a master taxa list for the current survey. The baseline status determinations in this master taxa list were then compared against introduction statuses reported in other datasets, including CDFG (2002) and CDFG's California Aquatic Non-native Organism Database (CANOD). When status discrepancies were found, further literature reviews were conducted by MLML to refine information regarding the species' native range, current known distribution and reported introductions. These literature reviews targeted multiple sources of information including peer reviewed scientific publications, web sites, agency literature, field surveys and personal communications. Final species status determinations were based on all available sources, and after consultation with taxonomists. Sources used in making status determinations were documented, and the master taxa list was used to identify introduced and cryptogenic species collected from the field surveys of this study.

Survey Site Selection

OSPR identified potential areas within San Francisco Bay to conduct field and laboratory studies on the presence of NIS. These areas included a variety of natural habitat types, such as rocky points, sandy beaches and muddy soft bottom, as well as submerged and floating man-made structures. Also of interest were port and marina locations significant to concerns regarding ballast water exchange.

DFG/OSPR in conjunction with MLML developed a list of 50 sites within San Francisco Bay for subtidal surveys of epifaunal and infaunal communities. In addition, 10 rocky intertidal and 10 sandy intertidal sites within the Bay were selected for surveys. Criteria used during site selection included 1) obtain good geographic distribution over sample regions, 2) target areas likely to be impacted by anthropogenic activities, 3) locate and sample sites harboring a variety of hard substrates with fouling communities (for subtidal surveys), 4) locate and sample sites with available intertidal natural rocky reef if possible (for rocky intertidal surveys), and 5) overlap with historical and/or current survey sites if possible. Natural rocky and sandy intertidal habitat is limited within the Bay, so geographic distribution for those sample sites was limited.

Sampling Design

The basic sampling design was adopted from the DFG/MLML 2000-2001 NIS survey of California's bays and harbors (Foss et al. 2007). Intertidal sampling was modeled on the Outer Coast NIS study (Maloney et al. 2007). Depending on sampling location and the collection method, sampling can potentially underestimate the true populations if not all habitat types are represented, as seen in studies of ships' ballast (Carlton and Geller, 1993). Although all possible habitats and communities were not sampled in this survey, we attempted to be as representative as possible within the logistical and budgetary constraints of the project.

Four main habitat types were targeted: intertidal rocky, intertidal sandy, subtidal fouling (also called epifaunal in this report), and subtidal infaunal communities. The overriding principle was to collect samples from as many different habitats as possible, and within each of those habitats to target the most diverse appearing areas, rather than randomly selecting locations for sample collections. Sampling included the use of qualitative and quantitative sampling protocols to survey representative communities for the presence of NIS. Methods employed included the use of sediment cores and grabs, quadrat clearings, and qualitative taxonomic surveys. Samples were then preserved and transported to the appropriate laboratories and taxonomists for identification and enumeration. Taxonomists also occasionally provided information about historical or ongoing ecological or monitoring research conducted at or near survey sites.

Subtidal sampling focused on average depths less than 30 feet, and epifaunal subtidal sampling in particular often focused on substrates at or near the surface. Due to habitat differences that could influence larval recruitment and subsequent colonization, the sampling strategy encompassed multiple depths, substrates, orientations and light exposure conditions.

Field Sampling Methods

Epifaunal Sample Collection

Quantitative quadrat clearings

At each of the 50 subtidal and 10 rocky intertidal survey sites (Figures 1-3), epifaunal samples were collected quantitatively from rocky or fouling substrate by scraping clear and collecting the biological contents from quadrats of known areas (0.05 m^2). Whereas 2 quadrats (0.1 m^2 each) were used at each site in the 2002 DFG/MLML survey of bays and harbors, the current survey used 4 quadrats (0.05 m^2 each, totaling the same area collected per site as in 2002), in order to target a larger variety of physical conditions and biological communities. The current protocol of using 4 quadrats was also used during the DFG/MLML survey of the outer coast (2004) and the USFWS/MLML survey of San Diego Bay (2005).

Subtidal surveys were conducted by SCUBA divers. In order to increase the chances of detecting a non-native species, field samplers selectively placed quadrats in areas that appeared to have the most diversity or were likely to harbor non-native species, including but not limited to wooden, metal and styrofoam dock sides and undersides, pilings, floating logs or buoys and hulls of vessels. A variety of substrates were targeted from each survey site. Vertical and horizontal orientations of substrates were noted. Samplers carefully and completely collected everything found within each of the quadrat clearings. Quadrat samples

collected underwater were placed in mesh bags (0.5mm mesh), which were closed tight and transferred to the surface. On the boat, the entire contents within the mesh bags for each sample were carefully sieved through a 0.5mm screen and then transferred into separate containers and labeled.

At rocky intertidal survey sites, the 4 intertidal quadrat clearings were distributed in the intertidal as follows whenever possible: 1) one clearing from the mid-zone mussel bed; 2) one clearing from the mid zone, non-mussel bed, in what appeared to be the most diverse habitat, 3) one clearing from the low zone, oriented horizontally, in the most seemingly diverse habitat; 4) one clearing from the low zone on a vertical surface or under an overhanging rock. Intertidal collections were placed first in a ziplock bag and then transferred to separate containers and labeled. All quantitative clearing samples were fixed in 10% formalin in the field and later preserved in 80% ethanol.

Visual Searches

At each subtidal survey site, MLML staff divers familiar with many of the introduced species present conducted swimming visual searches via SCUBA for approximately 20 minutes. The visual searches focused on all fouling communities found at each site from depths of approximately 15 feet or less. During swimming surveys, all unidentified species observed were collected as well as introduced species for verification by taxonomists.

At each rocky intertidal survey site, taxonomists and/or natural historians familiar with the local flora and fauna conducted qualitative visual searches for introduced species, collecting algae and invertebrates that they either recognized as non-native species or did not recognize at all. At least one invertebrate expert and one phycologist spent one low tide (approximately 3 hours) conducting the visual survey at each rocky intertidal site. Visual searches were not conducted at sandy intertidal sites.

Since the priority of this survey was detection of NIS, search time, expertise, and search effort between sites was not standardized, making between-site quantitative comparisons difficult. However, the total time searched and personnel involved were recorded for each site. Specimens collected during the visual searches were sorted into rough groups and fixed in a manner that best preserved identification characteristics, as recommended by taxonomists for each phylum. A 10% formalin fixative was used with most specimens. Exceptions include bryozoans, hydroids and echinoderms which were fixed in 70% isopropanol, and poriferans, oysters, *Crepidula* and *Mytilus* which were fixed directly in 85-95% ethanol. *Diadumene spp*. were divided and fixed in both formalin and ethanol when enough specimens were present. Ascidians were also relaxed in a mixture of freshwater and magnesium chloride, until unresponsive to touch, before being fixed in the formalin. Algal collections were pressed on herbarium paper, and some were also preserved in 5-10% formalin or in silica gel for potential future genetic analysis. Pre-preservation photographs were taken of all poriferans and several other organisms to record live color and appearances.

Infaunal Sample Collection

At each subtidal survey site, one benthic infaunal sample was collected for community analyses with a Young-modified Van Veen sediment grab (0.05m² area). Between sites, the grab was rinsed with seawater. Collections from the middle of the channel were avoided as much as possible. The contents of each grab were sieved through a 0.5 mm screen.

In order to target as many habitats as possible at each site (Figures 1-3), five quantitative benthic infaunal cores were collected for community analyses from the low intertidal (targeting -1.0 ft tide height, below the sand crab zone), 5 cores were collected from the high intertidal (targeting substrate underneath beach wrack and sampling through beach wrack whenever possible) at each sandy intertidal survey site. Cores were taken using large (15 cm diameter) coffee cans and lowering them to a maximum depth of 10 cm where possible, making sure to capture the surface layer. The multiple core samples collected resulted in a total surface area of 0.1m² collected from each of the two zones. The five cores in each zone were spread out over approximately 10-20 meters. Contents from high zone core samples were sieved through a 1.0 mm mesh screen, and the contents from low zone and subtidal core samples were sieved through a 0.5 mm screen.

Residues (e.g., organisms and remaining sediments) from each infaunal sample were rinsed into unique, pre-labeled storage containers and fixed with a 10% formalin solution (stained with rose-bengal). After at least 28 hours in formalin, samples were transferred and preserved in 80% ethanol.

Supplemental Zooplankton Sample Collection

To augment the sampling methods described above, we include results of zooplankton sampling conducted in San Francisco Bay between March, 2006 and March 2007. Vertical tows were made in both shoal and channel locations within San Francisco Bay with a 150 µm mesh net with a 50 cm diameter mouth. Sampling was done approximately quarterly by both Romberg Tiburon Center staff at 12 stations in South San Francisco Bay, Central San Francisco Bay, and San Pablo Bay. Additional sampling was done approximately quarterly in the Port of Oakland by CDFG staff. Samples were preserved in formalin and sent to Romberg Tiburon Center for identification by Dr. H.K. Choi.

Grain Size Sample Collection

At each subtidal site, sediment samples were collected for grain size analysis using a 0.05m² Young-modified Van Veen grab. Between sites, the grab was rinsed with seawater. The top 5 cm was subsampled and placed in a clean, labeled ziplock bag for grain size analysis. Sandy intertidal sediment samples were also collected for grain size analysis, one sample from the low zone and one from the high zone. For each grain size collection, a tube was lowered approximately 5-10 cm into the sand, and the entire sample placed in a bag and kept cool. Samples were then transferred to MLML's Benthic Laboratory for analysis.

Documentation of Sample Sites

Latitude and longitude coordinates were documented for each survey site. If epifaunal and infaunal collections were not taken from the same approximate location for a given survey site, additional coordinates were documented for specific collection locations. Notes were taken on anything unique about the area searched, and digital overview photos were also taken of each site.

Laboratory Processing Methods for Quantitative Samples

Quantitative (i.e. quadrat clearing) field samples were sent to MLML's Benthic Laboratory for processing and sorting and were then sent to taxonomists for identification. Samples were fixed in 10% buffered formalin in the field. Formaldehyde penetrates tissue at about 5 mm per

day and, after a few days, acidity can begin breaking down small calcareous structures. Because almost all organisms were very small, complete penetration through all tissue was easily completed in 3-4 days and samples were transferred from formalin to a preserving solution of 70% isopropyl or 80 % ethyl alcohol. All quantitative samples were stained with rose Bengal, a vital stain that colors animal tissue red. The red color allows animals, particularly small ones, to be more easily recognized and separated from detritus and sediment during sorting. Staining was necessary because of the very large size of samples, great quantity of detritus, and great disparity in animal sizes.

Subsampling

Laboratory sorting was accomplished by placing the entire sample contents into a large, flat photographic tray marked into 4 equal-sized quadrats for subsampling, a procedure modified from Harrington and Born (Lazorchak et al., 1999). The sample was gently agitated until equally distributed across the tray. Most of the alcohol was then drawn off the sample by suctioning with a turkey baster from the center of the tray until the sample was immobile within the tray. Animals that were drawn up with the alcohol were caught on a screen guard and returned to the center of the tray. A flat plastic blade was used to draw the sample in from the sides of a randomly selected quadrat until the sample was concentrated into the corner of the selected quadrat, away from the other three quadrats. This isolated portion of the entire sample was the one-quarter quantitative subsample. Depending on the size of the sample, contents were subsampled to one half, one quarter, one eighth, and occasionally one sixteenth, one thirty-second, and one sixty-fourth. The sample was then sorted by standard sorting procedure. The unsorted faction was redistributed in the tray and inspected with a magnifying glass or magnifying lamp. Any taxa that were not represented in the sorted fraction were removed for a qualitative subsample (called a “scan” sample) of the remaining sample. The remaining unsorted residues were archived. A subsampling log was maintained, and entries were made for each sample, including those which were not subsampled.

Sorting

Animals were sorted in water or alcohol with fine forceps from residue into appropriate size container, mostly 1 dm glass shell vials. They were separated into phylogenetic group: Amphipoda, Arachnida, Arthropoda, Cirripedia, Bryozoa, Cnidaria, Crustacea, Echinodermata, Gastropoda, Hydrozoa, Insecta, Isopoda, Kamptozoa, Mollusca, Mytilus, Nemertea, Oligochaeta, Ophiuroidea, Platyhelminthes, Pollicipes, Polychaeta, Porifera, Pycnogonida, Sipuncula, Urochordata, and Other. Some duplication of taxa (Amphipoda and Crustacea, for example) allowed the sorters to place large numbers of a particular taxon into a separate container, to assist the taxonomists with sample handling.

Specimen Identification

Specialized taxonomists received both qualitative (preserved according to taxonomic group in the field and sent directly to taxonomists) and quantitative (fixed in formalin in the field and sorted as per the above protocols) field samples for identification. Taxonomists were selected according to qualifications, experience, and specialty (Appendix A).

Taxonomists were directed to provide a list of species identified from each sample, to count non-native species in the quadrat clearings and infaunal samples, to maintain a list of all species reported for this survey, and to create vouchers of introduced, cryptogenic, and provisional species identified in the current survey. On the list of species they identify,

taxonomists were asked to fill in details pertinent to each particular species, including but not limited to higher taxonomic classifications, taxonomic authority/date, primary identification source, and up-to-date assessments and information about each species' introduction status with regards to the boundaries of California (as per the terminology outlined below). Taxonomists were urged to identify specimens to the lowest taxonomic level possible in order to make status determinations; however, emphasis was placed on careful identification and taxonomists were encouraged to seek the help of other experts whenever necessary.

Grain Size Analysis

Sediment samples collected for grain size analysis were transferred to MLML's Benthic Ecology Lab for analysis. Particle size analyses were carried out with a Beckman-Coulter LS 13 320 laser particle size analyzer. For the relatively coarse, silt to sand size beach samples, the analyses were done with an attached dry module and conventional (Fraunhofer), laser beam diffraction (from 0.4 µm to 2 mm). For very fine sediments, particle size analyses were done with an aqueous module equipped with a pump and a built-in ultrasound unit. This module analyzes very small (~1 g) amounts of sediments and the measured size distributions range from 0.04 µm to 2 mm. Measurements of such a wide particle size range are possible because the particle sizer equipped with the aqueous module combines conventional laser beam diffraction with polarized intensity differential scatter (PIDS), which measures particles based on the Mie theory of light scattering (Beckman Coulter, Inc., 2003).

Particle size data include the mean size and mode for both bulk and non-organic carbon fractions and 30 s sonication. Further statistical data include (SD) standard deviation and three percentiles (10%, 50%, and 90%). Percent fines were summarized and reported as the sum of clay, fine silt and coarse silt fractions (0-64 µm grain sizes).

Data QA/QC Methods

Extensive measures were taken to assure the quality and accuracy of reported data in this survey. All data was scrutinized and underwent rigorous quality control checks, both manual and computer-based, before any analyses were performed.

Data Handling

Datasheets from the field were entered into an Access database and queries were used to check for missing or inaccurate data. Spreadsheets of missing data were generated from these queries and sent to the appropriate taxonomist to be completed (e.g. missing counts for non-native species, missing introduction status assessments, missing authority and dates).

Voucher and Archiving Methods

Voucher Collection

Representative examples of introduced, cryptogenic, and provisional species from all sample types have been vouchered by taxonomists during the identification process and will be stored in a collection at MLML. In addition, respective taxonomists were required to submit informal descriptions of unpublished provisional species reported in this survey to be stored in conjunction with the voucher collection. These voucher specimens will be made available to interested taxonomists for purposes of species verification or appropriate related research.

Archiving

All samples collected in the current survey were archived until further notice by MLML, with the exception of native species identified from the qualitative visual searches and some taxa of interest that have been sent to natural history museums or herbariums. In addition, unsorted sample portions are stored at MLML storage facilities and will be made available for processing if it is determined that more data are required. The specific storage location of all samples is recorded in MLML's database so that samples may be relocated in the future.

Terminology

Definition of terms used in this study is important because terminology in the scientific literature is not standardized. A variety of descriptors have been used to describe a species' biogeography as being either native, including pre-historical invasions (Carlton, 1996), introduced, invasive, exotic, or cryptogenic (Cohen and Carlton, 1995). This report used the definition of Boudouresque and Verlaque (2002), as they categorize an introduced species with these four succinct points:

> "1) It colonizes a new area where it was not previously.
> 2) The extension of range is linked, directly or indirectly, to human activity.
> 3) There is a geographic discontinuity between native area and new area (remote dispersal).
> 4) Finally, new generations of the non-native species are born in situ without human assistance, thus constituting self-sustaining populations: the species is established."

In addition, the classification of "introduced" species used in this study will refer to both innocuous and invasive introductions without specificity to either. In order to address the stipulations of the legislation, and for the purposes of this report, any species that is not native to California waters and whose native range is outside of the California borders is considered an introduced species. This includes species whose native range is elsewhere along the northeast Pacific coastline, not including California. These criteria result in a non-intuitive definition of "introduction" based on geopolitical boundaries rather than biological range or habitats, but this is necessary to meet the legislative intent of the Marine Invasive Species Act of 2003 in collecting baseline information on the presence, distribution and abundance of NIS in California waters.

A cryptogenic species is defined as "a species that is not demonstrably native or introduced" (Carlton, 1996). Cryptogenic is used as a default category for species with insufficiently documented life histories or native ranges to allow characterization as either native or introduced. In addition, when status discrepancies are found in the literature, that species is labeled here as cryptogenic until the discrepancy is resolved. As has been suggested by Carlton (1996), cryptogenic species are quite common, but have been underestimated to such an extent as to misshape our understanding of the true effects that invasions have on the ecosystem.

Unless compelling evidence was present that a species is either native or introduced to California, it was designated as cryptogenic. For instance, species were classified as cryptogenic if records of collections from outside of California were found in the literature and

native ranges were unclear. Many of the species listed as cryptogenic may be native to the California coastline but have gone previously undescribed. Occasionally, evidence suggests that a cryptogenic species is either more likely to be native or more likely to be introduced, even though not enough solid evidence is present to make the full determination of introduced or native. These cryptogenic species have been flagged in the database as "Likely Native" or "Likely Introduced" accordingly.

The "native" designation is complicated by the anthropogenic movement of organisms between regions of the California coast. Species that have been historically reported as native in southern California may not have been historically native in northern California, and vice versa. In the current survey, native California species were identified in areas where they have not been previously reported. For example, ascidians from the genus *Botrylloides*, previously known from southern California, were identified in the current San Francisco Bay survey. Although they are considered native species in Southern California, there were no botryllids in San Francisco Bay until mid 20th century and since they would have been transported anthropogenically, they are considered introduced to San Francisco Bay (G. Lambert personal communication, 2007).

For many species, there is no way to convincingly state whether the new identification is a result of sampling previously unsampled habitats, whether it is a natural range extension, or whether it is from an anthropogenic introduction. Considering the physical impediments to major natural range expansions in California, it is likely that many of these new identifications are a result of recent intrastate vessel activity, but proof is lacking. Previously, we listed these species as "Native X" (Foss et al. 2007), but the current report does not use that term. Rather, these species are reported here as native, and have been noted within the database as new records to a location or depth range. These assigned terms of introduced and cryptogenic should not be considered as static, but instead will be modified as research continues and taxonomy, native ranges, and vectors of introduction are better resolved.

Specimens that could not be identified to species level (e.g. *Ophiopholis sp*) could not be confidently classified as introduced, cryptogenic, or native and were assigned an "unresolved" status. Specimens given temporary provisional names were also classified as "unresolved" unless world-wide literature has been thoroughly researched to assure that no species with the same description has a native range that does not include California. Specimens classified as unresolved will require additional taxonomic resolution before a status can be confidently assigned. However, it is important to include these specimens in our reporting because they may prove to be new species or represent significant range extensions.

An additional term used to describe some biota in the literature is "invasive". An invasive species is generally considered any introduced species that has caused a disruption to the ecosystem, resulting in environmental or economical damage. Literature that uses the word "invasive" as a descriptor may refer to species with detrimental economic impacts on native populations, while others use the term to simply indicate weedy species that may or may not impact native communities. Our review found that the use of the term was so subjective in the literature that consistent application of the term was impossible. To avoid confusion, "invasive" was not used in this report.

RESULTS AND DISCUSSION

Field Surveys

Ten intertidal epifaunal samples (hard substrate scrapings), 10 intertidal sandy sediment samples, 50 subtidal fouling, and 47 infaunal samples were collected from San Francisco Bay sites. In addition, qualitative samples were collected during the visual scans at the 10 intertidal sites. Sixty-seven grain size samples were collected. Station position and sampling information for each location are given in Appendix B.

Taxonomic Identifications

From the samples collected during the current field surveys (including supplemental zooplankton sampling), a total of 512 (but not all these were identified to species level) species were identified, of which 88 (17% of all species identified) were classified as introduced, 98 were classified as cryptogenic, and 326 were classified as native to California. For a variety of reasons (which will be discussed below) an additional 314 taxa were collected which could not be identified to species level and were classified as unresolved or unresolved complexes. The compiled database (MS Access), available through CDFG/OSPR, gives detailed information for all samples and species identified, including native species.

Table 1 lists the field survey sites and the number and percentage of taxa identified within each classification (excluding unresolved taxa) at each site. Introduced species across sites ranged from a low of 5 species at both Crissy Field and Aquatic Park to a high of 43 species at Ayala Cove, and represented 6.0% to 70.6% of the total taxa collected from each site. The Pacheco Creek Oil Pier site had the highest percentage of introduced species (70.6%), even though only 12 non-native species were found here. The 2 sites at Mare Island also had very high percentages of non-native species (66.7%). Cryptogenic species ranged from 0 to 40 species collected per site, representing 0% to 37.5% of total taxa at each site, while native species ranged from 5 to 106 per site, representing 18.6% to 83.6% of the total species collected at each site.

Table 1. Number and percentage of total taxa identified for each classification at each site. (Does not include supplemental zooplankton sampling.)

Station Name	Introduced	Cryptogenic	Native	Total Species
Ayala Cove	43 (22.8%)	40 (21.2%)	106 (56.1%)	189
Richmond Marina	41 (38.7%)	22 (20.8%)	43 (40.6%)	106
Coyote Point	38 (40.4%)	12 (12.8%)	44 (46.8%)	94
Sea Plane Lagoon	37 (40.7%)	30 (33%)	24 (26.4%)	91
Coyote Point Marina	31 (52.5%)	10 (16.9%)	18 (30.5%)	59
Central Basin	30 (44.8%)	15 (22.4%)	22 (32.8%)	67
China Camp	29 (46.8%)	2 (3.2%)	31 (50%)	62
Redwood Creek - marina	29 (58%)	10 (20%)	11 (22%)	50
Santa Fe Channel - front	29 (54.7%)	14 (26.4%)	10 (18.9%)	53
Santa Fe Channel - back	28 (46.7%)	18 (30%)	14 (23.3%)	60
Sierra Point Marina	28 (51.9%)	14 (25.9%)	12 (22.2%)	54
Paradise Cay	27 (45.8%)	16 (27.1%)	16 (27.1%)	59
Richardson Bay	27 (40.3%)	21 (31.3%)	19 (28.4%)	67
San Pablo Bay Pumphouse	27 (57.4%)	10 (21.3%)	10 (21.3%)	47

San Mateo Bridge	26 (48.1%)	14 (25.9%)	14 (25.9%)	54
Sea Plane Harbor	26 (51%)	11 (21.6%)	14 (27.5%)	51
China Basin	25 (38.5%)	14 (21.5%)	26 (40%)	65
Coast Guard Island	25 (58.1%)	10 (23.3%)	8 (18.6%)	43
Port of Oakland Office	25 (41%)	14 (23%)	22 (36.1%)	61
Oakland Inner Harbor - shipping cranes	24 (42.9%)	14 (25%)	18 (32.1%)	56
Oakland Inner Harbor - small marinas	24 (42.9%)	15 (26.8%)	17 (30.4%)	56
Oakland Outer harbor	24 (42.9%)	15 (26.8%)	17 (30.4%)	56
Point Richmond Piers	24 (35.8%)	23 (34.3%)	20 (29.9%)	67
Potrero Point	24 (34.3%)	17 (24.3%)	29 (41.4%)	70
Saint Francis Yacht Harbor	24 (41.4%)	16 (27.6%)	18 (31%)	58
Chevron Pier	23 (31.5%)	18 (24.7%)	32 (43.8%)	73
Redwood Creek - shipping	23 (46.9%)	11 (22.4%)	15 (30.6%)	49
Tiburon Rhomberg Center	23 (37.7%)	15 (24.6%)	23 (37.7%)	61
Treasure Island	23 (40.4%)	15 (26.3%)	19 (33.3%)	57
Berkeley Marina	22 (45.8%)	14 (29.2%)	12 (25%)	48
Hercules Wharf	22 (45.8%)	9 (18.8%)	17 (35.4%)	48
Pier 39	22 (34.9%)	17 (27%)	24 (38.1%)	63
Point San Pablo Yacht Harbor	22 (42.3%)	9 (17.3%)	21 (40.4%)	52
Cal Maritime Museum / Vallejo	21 (61.8%)	2 (5.9%)	11 (32.4%)	34
Dumbarton Bridge	21 (53.8%)	9 (23.1%)	9 (23.1%)	39
Loch Lomond Marina area	21 (60%)	6 (17.1%)	8 (22.9%)	35
Yerba Buena	21 (18.9%)	11 (9.9%)	79 (71.2%)	111
Cruise Ship Pier	20 (22%)	26 (28.6%)	45 (49.5%)	91
Mare Island Strait - marina	20 (66.7%)	1 (3.3%)	9 (30%)	30
Ballena Bay	19 (50%)	9 (23.7%)	10 (26.3%)	38
Ferry Terminal Pier	19 (20.9%)	25 (27.5%)	47 (51.6%)	91
Berkeley Flats/ Berkeley Pier	18 (30.5%)	22 (37.3%)	19 (32.2%)	59
Mare Island Strait - Navy	18 (66.7%)	3 (11.1%)	6 (22.2%)	27
Railroad bridge	18 (56.3%)	5 (15.6%)	9 (28.1%)	32
Napa Valley Marina	17 (60.7%)	2 (7.1%)	9 (32.1%)	28
Pier 45	17 (26.6%)	16 (25%)	31 (48.4%)	64
Tiburon	17 (20%)	8 (9.4%)	60 (70.6%)	85
Alcatraz	16 (13.9%)	12 (10.4%)	87 (75.7%)	115
Corinthian Marina	16 (26.2%)	16 (26.2%)	29 (47.5%)	61
Benicia Waterfront	15 (65.2%)	3 (13%)	5 (21.7%)	23
Martinez Marina	14 (63.6%)	1 (4.5%)	7 (31.8%)	22
Paradise Area	14 (36.8%)	13 (34.2%)	11 (28.9%)	38
Port Sonoma/ Petaluma R.	14 (66.7%)	1 (4.8%)	6 (28.6%)	21
Hayward Landing	13 (54.2%)	3 (12.5%)	8 (33.3%)	24
McNears Beach	13 (54.2%)	5 (20.8%)	6 (25%)	24
Toll Plaza	13 (31.7%)	12 (29.3%)	16 (39%)	41
Pacheco Creek Oil Pier	12 (70.6%)	0 (0%)	5 (29.4%)	17
Rodeo Marina	12 (50%)	4 (16.7%)	8 (33.3%)	24
New York Point	11 (47.8%)	4 (17.4%)	8 (34.8%)	23
Point Cavallo	11 (10.4%)	10 (9.4%)	85 (80.2%)	106
Crown Beach	10 (38.5%)	7 (26.9%)	9 (34.6%)	26
Petaluma River Turning Basin	9 (45%)	4 (20%)	7 (35%)	20
Fort Point	7 (6%)	12 (10.3%)	97 (83.6%)	116
Point Richmond	6 (27.3%)	4 (18.2%)	12 (54.5%)	22

Aquatic Park	5 (20.8%)	9 (37.5%)	10 (41.7%)	24
Crissy Field	5 (45.5%)	1 (9.1%)	5 (45.5%)	11

The average number of introduced species among all Bay sites was 20.9, representing an overall average of 42.9% of all species per site. The number of introduced species per site may be misleading, though, since varying numbers of habitats were sampled at each site. For example, 43 introduced species were found at Ayala Cove (Angel Island), but 4 different habitat types were sampled at this site, more than any other site. However, Ayala Cove also had the most cryptogenic and native species and thus the percentage of introduced species at this site was relatively low (26.5%). One question we might ask is: are there more introduced species at this site because there is more (and varied) habitat, because more vectors have influenced the number of species arriving in this area, or because more habitats were sampled?

To examine trends of introduced species distribution within the Bay, San Francisco Bay was divided into 4 sub-regions, South San Francisco Bay, Central San Francisco Bay, San Pablo Bay, and Suisun Bay (Figures 1-3). There were near equal numbers of total introduced species (the sum of all unique introduced species found at all stations) found in the South, Central, and San Pablo bays (Table 2). Far fewer introduced species were found in Suisun Bay. However, after adjusting for the number of samples taken in each (sub)bay (Table 2). This phenomenon appears to be due at least in part to a bias in sample design. The Central Bay had 7 of the survey's 10 subtidal rocky samples, which tended to have the highest number of introduced (and native) species. Intertidal rocky samples yielded 6.9 introduced species per sample (69 species in 10 samples) compared to an average of only 2.7 introduced species per intertidal sandy sample and about 1.0 introduced species per sample for subtidal samples. Therefore, it's likely that the relatively high number of rocky intertidal samples in the Central Bay contributed the higher numbers of introduced species found in this sub-region. This does not explain the relatively high numbers of introduced species in South San Francisco Bay, however.

Perhaps a more straightforward method of examining geographic trends in introduced species is to look at only unique introduced species found in each sub-region. After standardizing for the number of samples taken in each bay, the trend is the reverse of that of total introduced species (fewer species per sample in the South and Central bays, Table 2). Statistical testing is needed to determine if these differences is statistically significant.

Differences in salinity might be one possible explanation for higher numbers of introduced species in the South Bay. The South Bay resembles a tidal lagoon (Cheng et al. 1993; Uncles and Peterson 1995). Very little freshwater flows into the South Bay and salinities are homogeneous and are largely controlled by the exchange of water with the Central Bay. Ruiz et al. (2000) found that the number of NIS in San Francisco Bay increased three- to fourfold from low salinity zone to high salinity zone. They also noted that many species were euryhaline (tolerate a broad salinity range) and occur in several salinity zones.

An explanation for the higher numbers of introduced species in higher salinity zones is that those areas have received greater numbers of propagules. Ruiz et al. (2000) noted that propagules have arrived recurrently from high salinity zones of source regions. They hypothesized that for marine invertebrates and algae, numbers of human-transferred

propagules have generally been greatest from high salinity zones of donor regions. Further analysis is needed to reveal the causal mechanism of this phenomenon.

Table 2. Number of unique introduced species and samples per San Francisco Bay Sub-region.

Sub-region	Unique Introduced Species	Samples	Introduced Species per Habitat sampled
South Bay	68	38	1.8
Central Bay	64	49	1.3
San Pablo Bay	61	23	2.7
Suisun Bay	27	8	3.4

Subtidal habitats tended to have a higher percent of introduced species (Table 3). Epifaunal habitats (intertidal rocky and subtidal fouling) had the highest numbers of introduced species. Intertidal rocky habitat samples produced more total taxa than other habitats and had the highest percent of native species.

Table 3. Number of species and percentage of total taxa within each classification for each habitat type sampled.

Habitat	Introduced	Cryptogenic	Native	Total Species
Intertidal Rocky	69 (21.5%)	35 (10.9%)	217 (67.6%)	321
Intertidal Sandy	27 (25.7%)	27 (25.7%)	51 (48.6%)	105
Subtidal Fouling	69 (27.2%)	49 (19.3%)	136 (53.5%)	254
Subtidal Infauna	38 (28.4%)	30 (22.4%)	66 (49.3%)	134

The higher number of introduced species found in epifaunal habitat may be due, in part, to a greater sampling effort afforded in that habitat. A greater total area was sampled in epifaunal habitat than in infaunal habitat. Additionally, an on-site, qualitative visual search conducted via SCUBA accompanied surveys in epifaunal habitat but not in infaunal habitat. Several species were identified from the visual searches in epifaunal habitat which were not detected in the quantitative samples collected from the same sites and habitats. More investigation into possible habitat type preferences for introduced species may help explain the trends observed in the current survey**.** Although challenging**,** a quantification of the total available area of each type of habitat might provide insight into differences between numbers of species found among habitat types.

Table 4 details the number and percentage of species within each classification for the major phyla. Introduced species were found from 11 different phyla in the Bay. The phylum Arthropoda had the highest number of introduced species. Eleven of the 15 species (73%) of the Echiurians (spoon worms) were classified as introduced to California. A relatively high

percent of Arthropods (32%) and Echinoderms (31%) were introduced. Annelids and arthropods accounted for a large portion of the total species encountered.

Table 4. Number and percentage of species in each classification by phylum.

Phylum	Introduced	Cryptogenic	Native	Total Species
Annelida	12 (8.3%)	49 (33.8%)	84 (57.9%)	145
Arthropoda	37 (31.9%)	15 (12.9%)	64 (55.2%)	116
Chlorophyta	15 (23.4%)	1 (1.6%)	48 (75.0%)	64
Chordata	4 (6.7%)	1 (1.7%)	55 (91.7%)	60
Cnidaria	7 (41.2%)	0	10 (58.8%)	17
Echinodermata	9 (31.0%)	4 (13.8%)	16 (55.2%)	29
Echiura	11 (73.3%)	0	4 (26.7%)	15
Ectoprocta	0	5 (35.7%)	9 (64.3%)	14
Entoprocta	0	2 (20.0%)	8 (80.0%)	10
Heterokontophyta	3 (16.7%)	0	15 (83.3%)	18
Mollusca	1 (10.0%)	1 (10.0%)	8 (80.0%)	10
Nematoda	2 (50.0%)	0	2 (50.0%)	4
Nemertea	0	1 (16.7%)	5 (83.3%)	6
Phorona	1 (33.3%)	0	2 (66.7%)	3
Platyhelminthes	0	2 (100.0%)	0	2
Porifera	0	0	1 (100.0%)	1

Within each phylum, there were between 0 and 127 unresolved unique taxa collected. One group that was particularly challenging (and numerous) was the annelids. Specimens were classified as ‘unresolved’ as a result of insufficient taxonomic resolution at the species level, which may have been due to a variety of reasons including damaged or juvenile specimens, undescribed species, and problems in the taxonomic literature. Approximately 36% of the total taxa collected were classified as unresolved; which points to the difficulty facing scientists when evaluating introductions and the need for continued basic research on resolving taxonomy of marine species.

About 47% (127) of unresolved identifications were annelids (Table 5). The presence of juvenile or non-reproductive specimens was primarily responsible for the high number of unresolved annelid identifications.

Table 5. Number and percentage of unresolved taxa by phylum.

Phylum	Unresolved Taxa	% Unresolved Taxa
Annelida	127	46.7
Arthropoda	57	32.9
Chlorophyta	20	23.8
Cnidaria	17	50.0
Ectoprocta	12	46.2
Entoprocta	12	54.5

Echiura	11	42.3
Nematoda	7	63.6
Chordata	6	9.1
Echinodermata	4	12.1
Heterokontophyta	3	14.3
Nemertea	3	33.3
Platyhelminthes	2	50.0
Mollusca	1	9.1
Phorona	1	25.0
Rhodophyta	1	100.0
Sipuncula	1	100.0
Porifera	0	0.0

In order to determine the factors causing the high numbers of unresolved taxa in this survey, MLML asked taxonomists to record the reason that identification could not resolved to species level. Of the approximately 149,000 unresolved identifications, almost half were due to juvenile or non-reproductive specimens, 26% were due to undescribed or unrecognized species, and 22% were due to damaged specimens (Table 6). In particular, the identification of Molluscs and Nemerteans was hampered by the presence of juvenile or non-reproductive specimens. The presence of undescribed or unrecognized species played a substantial role in limiting identification of Cnidarians to higher than species level. Nearly 100% of this group was either unrecognized or undescribed. Damaged specimens (presumably damaged during the collection process) made it difficult for taxonomists to identify Arthropods and Echinoderms. The fragility of certain groups of organisms is problematic, but further refinements in sampling and handling methods may be required for these groups to ensure that whole specimens are available to taxonomists.

Table 6. Number and percentage of total unresolved identifications for each phylum and unresolved taxa category.

Phylum	Juvenile or Non-reproductive Specimen	Damaged Specimen	Undescribed/ Unrecognized Specimen	Other	Multiple Categories	Total Unresolved Identifications
Annelida	24,625 (53%)	3,975 (9%)	10,084 (22%)	4631 (10%)	2,834 (6%)	46,149
Arthropoda	17,248 (38%)	27,862 (62%)	0	32 (<1%)	12 (<1%)	45,154
Chordata	1,683 (43%)	333 (9%)	32 (1%)	0	1,852 (47%)	3,900
Cnidaria	14 (<1%)	17 (<1%)	6,847 (100%)	1(<1%)	0	6,879
Echinodermata	4 (6%)	64 (93%)	1 (1%)	0	0	69
Mollusca	245 (97%)	4 (2%)	0	0	4 (2%)	253
Nematoda	0	0	0	67 (100%)	0	67
Nemertea	915 (93%)	14 (1%)	38 (4%)	12 (1%)	4	983
Phorona	0	0	3 (100%)	0	0	3
Platyhelminthes	24,606 (54%)	0	20,951 (46%)	0	0	45,557
Sipuncula	0	0	4 (33%)	8 (67%)	0	12
Total	69,340 (47%)	32,269 (22%)	37,960 (25%)	4751 (3%)	4,706 (3%)	149,026

Appendix C lists the NIS collected in the current survey, the number of individuals of each species found at each station, and the number of stations where each species was found.

Numbers of individual organisms are shown for identifications made from quantitative samples which were counted. The area sampled among sites is not standardized, so comparisons between stations should be made cautiously.

Appendix D lists the cryptogenic species collected in the current survey, along with assessments of whether some of those species are most likely native or introduced, and the number of survey sites where each species was observed. Of the 81 cryptogenic species listed, 11 have been considered to be “likely native” while 8 have been considered “likely introduced”.

Results from the current survey can be compared to the list of organisms from San Francisco Bay in the Department of Fish and Game’s statewide database of introduced organisms, CANOD. The database is a compilation of previous biological surveys and published literature (Foss et al. 2007). The database lists 122 introduced species in San Francisco Bay, excluding strictly freshwater species, fish, vascular plants, and microinvertebrates. Including zooplankton found in the supplemental survey, 70 of the species found in the database were identified in the current survey, but 52 were not. An additional 44 NIS that were not listed in CANOD were identified during the survey.

A number of sampling biases can be identified to explain why many of the species historically found in the Bay were not identified in the current study. The largest group of organisms that were not sampled in the current survey are pelagic organisms, such as hydromedusae and mysids. The San Francisco Bay sampling design did not include plankton sampling, although supplemental sampling in San Francisco Bay has been ongoing and is reported here (Table 8). Another group that was poorly sampled includes mobile or migratory species, such as the mitten crab, *Eriocheir sinensis*, and gastropods, including nudibranchs.

Supplemental zooplankton sampling conducted in San Francisco Bay and Port of Oakland revealed 10 introduced species, 20 native species, and 4 cryptogenic species (Table 7). Most of the zooplankton species identified were found in Port of Oakland; only 2 species were found in samples taken outside of the Port that were not found in Port of Oakland samples. No new species have been discovered to date, but samples are still being processed.

Table 7. Zooplankton identified in Port of Oakland and San Francisco Bay samples.

Species	Introduction Status	Port of Oakland	San Francisco Bay
Cumella vulgaris	Cryptogenic	**X**	**X**
Eurytemora affinis	Cryptogenic	**X**	
Hemicyclops japonicus	Cryptogenic	**X**	**X**
Hyalella azteca	Cryptogenic	**X**	
Oithona davisae	Introduced	**X**	**X**
Pseudodiaptomus marinus	Introduced	**X**	**X**
Tortanus dextrilobatus	Introduced	**X**	**X**
Monocorophium insidiosum	Introduced	**X**	**X**

Oithona similis	Introduced	**X**	**X**
Pseudodiaptomus forbesi	Introduced	**X**	
Coullana canadensis	Introduced	**X**	
Microsetella norvegica	Introduced	**X**	**X**
Nippoleucon hinumensis	Introduced	**X**	
Monocorophium acherusicum	Introduced		**X**
Acartia hudsonica	Native	**X**	**X**
Paracalanus indicus	Native	**X**	**X**
Acartia californiensis	Native	**X**	**X**
Acartia tonsa	Native	**X**	**X**
Oikopleura dioica	Native	**X**	**X**
Labidocera trispinosa	Native	**X**	**X**
Podon polyphemoides	Native	**X**	**X**
Zaus spinatus	Native	**X**	
Calanus pacificus	Native	**X**	
Euterpina acutifrons	Native	**X**	**X**
Alienacanthomysis macropsis	Native	**X**	
Corycaeus affinis	Native	**X**	**X**
Corycaeus subtilis	Native	**X**	
Epilabidocera longipedata	Native	**X**	
Limoithona tetraspina	Native	**X**	
Microarthrion littorale	Native	**X**	
Oikopleura dioica dioica	Native	**X**	
Sagitta friderici	Native	**X**	
Tisbe furcata	Native	**X**	
Evadne nordmanni	Native		**X**

Appendix E shows results from the grain size analysis in percent fines for each survey site. Further analysis is required to uncover any possible relationship to non-native species distribution in San Francisco Bay.

Possible New Introductions

Two species, *Anopsilana jonesi* (an isopod) and a new (but unnamed) species of Bryopsis (so-called “hair” algae), *Bryopsis sp. KAM* are probable new introductions to California waters. Three species, *Caulacanthus ustulatus* (a red algae), *Ericthonius rubricornis* (a gammarid amphipod), and *Tricellaria erecta* (a bryozoan) are probable new invaders to San Francisco Bay.

Ongoing research

Literature research to refine the classifications and information related to species found in this survey is ongoing. CDFG funds special studies by researchers and taxonomists whenever possible to resolve taxonomic uncertainties and to reduce the number of unresolved and

cryptogenic identifications. Genetic studies are one promising area of research that has already helped to refine our knowledge of suspected NIS in California coastal waters.

Finally, while the results from the current survey serve as a baseline of information about the species from the targeted habitat types at the targeted sites, there are undoubtedly species that were missed in the survey. Some species may have been in microscopic or otherwise undetectable life stages during the time of sampling, whereas other species could be established in areas that were not surveyed. Repeated sampling and further investigations into other existing datasets would add to the understanding of introduced species in these marine and freshwater regions of California.

NIS Database

The data for this survey are assembled in a Microsoft Access 2000 relational database that includes both field and analytical data. In addition, to manage introduced species data from this survey as well as other sources, OSPR maintains the name and location of every known non-native (or suspected non-native) species on the California coast in the database. Called CANOD (California Aquatic Non-native Organism Database), the database is available to the public on the OSPR Web Site at http://www.dfg.ca.gov/ospr/; link to Invasive Species. A copy of the database also resides at Moss Landing Marine Laboratory's Marine Pollution Studies Lab.

CANOD serves as a baseline for addressing the following questions: 1. Which NIS have arrived in California via Ballast Water? 2. Is the rate of new introductions increasing or not? 3. Have ballast water regulations been successful in limiting introductions of new organisms? (a long-term question) 4. To what extent have humans redistributed marine aquatic plants and animals within California?

To answer these questions, the database includes information about the pathway of introduction (e.g. ballast water, intentional introduction), date of introduction, locations observed, and native region of each species. The online version of CANOD will be updated with relevant results from the current literature and field surveys, and will also be refined in the future as more surveys for non-native aquatic species are completed.

SUMMARY

From the samples collected during the current field surveys (including supplemental zooplankton sampling), a total of 514 species were identified, of which 113 (21% of all species identified) were classified as introduced, 84 were classified as cryptogenic, and 350 were classified as native to California. In addition, another 293 taxa were collected which could not be identified to species level and were classified as unresolved.

The site at Port Sonoma on the Petaluma River had the highest percentage of introduced species (76.2%), even though only 16 non-native species were found here. The 2 sites at Mare Island also had very high percentages of non-native species (71.4% and 63.0%).

There were more total introduced species (the sum of all introduced species found at all stations) found in the South and Central bays than in San Pablo and Suisun bays. However, if

we include only unique introduced species standardized for the number of samples taken in each bay, the trend is the reversed, that is, there are fewer species per sample in the South and Central bays.

Approximately 36% of the total taxa collected were classified as unresolved (not identified to species level); which points to the difficulty facing scientists when evaluating introductions and the need for continued basic research on resolving taxonomy of marine species. The majority of unresolved identifications were annelids (127, about 47% of all of the total unresolved identifications). The presence of juvenile or non-reproductive specimens was responsible for about half of the unresolved identifications. Undescribed (or unrecognized) species and damaged specimens were other causal factors.

The NIS list from the current survey was compared to a list of NIS in San Francisco Bay from the Department of Fish and Game's statewide database of NIS (CANOD). Excluding strictly freshwater species, fish, vascular plants, and phytoplankton, 70 of the species found in the database were identified in the current survey, but 52 were not. An additional 44 NIS that were not listed in CANOD were identified during the survey.

The sampling methods employed in this survey tend to miss pelagic organisms, such as hydromedusae and mysids, which explains in part why many of the species historically found in the Bay were not identified in the current study. Another group that was poorly sampled includes mobile or migratory species, such as the mitten crab, *Eriocheir sinensis*, and gastropods, including nudibranchs.

Two of the species collected in the present survey are likely new NIS in California and 3 species are likely to be new to San Francisco Bay.

The addition of zooplankton sampling to the suite of survey methods resulted in capturing numerous previously known NIS and cryptogenic species that would not otherwise be sampled, but to date has failed to find any new NIS.

REFERENCES

Beckman Coulter, Inc. 2003. *LS 13 320 Particle Size Analyzer Manual PN 7222061AI*. Miami (Beckman).

Boudouresque, C.F. and M. Verlaque. 2002. Biological pollution in the Mediterranean Sea: invasive versus introduced macrophytes. Marine Pollution Bulletin 44(1):32-38.

California Dept. Fish and Game. 2006. Introduced Aquatic Species in California Open Coastal Waters. Final Report. California Department of Fish and Game. Office of Spill Prevention and Response. Sacramento, CA. 93 pp.

Cheng, R.T., Casulli, V. and Gartner, J.W., 1993. Tidal, residual, intertidal mudflat (TRIM) model and its application to San Francisco Bay, California. Estuarine, Coastal and Shelf Sci. 36: 235-280.

Cohen, A.N. and J.T. Carlton. 1995. Nonindigenous Aquatic Species in a United States Estuary: A Case Study of the Biological Invasions of the San Francisco Bay and Delta. A Report for the United States Fish and Wildlife Service, Washington D.C. and The National Sea Grant College Program, Connecticut Sea Grant.

Cohen, A.N. and J.T. Carlton. 1998. Accelerating Invasion Rate in a Highly Invaded Estuary. Science (279): 555 – 558.

Cohen, A.N., L.H. Harris, B.L. Bingham, J.T. Carlton, J.W. Chapman, C.C. Lambert, G. Lambert, J.C. Ljubenkov, S.N. Murray, L.C. Rao, K. Reardon, and E. Schwindt. 2002. Project Report for the Southern California Exotics Expedition 2000: A Rapid Assessment Survey of Exotic Species in Sheltered Coastal Waters, California Department of Fish and Game, Sacramento, CA. State Water Resources Control Board, Sacramento, CA. National Fish and Wildlife Foundation, San Francisco, CA.

Cohen, A.N., L.H. Harris, B.L. Bingham, J.T. Carlton, J.W. Chapman, C.C. Lambert, G. Lambert, J.C. Ljubenkov, S.N. Murray, L.C. Rao, K. Reardon, and E. Schwindt. 2005. Rapid Assessment Survey for exotic organisms in southern California bays and harbors, and abundance in port and non-port areas. Biological Invasions 7:995-1002.

Cohen, A.N. 2005. Overview of 2004/05 Rapid Assessment Shore and Channel Surveys for Exotic Species in San Francisco Bay. Final Report for the California State Coastal Conservancy, Association of Bay Area Governments/San Francisco Bay-Delta Science Consortium, National Geographic Society and Rose Foundation. San Francisco Estuary Institute, Oakland, CA.

Foss, S. F., Ode, P., Sowby, M., and M. Ashe. 2007. Non-Indigenous Aquatic Organisms in the coastal waters of California. California Fish and Game 93(3):111-129.

Lazorchak, J., D. Klemm, D. Averill, and D. Peck. 1999. Environmental monitoring and assessment program – surface waters. Field operations and methods for measuring the

ecological condition of non-wadeable streams in Oregon. U.S. Environmental Protection Agency. Corvallis, Oregon.

Maloney, E., Fairey, R., Lyman, A., Reynolds, K., Sigala, M. 2007. Introduced Aquatic Species in San Diego Bay and the Sacramento-San Joaquin Delta. Final Report. United States Fish and Wildlife Service. Stockton, CA., 78pp

Nichols, F.H., and J.K. Thompson. 1985. Time scales of change in the San Francisco benthos. Hydrobiologia 129: 121-138.

Ruiz, G.M., Fofonoff, P.W., Carlton, J.T., Wonham, M.J., Hines, A.H. 2000. Invasion of Coastal Marine Communities in North America: Apparent Patterns, Processes, and Biases. Annual Review of Ecology and Systematics, Vol. 31, pp. 481-531.

Uncles R.J. and D.H. Peterson 1995. A computer model of long-term salinity in San Francisco Bay: sensitivity to mixing and inflows. Environment International, Volume 21, Number 5, 1995 , pp. 647-656(10).

WEB REFERENCE

California Aquatic Non-native Organism Database (CANOD). http://www.dfg.ca.gov/ospr/Science/invasive_species.aspx.

APPENDICES

Appendix A – Name, specialty and affiliation of taxonomists identifying specimens in the current survey.

Taxonomist Name	Specialty	Affiliation
Kelvin Barwick	Mollusca	City of San Diego, Environmental Monitoring & Technical Services Laboratory, SCAMIT
Chris Brown	Porifera	Smithsonian Environmental Research Center
Shannon Carpenter	Mollusca	Santa Barbara Museum of Natural History
Andy Cohen	Introduced Species	San Francisco Estuary Institute
Mary Megan Daly	Diadumene	Ohio State University
Patrick Gaffney	Oysters	University of Delaware College
Jeff Goddard	Nudibranchia	UC Santa Barbara
David Goodwin	Oysters	Department of Geosciences at Dennison University
Nick Haring	Echinodermata	City of San Diego, Environmental Monitoring & Technical Services Laboratory, SCAMIT
Leslie Harris	Polychaeta	Natural History Museum of Los Angeles County, SCAMIT
Gordon Hendler	Ophiuroidea	Natural History Museum of Los Angeles County, SCAMIT
Gretchen Lambert	Urochordata	University of Washington- Friday Harbor Labs, SCAMIT
Valerie Macdonald	Oligochaeta	Biologica Environmental Services, SCAMIT
Kathy Ann Miller	Marine Algae	University of California-Berkeley
Jaya Nolt	Mollusca	Santa Barbara Museum of Natural History
Dot Norris	Polychaeta	City and County of San Francisco, PUC / Natural Resources Oceanside Marine Laboratory
Tony Phillips	Nemertea & Platyhelminthes	City of Los Angeles, Environmental Monitoring Division, SCAMIT
Veronica Rodriguez	Polychaeta	UABC-IIO/EcoMar.org Consulting Services, SCAMIT
Rick Rowe	Polychaeta	City of San Diego, Polychaete Identification Consulting Services, SCAMIT
Greg Schroeder	Bryozoa	Moss Landing Marine Labs
Peter Slattery	Crustacea, Other	Moss Landing Marine Labs, SCAMIT
Paul Valentich-Scott	Mollusca	Santa Barbara Museum of Natural History, SCAMIT
John Ljubenkov	Cnidarians	Ljubenkov

Appendix B – Sampling Site Locations and Sample Dates

Site Name	Habitat Type	Sample Date	Latitude DD	Longitude DD
Alcatraz	Intertidal Rocky	16/Nov/2005	37.82534	-122.42228
Aquatic Park	Intertidal Sandy	07/Jun/2005	37.80798	-122.42156
Ayala Cove	Subtidal Infauna	21/Oct/2005	37.86798	-122.43497
Ayala Cove	Intertidal Rocky	19/Aug/2005	37.86922	-122.43466
Ayala Cove	Intertidal Sandy	19/Aug/2005	37.86715	-122.43449
Ayala Cove	Subtidal Fouling	21/Oct/2005	37.86798	-122.43497
Ballena Bay	Subtidal Fouling	05/Oct/2005	37.76616	-122.28418
Ballena Bay	Subtidal Infauna	08/Jun/2005	37.76608	-122.28340
Benicia Waterfront	Subtidal Infauna	07/Oct/2005	38.04005	-122.13853
Benicia Waterfront	Subtidal Fouling	07/Oct/2005	38.04005	-122.13853
Berkeley Flats/ Berkeley Pier	Subtidal Infauna	04/Oct/2005	37.86001	-122.32557
Berkeley Flats/ Berkeley Pier	Subtidal Fouling	04/Oct/2005	37.86001	-122.32557
Berkeley Marina	Subtidal Fouling	04/Oct/2005	37.86759	-122.31721
Cal Maritime Museum / Vallejo	Intertidal Rocky	14/Nov/2005	38.06612	-122.22987
Central Basin	Subtidal Infauna	25/Aug/2005	37.76429	-122.38625
Central Basin	Subtidal Fouling	25/Aug/2005	37.76429	-122.38625
Chevron Pier	Subtidal Fouling	06/Oct/2005	37.92280	-122.41050
Chevron Pier	Subtidal Infauna	06/Oct/2005	37.92280	-122.41050
China Basin	Subtidal Infauna	25/Aug/2005	37.77797	-122.38807
China Basin	Subtidal Fouling	25/Aug/2005	37.77797	-122.38807
China Camp	Intertidal Rocky	15/Nov/2005	38.00250	-122.46168
Coast Guard Island	Subtidal Infauna	05/Oct/2005	37.78124	-122.24567
Coast Guard Island	Subtidal Fouling	05/Oct/2005	37.78124	-122.24567
Corinthian Marina	Subtidal Fouling	21/Oct/2005	37.87256	-122.45625
Coyote Point	Intertidal Rocky	06/Jul/2005	37.59200	-122.32101
Coyote Pt Marina	Subtidal Infauna	09/Sep/2005	37.59052	-122.31766
Coyote Pt Marina	Subtidal Fouling	09/Sep/2005	37.59052	-122.31766
Crissy Field	Intertidal Sandy	07/Jun/2005	37.80585	-122.45656
Crown Beach	Intertidal Sandy	08/Jun/2005	37.76028	-122.27367
Cruise Ship Pier	Subtidal Infauna	08/Sep/2005	37.80852	-122.40601
Cruise Ship Pier	Subtidal Fouling	08/Sep/2005	37.80853	-122.40601
Dumbarton Bridge	Subtidal Infauna	07/Sep/2005	37.50703	-122.11675
Dumbarton Bridge	Subtidal Fouling	07/Sep/2005	37.50703	-122.11675
Ferry Terminal Pier	Subtidal Infauna	25/Aug/2005	37.79453	-122.39167
Ferry Terminal Pier	Subtidal Fouling	25/Aug/2005	37.79453	-122.39167
Fort Pt	Intertidal Rocky	07/Jun/2005	37.80950	-122.47607
Hayward Landing	Intertidal Sandy	10/Jun/2005	37.64466	-122.15431
Hercules Wharf	Subtidal Infauna	19/Oct/2005	38.02306	-122.29277
Hercules Wharf	Subtidal Fouling	19/Oct/2005	38.02306	-122.29277
Loch Lomond Marina area	Subtidal Fouling	20/Oct/2005	37.97203	-122.48322
Mare Island Strait - marina	Subtidal Infauna	19/Oct/2005	38.10508	-122.26672
Mare Island Strait - marina	Subtidal Fouling	19/Oct/2005	38.10508	-122.26672
Mare Island Strait - Navy	Subtidal Infauna	19/Oct/2005	38.10147	-122.26949

Mare Island Strait - Navy	Subtidal Fouling	19/Oct/2005	38.10147	-122.26949
Martinez Marina	Subtidal Infauna	07/Oct/2005	38.02759	-122.13711
Martinez Marina	Subtidal Fouling	07/Oct/2005	38.02759	-122.13711
McNears Beach	Intertidal Sandy	09/Jun/2005	37.99615	-122.45564
Napa Valley Marina	Subtidal Infauna	19/Oct/2005	38.21977	-122.31189
Napa Valley Marina	Subtidal Fouling	19/Oct/2005	38.21977	-122.31189
New York Point	Subtidal Infauna	07/Oct/2005	38.03995	-121.88631
New York Point	Subtidal Fouling	07/Oct/2005	38.03995	-121.88631
Oakland Inner Harbor - shipping cranes	Subtidal Fouling	04/Oct/2005	37.79572	-122.31355
Oakland Inner Harbor - shipping cranes	Subtidal Infauna	07/Jun/2005	37.79465	-122.30946
Oakland Inner Harbor - small marinas	Subtidal Fouling	05/Oct/2005	37.78450	-122.26739
Oakland Inner Harbor - small marinas	Subtidal Infauna	07/Jun/2005	37.78474	-122.26685
Oakland Outer harbor	Subtidal Fouling	04/Oct/2005	37.82212	-122.31201
Oakland Outer harbor	Subtidal Infauna	08/Jun/2005	37.82166	-122.31451
Pacheco Creek Oil Pier	Subtidal Infauna	18/Oct/2005	38.04888	-122.09028
Pacheco Creek Oil Pier	Subtidal Fouling	18/Oct/2005	38.04888	-122.09028
Paradise Area	Intertidal Sandy	09/Jun/2005	37.90619	-122.47678
Paradise Cay	Subtidal Fouling	21/Oct/2005	37.91469	-122.47744
Paradise Cay	Subtidal Infauna	09/Jun/2005	37.91464	-122.47763
Petaluma River Turning Basin	Subtidal Infauna	20/Oct/2005	38.23443	-122.63535
Petaluma River Turning Basin	Subtidal Fouling	15/Nov/2005	38.23443	-122.63535
Petaluma River Turning Basin	Subtidal Fouling	20/Oct/2005	38.23443	-122.63535
Pier 39	Subtidal Infauna	08/Sep/2005	37.81079	-122.40860
Pier 39	Subtidal Fouling	08/Sep/2005	37.81079	-122.40860
Pier 45	Subtidal Infauna	08/Sep/2005	37.81111	-122.41958
Pier 45	Subtidal Fouling	08/Sep/2005	37.81111	-122.41959
Point Cavallo	Intertidal Rocky	09/Jun/2005	37.83187	-122.47366
Point Richmond	Intertidal Sandy	08/Jul/2005	37.92120	-122.38705
Point Richmond Piers	Subtidal Infauna	06/Oct/2005	37.90845	-122.39126
Point Richmond Piers	Subtidal Fouling	06/Oct/2005	37.90845	-122.39126
Point San Pablo Yacht Harbor	Subtidal Infauna	20/Oct/2005	37.96429	-122.41846
Point San Pablo Yacht Harbor	Subtidal Fouling	20/Oct/2005	37.96429	-122.41846
Port of Oakland Office	Subtidal Fouling	05/Oct/2005	37.79541	-122.28041
Port of Oakland Office	Subtidal Infauna	07/Jun/2005	37.79541	-122.28042
Port Sonoma/ Petaluma R.	Subtidal Infauna	20/Oct/2005	38.11573	-122.50257
Port Sonoma/ Petaluma R.	Subtidal Fouling	20/Oct/2005	38.11573	-122.50257
Potrero Point	Subtidal Infauna	25/Aug/2005	37.75213	-122.37895
Potrero Point	Subtidal Fouling	25/Aug/2005	37.75213	-122.37895
Railroad bridge	Subtidal Infauna	07/Sep/2005	37.46019	-121.97495
Railroad bridge	Subtidal Fouling	07/Sep/2005	37.46019	-121.97495

Redwood Creek - marina	Subtidal Infauna	07/Sep/2005	37.50206	-122.21301
Redwood Creek - marina	Subtidal Fouling	07/Sep/2005	37.50206	-122.21301
Redwood Creek - shipping	Subtidal Infauna	07/Sep/2005	37.51201	-122.21094
Redwood Creek - shipping	Subtidal Fouling	07/Sep/2005	37.51201	-122.21094
Richardson Bay	Subtidal Fouling	21/Oct/2005	37.85885	-122.47984
Richardson Bay	Subtidal Infauna	09/Jun/2005	37.85884	-122.47977
Richmond Marina	Subtidal Infauna	06/Oct/2005	37.91369	-122.35035
Richmond Marina	Intertidal Rocky	08/Jul/2005	37.90933	-122.35735
Richmond Marina	Subtidal Fouling	06/Oct/2005	37.91369	-122.35035
Rodeo Marina	Subtidal Infauna	19/Oct/2005	38.03938	-122.27165
Rodeo Marina	Subtidal Fouling	19/Oct/2005	38.03938	-122.27165
Saint Francis Yacht Harbor	Subtidal Infauna	08/Sep/2005	37.80655	-122.44626
Saint Francis Yacht Harbor	Subtidal Fouling	08/Sep/2005	37.80655	-122.44626
San Mateo Bridge	Subtidal Infauna	09/Sep/2005	37.58057	-122.25426
San Mateo Bridge	Subtidal Fouling	09/Sep/2005	37.85057	-122.25426
San Pablo Bay Pumphouse	Subtidal Infauna	20/Oct/2005	38.04456	-122.43262
San Pablo Bay Pumphouse	Subtidal Fouling	20/Oct/2005	38.04456	-122.43262
Santa Fe Channel - back	Subtidal Infauna	06/Oct/2005	37.92065	-122.36842
Santa Fe Channel - back	Subtidal Fouling	06/Oct/2005	37.92065	-122.36842
Santa Fe Channel - front	Subtidal Infauna	06/Oct/2005	37.91006	-122.36436
Santa Fe Channel - front	Subtidal Fouling	06/Oct/2005	37.91006	-122.36436
Sea Plane Harbor	Subtidal Infauna	09/Sep/2005	37.63487	-122.38483
Sea Plane Harbor	Subtidal Fouling	09/Sep/2005	37.63487	-122.38483
Sea Plane Lagoon	Intertidal Sandy	08/Jun/2005	37.78050	-122.30721
Sea Plane Lagoon	Subtidal Fouling	05/Oct/2005	37.77615	-122.29978
Sea Plane Lagoon	Subtidal Infauna	08/Jun/2005	37.77609	-122.29980
Sierra Point Marina	Subtidal Infauna	09/Sep/2005	37.67397	-122.37923
Sierra Point Marina	Subtidal Fouling	09/Sep/2005	37.67397	-122.37923
Tiburon	Intertidal Rocky	07/Jul/2005	37.88826	-122.44446
Tiburon Rhomberg Center	Subtidal Fouling	21/Oct/2005	37.89063	-122.44577
Tiburon Rhomberg Center	Subtidal Infauna	09/Jun/2005	37.89030	-122.44574
Toll Plaza	Intertidal Sandy	10/Jun/2005	37.82662	-122.31657
Treasure Island	Subtidal Infauna	08/Sep/2005	37.81486	-122.37022
Treasure Island	Subtidal Fouling	08/Sep/2005	37.81486	-122.37022
Yerba Buena	Intertidal Rocky	08/Jun/2005	37.81456	-122.37122

Appendix C. Counts of introduced species individuals by station. (Colonial organisms not counted, a "P" indicates presence at a site.)

Species	Phylum	Total Count	Alcatraz	Aquatic Park	Ayala Cove	Ballena Bay	Benicia Waterfront	Berkeley Flats/ Pier	Berkeley Marina
Aeverrillia armata	Ectoprocta	P						P	
Aglaothamnion tenuissimum	Rhodophyta	P							
Alitta succinea	Annelida	251					14		
Amaeana sp. A Harris	Annelida	37			2				
Ampelisca abdita	Arthropoda	6310			13		48	1680	
Amphibalanus amphitrite	Arthropoda	22							
Amphibalanus improvisus	Arthropoda	5336					167	12	
Ampithoe valida	Arthropoda	4767			36		3	4	
Anguinella palmata	Ectoprocta	P			P			P	
Aoroides secundus	Arthropoda	11607	16		2	92			4380
Ascidia zara	Chordata	2698			P	162		8	424
Barentsia benedeni	Entoprocta	P			P		P		P
Boccardiella ligerica	Annelida	62							
Boonea bisuturalis	Mollusca	1							
Botrylloides violaceus	Chordata	590			10	P			64
Botryllus schlosseri	Chordata	359				8			48
Botryllus sp. A Lambert	Chordata	200							32
Branchiura sowerbyi	Annelida	1							
Bryopsis sp. 1 Miller	Chlorophyta	P				P			
Caprella mutica	Arthropoda	38162			342	164	35		7588
Carcinus maenas	Arthropoda	2							
Caulacanthus ustulatus	Rhodophyta	P			P				
Ciona intestinalis	Chordata	556			2	20			
Ciona savignyi	Chordata	3621			P	224			160
Clathria (Clathria) prolifera	Porifera	P	P			P		P	P
Codium fragile tomentosoides	Chlorophyta	P							
Conopeum tenuissimum	Ectoprocta	P	P	P	P		P	P	
Corbicula fluminea	Mollusca	8							
Corbula amurensis	Mollusca	1665			4		168		
Corophium alienense	Arthropoda	590							
Corophium heteroceratum	Arthropoda	1401		1	203			16	
Crassostrea virginica	Mollusca	2	1						
Crepidula fornicata	Mollusca	3							
Diadumene cincta	Cnidaria	P	P		P				
Diadumene franciscana	Cnidaria	P							
Diadumene leucolena	Cnidaria	P							
Diadumene lineata	Cnidaria	P	P						
Didemnum vexillum	Chordata	1405				20			28
Eochelidium	Arthropoda	16							
Eurylana arcuata	Arthropoda	2							

Eusarsiella zostericola	Arthropoda	260			3				
Ficopomatus enigmaticus	Annelida	1853							
Gammarus daiberi	Arthropoda	206							
Garveia franciscana	Cnidaria	P					P		
Gemma gemma	Mollusca	1495							
Geukensia demissa	Mollusca	10							
Grandidierella japonica	Arthropoda	7157			50		72	48	
Halichondria bowerbanki	Porifera	1	P		P	P		P	P
Haminoea japonica	Mollusca	P							
Ianiropsis serricaudis	Arthropoda	10868			144	36		32	1020
Ilyanassa obsoleta	Mollusca	1							
Jassa marmorata	Arthropoda	9521	16		1			220	240
Laonome sp. SF1 Norris	Annelida	64							
Littoridinops monroensis	Mollusca	6							
Littorina saxatilis	Mollusca	P							
Marenzelleria viridis	Annelida	2							
Melita nitida	Arthropoda	1869							12
Melita rylovae	Arthropoda	15337			6		6		
Molgula ficus	Chordata	108				108			
Molgula manhattensis	Chordata	24043			4	32		912	916
Monocorophium acherusicum	Arthropoda	7543			2	28	40		
Monocorophium insidiosum	Arthropoda	41196	16		262				
Musculista senhousia	Mollusca	3684	8		13			16	
Mya arenaria	Mollusca	131							
Mytilus galloprovincialis	Mollusca	3086			60			32	216
Nippoleucon hinumensis	Arthropoda	2183			46		144		
Okenia plana	Mollusca	162					2		
Palaemon macrodactylus	Arthropoda	43							
Paradexamine sp. SD1 SCAMIT	Arthropoda	2122			101	44			560
Paranthura japonica	Arthropoda	6170			19	320		269	648
Philine auriformis	Mollusca	5			2				
Pinauay crocea	Cnidaria	P							
Polysiphonia denudata	Rhodophyta	P							
Pseudosphaeroma campbellensis	Arthropoda	P	P		P				
Rhithropanopeus harrisii	Arthropoda	11							
Sabaco elongatus	Annelida	19							
Sargassum muticum	Heterokontophyta	P	P		P				
Schizoporella japonica	Ectoprocta	P	P	P	P				
Sphaeroma quoianum	Arthropoda	982		2	10				24
Streblospio benedicti complex	Annelida	5291							
Styela clava	Chordata	1257			P	40			116
Syllis nipponica	Annelida	5751			146	28		1364	56
Synidotea laticauda	Arthropoda	27570			2		271		
Theora lubrica	Mollusca	286			2				
Urosalpinx cinerea	Mollusca	75	4		1				
Venerupis philippinarum	Mollusca	107			1				
Watersipora subtorquata	Ectoprocta	P	P		P				
Watersipora subtorquata/ n. sp. Mackie	Ectoprocta	P	P	P	P				P

Species	Phylum	Cal Maritime Museum / Vallejo	Central Basin	Chevron Pier	China Basin	China Camp	Coast Guard Island	Corinthian Marina	Coyote Point
Aeverrillia armata	Ectoprocta								
Aglaothamnion tenuissimum	Rhodophyta					P			
Alitta succinea	Annelida	1				2			4
Amaeana sp. A Harris	Annelida		2	3	5				
Ampelisca abdita	Arthropoda		1	220	1				
Amphibalanus amphitrite	Arthropoda				14				
Amphibalanus improvisus	Arthropoda	120		84		20			
Ampithoe valida	Arthropoda	156	32	16		274	320	2	188
Anguinella palmata	Ectoprocta		P	P	P	P	P	P	P
Aoroides secundus	Arthropoda		254		226			80	
Ascidia zara	Chordata		17		14		184		P
Barentsia benedeni	Entoprocta	P	P		P	P		P	
Boccardiella ligerica	Annelida								4
Boonea bisuturalis	Mollusca								
Botrylloides violaceus	Chordata		16	126	26		P	2	16
Botryllus schlosseri	Chordata		12		8	P	8		P
Botryllus sp. A Lambert	Chordata								
Branchiura sowerbyi	Annelida								
Bryopsis sp. 1 Miller	Chlorophyta					P	P		P
Caprella mutica	Arthropoda		1198	8	3136		24	2880	
Carcinus maenas	Arthropoda	2				P			
Caulacanthus ustulatus	Rhodophyta								P
Ciona intestinalis	Chordata		8				92		
Ciona savignyi	Chordata		16	P	8		596		
Clathria (Clathria) prolifera	Porifera		P			P	P		P
Codium fragile tomentosoides	Chlorophyta								P
Conopeum tenuissimum	Ectoprocta	P	P			P	P		P
Corbicula fluminea	Mollusca	1							
Corbula amurensis	Mollusca	3				P			
Corophium alienense	Arthropoda								
Corophium heteroceratum	Arthropoda		74	10	8				
Crassostrea virginica	Mollusca	1							
Crepidula fornicata	Mollusca								3
Diadumene cincta	Cnidaria					P			
Diadumene franciscana	Cnidaria					P			
Diadumene leucolena	Cnidaria	P							P
Diadumene lineata	Cnidaria					P			
Didemnum vexillum	Chordata		78		52			P	
Eochelidium	Arthropoda								

Eurylana arcuata	Arthropoda								
Eusarsiella zostericola	Arthropoda								
Ficopomatus enigmaticus	Annelida	P							
Gammarus daiberi	Arthropoda								
Garveia franciscana	Cnidaria	P				P			
Gemma gemma	Mollusca								
Geukensia demissa	Mollusca	2				1			
Grandidierella japonica	Arthropoda		3	2			2		8
Halichondria bowerbanki	Porifera		P	P	P	P	P	P	P
Haminoea japonica	Mollusca								P
Ianiropsis serricaudis	Arthropoda				214		104	2064	
Ilyanassa obsoleta	Mollusca								P
Jassa marmorata	Arthropoda		3106	424				3678	
Laonome sp. SF1 Norris	Annelida								
Littoridinops monroensis	Mollusca								
Littorina saxatilis	Mollusca								P
Marenzelleria viridis	Annelida								
Melita nitida	Arthropoda					1			4
Melita rylovae	Arthropoda	4							64
Molgula ficus	Chordata								
Molgula manhattensis	Chordata	2	882	388	98	2	4		212
Monocorophium acherusicum	Arthropoda					124			1480
Monocorophium insidiosum	Arthropoda								16208
Musculista senhousia	Mollusca	4	4	89		P	43		23
Mya arenaria	Mollusca	2				P			
Mytilus galloprovincialis	Mollusca	5	42	44	16	11	24	34	21
Nippoleucon hinumensis	Arthropoda		2	6	3		14		
Okenia plana	Mollusca	P				14			
Palaemon macrodactylus	Arthropoda								
Paradexamine sp. SD1 SCAMIT	Arthropoda		203	12	166		40	2	
Paranthura japonica	Arthropoda		63	73	148		182		141
Philine auriformis	Mollusca				1	1			1
Pinauay crocea	Cnidaria								
Polysiphonia denudata	Rhodophyta								P
Pseudosphaeroma campbellensis	Arthropoda								P
Rhithropanopeus harrisii	Arthropoda								
Sabaco elongatus	Annelida								
Sargassum muticum	Heterokontophyta								P
Schizoporella japonica	Ectoprocta		P	P		P		P	P
Sphaeroma quoianum	Arthropoda								
Streblospio benedicti complex	Annelida								
Styela clava	Chordata		8	8	32		62	4	2
Syllis nipponica	Annelida		103	389	345	4	40	154	48
Synidotea laticauda	Arthropoda	8							
Theora lubrica	Mollusca		1	1	2		6		
Urosalpinx cinerea	Mollusca						8		18
Venerupis philippinarum	Mollusca	P				1			6
Watersipora subtorquata	Ectoprocta								P
Watersipora subtorquata/ n. sp. Mackie	Ectoprocta		P	P	P		P	P	P

Species	Phylum	Coyote Pt Marina	Crissy Field	Crown Beach	Cruise Ship Pier	Dumbarton Bridge	Ferry Terminal Pier	Fort Pt	Hayward Landing
Aeverrillia armata	Ectoprocta								
Aglaothamnion tenuissimum	Rhodophyta								
Alitta succinea	Annelida	1	1			11			25
Amaeana sp. A Harris	Annelida								
Ampelisca abdita	Arthropoda	3			10	650	12		1
Amphibalanus amphitrite	Arthropoda						8		
Amphibalanus improvisus	Arthropoda	2						12	
Ampithoe valida	Arthropoda			3					1
Anguinella palmata	Ectoprocta	P			P	P	P		
Aoroides secundus	Arthropoda	240							
Ascidia zara	Chordata	173			4				
Barentsia benedeni	Entoprocta					P			
Boccardiella ligerica	Annelida								
Boonea bisuturalis	Mollusca								1
Botrylloides violaceus	Chordata	1			10		52		
Botryllus schlosseri	Chordata	16					P		
Botryllus sp. A Lambert	Chordata	60							
Branchiura sowerbyi	Annelida								
Bryopsis sp. 1 Miller	Chlorophyta								
Caprella mutica	Arthropoda				198		92		
Carcinus maenas	Arthropoda								
Caulacanthus ustulatus	Rhodophyta								
Ciona intestinalis	Chordata	28			8				
Ciona savignyi	Chordata	112							
Clathria (Clathria) prolifera	Porifera	P							
Codium fragile tomentosoides	Chlorophyta	P							
Conopeum tenuissimum	Ectoprocta		P	P		P			P
Corbicula fluminea	Mollusca								
Corbula amurensis	Mollusca								6
Corophium alienense	Arthropoda								
Corophium heteroceratum	Arthropoda			23	1	8	40		
Crassostrea virginica	Mollusca								
Crepidula fornicata	Mollusca								
Diadumene cincta	Cnidaria								
Diadumene franciscana	Cnidaria								
Diadumene leucolena	Cnidaria								
Diadumene lineata	Cnidaria								
Didemnum vexillum	Chordata	26			5		4		
Eochelidium	Arthropoda								
Eurylana arcuata	Arthropoda	1							
Eusarsiella zostericola	Arthropoda						5		
Ficopomatus enigmaticus	Annelida								

Gammarus daiberi	Arthropoda								
Garveia franciscana	Cnidaria								
Gemma gemma	Mollusca			18					351
Geukensia demissa	Mollusca								
Grandidierella japonica	Arthropoda	6	1	130					78
Halichondria bowerbanki	Porifera	P				P		P	
Haminoea japonica	Mollusca								
Ianiropsis serricaudis	Arthropoda	2394			8	1	12		
Ilyanassa obsoleta	Mollusca					1			
Jassa marmorata	Arthropoda				27			536	
Laonome sp. SF1 Norris	Annelida								
Littoridinops monroensis	Mollusca								
Littorina saxatilis	Mollusca								
Marenzelleria viridis	Annelida								
Melita nitida	Arthropoda								1
Melita rylovae	Arthropoda								
Molgula ficus	Chordata								
Molgula manhattensis	Chordata	2158			4	382			
Monocorophium acherusicum	Arthropoda	11					4		
Monocorophium insidiosum	Arthropoda								78
Musculista senhousia	Mollusca	22		3	4	2			
Mya arenaria	Mollusca								11
Mytilus galloprovincialis	Mollusca	24				1	36	4	
Nippoleucon hinumensis	Arthropoda	3		2	10				2
Okenia plana	Mollusca								
Palaemon macrodactylus	Arthropoda	10							
Paradexamine sp. SD1 SCAMIT	Arthropoda	32		1	12		36		
Paranthura japonica	Arthropoda	402			30	37	128		
Philine auriformis	Mollusca								
Pinauay crocea	Cnidaria						P		
Polysiphonia denudata	Rhodophyta								
Pseudosphaeroma campbellensis	Arthropoda								
Rhithropanopeus harrisii	Arthropoda								
Sabaco elongatus	Annelida					1	2		
Sargassum muticum	Heterokontophyta								
Schizoporella japonica	Ectoprocta				P	P	P		
Sphaeroma quoianum	Arthropoda					2			
Streblospio benedicti complex	Annelida		2						116
Styela clava	Chordata	42			12	2			
Syllis nipponica	Annelida	1		1	32	7	32		
Synidotea laticauda	Arthropoda					145			
Theora lubrica	Mollusca	1			29	1			
Urosalpinx cinerea	Mollusca	2				4		4	
Venerupis philippinarum	Mollusca			2					
Watersipora subtorquata	Ectoprocta							P	
Watersipora subtorquata/ n. sp. Mackie	Ectoprocta	P	P		P		P	P	

Species	Phylum	Hercules Wharf	Loch Lomond Marina area	Mare Island Strait - marina	Mare Island Strait - Navy	Martinez Marina	McNears Beach	Napa Valley Marina	New York Point
Aeverrillia armata	Ectoprocta								
Aglaothamnion tenuissimum	Rhodophyta								
Alitta succinea	Annelida	6		2	18		1		
Amaeana sp. A Harris	Annelida								
Ampelisca abdita	Arthropoda	483		4			145		1
Amphibalanus amphitrite	Arthropoda								
Amphibalanus improvisus	Arthropoda	236		166	447	464		51	67
Ampithoe valida	Arthropoda		100	12	54	8		3	
Anguinella palmata	Ectoprocta		P						
Aoroides secundus	Arthropoda								
Ascidia zara	Chordata								
Barentsia benedeni	Entoprocta	P		P	P	P			
Boccardiella ligerica	Annelida								
Boonea bisuturalis	Mollusca								
Botrylloides violaceus	Chordata		P						
Botryllus schlosseri	Chordata		12						
Botryllus sp. A Lambert	Chordata		4						
Branchiura sowerbyi	Annelida								1
Bryopsis sp. 1 Miller	Chlorophyta	P							
Caprella mutica	Arthropoda		8						
Carcinus maenas	Arthropoda								
Caulacanthus ustulatus	Rhodophyta								
Ciona intestinalis	Chordata								
Ciona savignyi	Chordata								
Clathria (Clathria) prolifera	Porifera		P						
Codium fragile tomentosoides	Chlorophyta								
Conopeum tenuissimum	Ectoprocta	P		P	P	P	P	P	P
Corbicula fluminea	Mollusca								7
Corbula amurensis	Mollusca	138		14	51	52	250	6	
Corophium alienense	Arthropoda					293			

Corophium heteroceratum	Arthropoda		12	4	1				43
Crassostrea virginica	Mollusca								
Crepidula fornicata	Mollusca								
Diadumene cincta	Cnidaria								
Diadumene franciscana	Cnidaria								
Diadumene leucolena	Cnidaria								
Diadumene lineata	Cnidaria								
Didemnum vexillum	Chordata								
Eochelidium	Arthropoda								
Eurylana arcuata	Arthropoda						1		
Eusarsiella zostericola	Arthropoda	81							
Ficopomatus enigmaticus	Annelida			19		80		1553	
Gammarus daiberi	Arthropoda								206
Garveia franciscana	Cnidaria					P			
Gemma gemma	Mollusca	35							
Geukensia demissa	Mollusca							4	
Grandidierella japonica	Arthropoda	494	388	8	1	283	19	7	
Halichondria bowerbanki	Porifera		P						
Haminoea japonica	Mollusca								
Ianiropsis serricaudis	Arthropoda	26		27	4				
Ilyanassa obsoleta	Mollusca								
Jassa marmorata	Arthropoda								
Laonome sp. SF1 Norris	Annelida			1				12	20
Littoridinops monroensis	Mollusca								6
Littorina saxatilis	Mollusca								
Marenzelleria viridis	Annelida							2	
Melita nitida	Arthropoda	8	40	2	16		1	4	
Melita rylovae	Arthropoda		140		39	160		7	
Molgula ficus	Chordata								
Molgula manhattensis	Chordata		944						
Monocorophium acherusicum	Arthropoda	115	2432	18			12		
Monocorophium insidiosum	Arthropoda	4	32	6	2		6	1	
Musculista senhousia	Mollusca	14		2	3				
Mya arenaria	Mollusca	50					5		
Mytilus galloprovincialis	Mollusca	60	32		2				
Nippoleucon hinumensis	Arthropoda	93	104	87	43	55	88	36	37
Okenia plana	Mollusca				10				
Palaemon macrodactylus	Arthropoda		4			4			
Paradexamine sp. SD1 SCAMIT	Arthropoda								
Paranthura japonica	Arthropoda		68						
Philine auriformis	Mollusca								
Pinauay crocea	Cnidaria								
Polysiphonia denudata	Rhodophyta								
Pseudosphaeroma campbellensis	Arthropoda								
Rhithropanopeus harrisii	Arthropoda							11	
Sabaco elongatus	Annelida								
Sargassum muticum	Heterokontophyta								
Schizoporella japonica	Ectoprocta								
Sphaeroma quoianum	Arthropoda	154	20	140	24	64		6	

Streblospio benedicti complex	Annelida	562		18			35	34	
Styela clava	Chordata								
Syllis nipponica	Annelida								
Synidotea laticauda	Arthropoda	38	8	78	1139	521		11	1
Theora lubrica	Mollusca								
Urosalpinx cinerea	Mollusca								
Venerupis philippinarum	Mollusca	10							
Watersipora subtorquata	Ectoprocta								
Watersipora subtorquata/ n. sp. Mackie	Ectoprocta						P		

Species	**Phylum**	Oakland Inner Hrbr - shipping cranes	Oakland Inner Hrbr - small marinas	Oakland Outer harbor	Pacheco Creek Oil Pier	Paradise Area	Paradise Cay	Petaluma River Turning Basin	Pier 39
Aeverrillia armata	Ectoprocta								
Aglaothamnion tenuissimum	Rhodophyta								
Alitta succinea	Annelida				7	8			
Amaeana sp. A Harris	Annelida	1	4	7					
Ampelisca abdita	Arthropoda	9	12	2		3	251	92	2
Amphibalanus amphitrite	Arthropoda								
Amphibalanus improvisus	Arthropoda				271				40
Ampithoe valida	Arthropoda			4		17	44		
Anguinella palmata	Ectoprocta		P				P		
Aoroides secundus	Arthropoda	2	2				4		
Ascidia zara	Chordata	219	57	76			8		
Barentsia benedeni	Entoprocta	P			P				P
Boccardiella ligerica	Annelida								
Boonea bisuturalis	Mollusca								
Botrylloides violaceus	Chordata	6	12	5					6
Botryllus schlosseri	Chordata	4	P				8		9
Botryllus sp. A Lambert	Chordata						46		
Branchiura sowerbyi	Annelida								
Bryopsis sp. 1 Miller	Chlorophyta								P
Caprella mutica	Arthropoda		2	37			102	3	624
Carcinus maenas	Arthropoda								
Caulacanthus ustulatus	Rhodophyta								
Ciona intestinalis	Chordata	10	63	28			P		4
Ciona savignyi	Chordata	436	398	536			44		8
Clathria (Clathria) prolifera	Porifera			P			P		

Codium fragile tomentosoides	Chlorophyta								
Conopeum tenuissimum	Ectoprocta	P		P	P	P			P
Corbicula fluminea	Mollusca								
Corbula amurensis	Mollusca	1			26	58		2	
Corophium alienense	Arthropoda								
Corophium heteroceratum	Arthropoda		90	37		312			52
Crassostrea virginica	Mollusca								
Crepidula fornicata	Mollusca								
Diadumene cincta	Cnidaria								
Diadumene franciscana	Cnidaria								
Diadumene leucolena	Cnidaria								
Diadumene lineata	Cnidaria								
Didemnum vexillum	Chordata						P		70
Eochelidium	Arthropoda								
Eurylana arcuata	Arthropoda								
Eusarsiella zostericola	Arthropoda								
Ficopomatus enigmaticus	Annelida							200	
Gammarus daiberi	Arthropoda								
Garveia franciscana	Cnidaria								
Gemma gemma	Mollusca					2			
Geukensia demissa	Mollusca								
Grandidierella japonica	Arthropoda				2	1369	3	240	
Halichondria bowerbanki	Porifera	P	P	P			P		
Haminoea japonica	Mollusca								
Ianiropsis serricaudis	Arthropoda	328	34	86					4
Ilyanassa obsoleta	Mollusca								
Jassa marmorata	Arthropoda								14
Laonome sp. SF1 Norris	Annelida							16	
Littoridinops monroensis	Mollusca								
Littorina saxatilis	Mollusca								
Marenzelleria viridis	Annelida								
Melita nitida	Arthropoda		2	8	1135				
Melita rylovae	Arthropoda								
Molgula ficus	Chordata								
Molgula manhattensis	Chordata	20	4	24			365		70
Monocorophium acherusicum	Arthropoda		2		179	1	104	118	
Monocorophium insidiosum	Arthropoda			13	2	332	13		128
Musculista senhousia	Mollusca	269	173						
Mya arenaria	Mollusca	1				23			
Mytilus galloprovincialis	Mollusca	12	4	754			89		69
Nippoleucon hinumensis	Arthropoda	2		3	3	398	63	406	9
Okenia plana	Mollusca								
Palaemon macrodactylus	Arthropoda								
Paradexamine sp. SD1 SCAMIT	Arthropoda			41			126		4
Paranthura japonica	Arthropoda	72	38	52			7	2	8
Philine auriformis	Mollusca								
Pinauay crocea	Cnidaria								
Polysiphonia denudata	Rhodophyta								
Pseudosphaeroma campbellensis	Arthropoda								

Rhithropanopeus harrisii	Arthropoda								
Sabaco elongatus	Annelida						1		
Sargassum muticum	Heterokontophyta								
Schizoporella japonica	Ectoprocta								
Sphaeroma quoianum	Arthropoda				15				
Streblospio benedicti complex	Annelida	52	1			430	1		
Styela clava	Chordata	52	16	12			4		
Syllis nipponica	Annelida	66	47	65			70		1
Synidotea laticauda	Arthropoda				423				
Theora lubrica	Mollusca	15	10	1			1		
Urosalpinx cinerea	Mollusca								
Venerupis philippinarum	Mollusca					11			
Watersipora subtorquata	Ectoprocta								
Watersipora subtorquata/ n. sp. Mackie	Ectoprocta	P	P	P			P		P

Species	**Phylum**	Pier 45	Point Cavallo	Point Richmond	Point Richmond Piers	Point San Pablo Yacht Hrbr	Port of Oakland Office	Port Sonoma/ Petaluma R.	Potrero Point
Aeverrillia armata	Ectoprocta								
Aglaothamnion tenuissimum	Rhodophyta								
Alitta succinea	Annelida			4				3	
Amaeana sp. A Harris	Annelida								
Ampelisca abdita	Arthropoda	8			4	242	2		1
Amphibalanus amphitrite	Arthropoda								
Amphibalanus improvisus	Arthropoda					14		320	
Ampithoe valida	Arthropoda			5		180	40	24	
Anguinella palmata	Ectoprocta				P	P			P
Aoroides secundus	Arthropoda	328			116		82		
Ascidia zara	Chordata				20		62		12
Barentsia benedeni	Entoprocta							P	
Boccardiella ligerica	Annelida								
Boonea bisuturalis	Mollusca								
Botrylloides violaceus	Chordata	P			56		10		12
Botryllus schlosseri	Chordata				4	17	22		16
Botryllus sp. A Lambert	Chordata				6				
Branchiura sowerbyi	Annelida								
Bryopsis sp. 1 Miller	Chlorophyta								
Caprella mutica	Arthropoda	144			74	227	22		4
Carcinus maenas	Arthropoda								
Caulacanthus ustulatus	Rhodophyta								
Ciona intestinalis	Chordata						16		

Ciona savignyi	Chordata				2		268		
Clathria (Clathria) prolifera	Porifera				P	P	P		P
Codium fragile tomentosoides	Chlorophyta								
Conopeum tenuissimum	Ectoprocta		P		P			P	P
Corbicula fluminea	Mollusca								
Corbula amurensis	Mollusca			9		2		267	
Corophium alienense	Arthropoda								
Corophium heteroceratum	Arthropoda	76			4	4	40		112
Crassostrea virginica	Mollusca								
Crepidula fornicata	Mollusca								
Diadumene cincta	Cnidaria		P						
Diadumene franciscana	Cnidaria								
Diadumene leucolena	Cnidaria								
Diadumene lineata	Cnidaria								
Didemnum vexillum	Chordata	6			28				69
Eochelidium	Arthropoda								
Eurylana arcuata	Arthropoda								
Eusarsiella zostericola	Arthropoda								
Ficopomatus enigmaticus	Annelida								
Gammarus daiberi	Arthropoda								
Garveia franciscana	Cnidaria								
Gemma gemma	Mollusca								
Geukensia demissa	Mollusca								
Grandidierella japonica	Arthropoda		4		24	362	3		
Halichondria bowerbanki	Porifera		P		P	P	P		P
Haminoea japonica	Mollusca								
Ianiropsis serricaudis	Arthropoda	536	154		224	6	98	1	4
Ilyanassa obsoleta	Mollusca								
Jassa marmorata	Arthropoda		536		116				236
Laonome sp. SF1 Norris	Annelida								
Littoridinops monroensis	Mollusca								
Littorina saxatilis	Mollusca								
Marenzelleria viridis	Annelida								
Melita nitida	Arthropoda								
Melita rylovae	Arthropoda								
Molgula ficus	Chordata								
Molgula manhattensis	Chordata	P			490	649	4		1344
Monocorophium acherusicum	Arthropoda	12		402		23	10	1	
Monocorophium insidiosum	Arthropoda								
Musculista senhousia	Mollusca				20	6	77		8
Mya arenaria	Mollusca								
Mytilus galloprovincialis	Mollusca	16	2		30	10	12		125
Nippoleucon hinumensis	Arthropoda	4		2		48	6	8	2
Okenia plana	Mollusca								
Palaemon macrodactylus	Arthropoda							13	
Paradexamine sp. SD1 SCAMIT	Arthropoda	60		1		65	4		16
Paranthura japonica	Arthropoda	216			348		75	1	52
Philine auriformis	Mollusca								
Pinauay crocea	Cnidaria								
Polysiphonia denudata	Rhodophyta								

Pseudosphaeroma campbellensis	Arthropoda								
Rhithropanopeus harrisii	Arthropoda								
Sabaco elongatus	Annelida								
Sargassum muticum	Heterokontophyta								
Schizoporella japonica	Ectoprocta								P
Sphaeroma quoianum	Arthropoda	4						63	
Streblospio benedicti complex	Annelida					2		2	
Styela clava	Chordata	P			12	2	90		1
Syllis nipponica	Annelida				329	25	44		46
Synidotea laticauda	Arthropoda					22		192	
Theora lubrica	Mollusca	4					31		8
Urosalpinx cinerea	Mollusca		8						
Venerupis philippinarum	Mollusca		P						
Watersipora subtorquata	Ectoprocta		P						
Watersipora subtorquata/ n. sp. Mackie	Ectoprocta	P	P		P		P		P

Species	**Phylum**	Railroad Bridge	Redwood Creek - marina	Redwood Crk - shipping	Richardson Bay	Richmond Marina	Rodeo Marina	Saint Francis Yacht Hrbr	San Mateo Bridge
Aeverrillia armata	Ectoprocta								P
Aglaothamnion tenuissimum	Rhodophyta								
Alitta succinea	Annelida		20	40			1		16
Amaeana sp. A Harris	Annelida		1						
Ampelisca abdita	Arthropoda	1	13	16	20	13		1	
Amphibalanus amphitrite	Arthropoda								
Amphibalanus improvisus	Arthropoda	706		512		16	41		
Ampithoe valida	Arthropoda					2340		4	
Anguinella palmata	Ectoprocta	P	P	P		P		P	P
Aoroides secundus	Arthropoda				464	1096		174	
Ascidia zara	Chordata		57	48	32	225		16	32
Barentsia benedeni	Entoprocta	P							P
Boccardiella ligerica	Annelida	58							
Boonea bisuturalis	Mollusca								
Botrylloides violaceus	Chordata			P	16	24		1	P
Botryllus schlosseri	Chordata		4			28		4	
Botryllus sp. A Lambert	Chordata				4			8	
Branchiura sowerbyi	Annelida								
Bryopsis sp. 1 Miller	Chlorophyta					P			P
Caprella mutica	Arthropoda				2460	5716		134	
Carcinus maenas	Arthropoda					P			
Caulacanthus ustulatus	Rhodophyta					P			
Ciona intestinalis	Chordata		4		8			46	

Ciona savignyi	Chordata		24	12	76	176		56	8
Clathria (Clathria) prolifera	Porifera					P			P
Codium fragile tomentosoides	Chlorophyta					P			
Conopeum tenuissimum	Ectoprocta	P		P		P	P		P
Corbicula fluminea	Mollusca								
Corbula amurensis	Mollusca	39					9		
Corophium alienense	Arthropoda						297		
Corophium heteroceratum	Arthropoda			2	52				1
Crassostrea virginica	Mollusca								
Crepidula fornicata	Mollusca								
Diadumene cincta	Cnidaria								
Diadumene franciscana	Cnidaria								
Diadumene leucolena	Cnidaria						P		P
Diadumene lineata	Cnidaria								
Didemnum vexillum	Chordata		24	14	32	72		P	
Eochelidium	Arthropoda		1	2	8				
Eurylana arcuata	Arthropoda								
Eusarsiella zostericola	Arthropoda								
Ficopomatus enigmaticus	Annelida						1		
Gammarus daiberi	Arthropoda								
Garveia franciscana	Cnidaria								
Gemma gemma	Mollusca								
Geukensia demissa	Mollusca			3					
Grandidierella japonica	Arthropoda	36	58	30	24	152	76		1
Halichondria bowerbanki	Porifera		P	P	P	P		P	1
Haminoea japonica	Mollusca								
Ianiropsis serricaudis	Arthropoda	32	624		204	792			24
Ilyanassa obsoleta	Mollusca								
Jassa marmorata	Arthropoda				80	20			
Laonome sp. SF1 Norris	Annelida	15							
Littoridinops monroensis	Mollusca								
Littorina saxatilis	Mollusca								
Marenzelleria viridis	Annelida								
Melita nitida	Arthropoda	P	12			32	1		
Melita rylovae	Arthropoda	13054				88			
Molgula ficus	Chordata								
Molgula manhattensis	Chordata		3381	2848	138	117		8	4064
Monocorophium acherusicum	Arthropoda	2	520		4			12	
Monocorophium insidiosum	Arthropoda	1	908			12454			
Musculista senhousia	Mollusca		44	430	4	12		1	2195
Mya arenaria	Mollusca					P			
Mytilus galloprovincialis	Mollusca		4	4	16	157	3	12	68
Nippoleucon hinumensis	Arthropoda	39	1	8	8	2	256		1
Okenia plana	Mollusca								
Palaemon macrodactylus	Arthropoda								
Paradexamine sp. SD1 SCAMIT	Arthropoda				196	84		1	
Paranthura japonica	Arthropoda		398	100	116	244		29	430
Philine auriformis	Mollusca								
Pinauay crocea	Cnidaria								
Polysiphonia denudata	Rhodophyta								

Pseudosphaeroma campbellensis	Arthropoda					P			
Rhithropanopeus harrisii	Arthropoda								
Sabaco elongatus	Annelida		2			2			
Sargassum muticum	Heterokontophyta								
Schizoporella japonica	Ectoprocta				P	P		P	P
Sphaeroma quoianum	Arthropoda	4	60			24	163		
Streblospio benedicti complex	Annelida	114	1	8		4			
Styela clava	Chordata		8	24	44	44		4	224
Syllis nipponica	Annelida		5		150	33		5	407
Synidotea laticauda	Arthropoda	8413			32				
Theora lubrica	Mollusca		6	138				3	1
Urosalpinx cinerea	Mollusca		24						
Venerupis philippinarum	Mollusca					1			44
Watersipora subtorquata	Ectoprocta					P			
Watersipora subtorquata/ n. sp. Mackie	Ectoprocta		P	P	P	P		P	P

Species	**Phylum**	San Pablo Bay Pumphouse	Santa Fe Channel - back	Santa Fe Channel - front	Sea Plane Harbor	Sea Plane Lagoon	Sierra Point Marina	Tiburon	Tiburon Romberg Center
Aeverrillia armata	Ectoprocta								
Aglaothamnion tenuissimum	Rhodophyta								
Alitta succinea	Annelida	32			17	10			
Amaeana sp. A Harris	Annelida	4							8
Ampelisca abdita	Arthropoda	105		6	1	17	12		2200
Amphibalanus amphitrite	Arthropoda								
Amphibalanus improvisus	Arthropoda	116		820		16		88	
Ampithoe valida	Arthropoda					8		848	
Anguinella palmata	Ectoprocta		P	P			P	P	P
Aoroides secundus	Arthropoda		76	40	2	3381			
Ascidia zara	Chordata		112	157	11	360	80		1
Barentsia benedeni	Entoprocta	P				P			
Boccardiella ligerica	Annelida								
Boonea bisuturalis	Mollusca								
Botrylloides violaceus	Chordata		40	12	4	16	P		5
Botryllus schlosseri	Chordata		78	28	5	20	P		
Botryllus sp. A Lambert	Chordata		8			24			
Branchiura sowerbyi	Annelida								
Bryopsis sp. 1 Miller	Chlorophyta						P		
Caprella mutica	Arthropoda	8	600	424	5	8991	44		2
Carcinus maenas	Arthropoda								
Caulacanthus ustulatus	Rhodophyta								
Ciona intestinalis	Chordata		6	48	5	36	88		

Ciona savignyi	Chordata		30	152	P	128	50		2
Clathria (Clathria) prolifera	Porifera		P	P		P	P	P	
Codium fragile tomentosoides	Chlorophyta								
Conopeum tenuissimum	Ectoprocta	P	P		P	P		P	
Corbicula fluminea	Mollusca								
Corbula amurensis	Mollusca	539				1			
Corophium alienense	Arthropoda								
Corophium heteroceratum	Arthropoda	11	68	16			72		8
Crassostrea virginica	Mollusca								
Crepidula fornicata	Mollusca								
Diadumene cincta	Cnidaria							P	
Diadumene franciscana	Cnidaria								
Diadumene leucolena	Cnidaria								
Diadumene lineata	Cnidaria							P	
Didemnum vexillum	Chordata			212			38		
Eochelidium	Arthropoda			4		1			
Eurylana arcuata	Arthropoda								
Eusarsiella zostericola	Arthropoda	1							
Ficopomatus enigmaticus	Annelida								
Gammarus daiberi	Arthropoda								
Garveia franciscana	Cnidaria	P							
Gemma gemma	Mollusca					76			
Geukensia demissa	Mollusca								
Grandidierella japonica	Arthropoda	1		172	5	651	148		48
Halichondria bowerbanki	Porifera	P	P	P	P	P	P	P	P
Haminoea japonica	Mollusca								
Ianiropsis serricaudis	Arthropoda	16	30	100	4	982	498		
Ilyanassa obsoleta	Mollusca								
Jassa marmorata	Arthropoda					68			14
Laonome sp. SF1 Norris	Annelida								
Littoridinops monroensis	Mollusca								
Littorina saxatilis	Mollusca								
Marenzelleria viridis	Annelida								
Melita nitida	Arthropoda		4	16	1	568			
Melita rylovae	Arthropoda		32	20		1717			
Molgula ficus	Chordata								
Molgula manhattensis	Chordata	24	38	41	26	1263	1982		15
Monocorophium acherusicum	Arthropoda	95				2	40	1524	195
Monocorophium insidiosum	Arthropoda		28			1330	64	5168	
Musculista senhousia	Mollusca	17	10	4	2	52	41	38	7
Mya arenaria	Mollusca	1				13			
Mytilus galloprovincialis	Mollusca	256	20	44		84	30	102	6
Nippoleucon hinumensis	Arthropoda	11			15	1	4		12
Okenia plana	Mollusca	136							
Palaemon macrodactylus	Arthropoda	8			4				
Paradexamine sp. SD1 SCAMIT	Arthropoda		24	156	27		16		37
Paranthura japonica	Arthropoda		126	164	40	864	110		24
Philine auriformis	Mollusca								
Pinauay crocea	Cnidaria								
Polysiphonia denudata	Rhodophyta								

Pseudosphaeroma campbellensis	Arthropoda							P	
Rhithropanopeus harrisii	Arthropoda								
Sabaco elongatus	Annelida	4	4		1		2		
Sargassum muticum	Heterokontophyta							P	
Schizoporella japonica	Ectoprocta		P		P			P	P
Sphaeroma quoianum	Arthropoda			20	21		10		
Streblospio benedicti complex	Annelida	13	240						
Styela clava	Chordata		10	16	10	112	62		2
Syllis nipponica	Annelida	8	106	36	22	465	18		109
Synidotea laticauda	Arthropoda	16021	4	240		1			
Theora lubrica	Mollusca	3		22					
Urosalpinx cinerea	Mollusca				2				
Venerupis philippinarum	Mollusca					29			2
Watersipora subtorquata	Ectoprocta							P	
Watersipora subtorquata/ n. sp. Mackie	Ectoprocta					P	P	P	P

Species	**Phylum**	Toll Plaza	Treasure Isl.	Yerba Buena
Aeverrillia armata	Ectoprocta			
Aglaothamnion tenuissimum	Rhodophyta			
Alitta succinea	Annelida	7		
Amaeana sp. A Harris	Annelida			
Ampelisca abdita	Arthropoda	5		
Amphibalanus amphitrite	Arthropoda			
Amphibalanus improvisus	Arthropoda			528
Ampithoe valida	Arthropoda	13		28
Anguinella palmata	Ectoprocta			P
Aoroides secundus	Arthropoda		550	
Ascidia zara	Chordata		127	
Barentsia benedeni	Entoprocta			P
Boccardiella ligerica	Annelida			
Boonea bisuturalis	Mollusca			
Botrylloides violaceus	Chordata		37	5
Botryllus schlosseri	Chordata		P	
Botryllus sp. A Lambert	Chordata		8	
Branchiura sowerbyi	Annelida			
Bryopsis sp. 1 Miller	Chlorophyta			
Caprella mutica	Arthropoda		2866	
Carcinus maenas	Arthropoda			

Caulacanthus ustulatus	Rhodophyta			
Ciona intestinalis	Chordata		36	
Ciona savignyi	Chordata		99	
Clathria (Clathria) prolifera	Porifera		P	
Codium fragile tomentosoides	Chlorophyta			
Conopeum tenuissimum	Ectoprocta			P
Corbicula fluminea	Mollusca			
Corbula amurensis	Mollusca	20		
Corophium alienense	Arthropoda			
Corophium heteroceratum	Arthropoda			
Crassostrea virginica	Mollusca			
Crepidula fornicata	Mollusca			
Diadumene cincta	Cnidaria			P
Diadumene franciscana	Cnidaria			
Diadumene leucolena	Cnidaria			P
Diadumene lineata	Cnidaria			P
Didemnum vexillum	Chordata		627	
Eochelidium	Arthropoda			
Eurylana arcuata	Arthropoda			
Eusarsiella zostericola	Arthropoda	170		
Ficopomatus enigmaticus	Annelida			
Gammarus daiberi	Arthropoda			
Garveia franciscana	Cnidaria			
Gemma gemma	Mollusca	1013		
Geukensia demissa	Mollusca			
Grandidierella japonica	Arthropoda	1808	340	
Halichondria bowerbanki	Porifera		P	P
Haminoea japonica	Mollusca			
Ianiropsis serricaudis	Arthropoda		1	
Ilyanassa obsoleta	Mollusca			
Jassa marmorata	Arthropoda		172	17
Laonome sp. SF1 Norris	Annelida			
Littoridinops monroensis	Mollusca			
Littorina saxatilis	Mollusca			
Marenzelleria viridis	Annelida			
Melita nitida	Arthropoda		1	
Melita rylovae	Arthropoda			
Molgula ficus	Chordata			
Molgula manhattensis	Chordata		188	
Monocorophium acherusicum	Arthropoda	31		
Monocorophium insidiosum	Arthropoda	4132	1	7
Musculista senhousia	Mollusca			24
Mya arenaria	Mollusca	25		
Mytilus galloprovincialis	Mollusca		462	31
Nippoleucon hinumensis	Arthropoda	96		
Okenia plana	Mollusca			
Palaemon macrodactylus	Arthropoda			
Paradexamine sp. SD1 SCAMIT	Arthropoda		55	
Paranthura japonica	Arthropoda		126	0
Philine auriformis	Mollusca			

Pinauay crocea	Cnidaria			
Polysiphonia denudata	Rhodophyta			
Pseudosphaeroma campbellensis	Arthropoda			
Rhithropanopeus harrisii	Arthropoda			
Sabaco elongatus	Annelida			
Sargassum muticum	Heterokontophyta			P
Schizoporella japonica	Ectoprocta			P
Sphaeroma quoianum	Arthropoda			152
Streblospio benedicti complex	Annelida	3656		
Styela clava	Chordata		180	
Syllis nipponica	Annelida	2	941	1
Synidotea laticauda	Arthropoda			
Theora lubrica	Mollusca			
Urosalpinx cinerea	Mollusca			
Venerupis philippinarum	Mollusca			
Watersipora subtorquata	Ectoprocta			P
Watersipora subtorquata/ n. sp. Mackie	Ectoprocta		P	P

Appendix D - Cryptogenic species identified in the current survey of San Francisco Bay.

Species	Phylum	Likely Introduced or Native	Total Sites Observed
Acerotisa californica	Platyhelminthes		7
Alcyonidium parasiticum	Ectoprocta		3
Amathia distans	Ectoprocta		1
Ammothea hilgendorfi	Arthropoda		14
Amphipholis squamata	Echinodermata		3
Ampithoe lacertosa	Arthropoda		10
Aphelochaeta monilaris	Annelida		4
Apoprionospio pygmaea	Annelida		1
Boccardia proboscidea	Annelida	Native	1
Boccardiella hamata	Annelida	Introduced	2
Bowerbankia gracilis	Ectoprocta		10
Bugula neritina	Ectoprocta	Introduced	27
Capitella	Annelida		2
Caprella angusta	Annelida		6
Caprella californica	Arthropoda	Native	11
Caprella equilibra	Arthropoda		4
Caprella natalensis	Arthropoda	Native	22
Carinomella lactea	Nemertea	Native	5
Chaetozone bansei	Annelida	Native	2
Ctenodrilus serratus	Annelida	Introduced	29
Cumella vulgaris	Arthropoda		7
Dipolydora caulleryi	Annelida		1
Dipolydora socialis	Annelida		22
Dispio uncinata	Annelida		1
Dorvillea rudolphi	Annelida		24
Elachista fucicola	Heterokontophyta		1
Euchone limnicola	Annelida		23
Eudorella pacifica	Arthropoda	Native	15
Eurylepta aurantiaca	Platyhelminthes		12
Exogone lourei	Annelida	Native	46
Glycera americana	Annelida	Native	5
Glycinde picta	Annelida	Native	33
Grateloupia californica	Rhodophyta		10
Harmothoe imbricata	Annelida		21
Hemipodia simplex	Annelida		2
Heteropodarke heteromorpha	Annelida		1
Ianiropsis tridens	Arthropoda		1
Jassa carltoni	Arthropoda		5
Jassa slatteryi	Arthropoda		8
Laticorophium baconi	Arthropoda		29
Leptochelia dubia	Arthropoda		24
Leucothoe alata	Arthropoda		21
Lineus ruber	Nemertea		1
Marphysa sp C Harris	Annelida		1

Mediomastus ambiseta	Annelida		2
Mediomastus californiensis	Annelida		1
Myrianida sp 1 Harris	Annelida	Introduced	7
Myxicola infundibulum	Annelida		3
Naineris quadricuspidata	Annelida		4
Neanthes arenaceodentata	Annelida		1
Nereis grubei	Annelida		1
Nereis mediator	Annelida		2
Nicolea ?amnis	Annelida	Introduced	17
Nipponemertes bimaculata	Nemertea	Native	1
Nipponemertes pacifica	Nemertea	Native	1
Notomastus lineatus	Annelida		1
Notomastus tenuis	Annelida		3
Paranais litoralis	Annelida		2
Paraprionospio pinnata	Annelida		3
Pettiboneia sanmatiensis	Annelida		2
Phascolosoma agassizii	Sipuncula		2
Phyllodoce longipes	Annelida		2
Phyllodoce madeirensis	Annelida		1
Platynereis bicanaliculata	Annelida		14
Polycera hedgpethi	Mollusca		1
Polydora cornuta	Annelida	Introduced	45
Polydora websteri	Annelida		10
Proceraea okadai	Annelida		1
Pseudopolydora kempi	Annelida	Introduced	12
Pygodelphys aquilonaris	Arthropoda		1
Pygospio elegans	Annelida		3
Scolelepis squamata	Annelida		2
Scoletoma tetraura Complex	Annelida		3
Sphaerosyllis sp SF1 Harris	Annelida	Introduced	32
Sternaspis fossor	Annelida		1
Stygocapitella subterranea	Annelida		7
Teneridrilus mastix	Annelida		1
Thysanocardia nigra	Sipuncula		2
Typosyllis armillaris	Annelida		20
Zeuxo normani	Arthropoda		3
Zygonemertes virescens	Nemertea		4

Appendix E – Percent fines and collection depths for San Francisco Bay survey sites.
Collection depths for intertidal sandy sites show relative location on beach (low or high).

Site Name	Collection Depth (m)	% Fines
Aquatic Park	Low	0.00
Aquatic Park	High	0.00
Ayala Cove	Low	0.49
Ayala Cove	High	0.00
Ayala Cove	5.9	74.86
Ballena Bay	4	62.07
Benicia Waterfront	1.2	50.43
Berkeley Flats/ Berkeley Pier	3.9	66.07
Central Basin	2.4	67.84
Chevron Pier	2.3	85.63
China Basin	4.7	92.56
Coast Guard Island	3.9	90.07
Coyote Pt Marina	3.7	89.58
Crissy Field	Low	0.00
Crissy Field	High	0.00
Crown Beach	High	0.59
Crown Beach	Low	0.50
Cruise Ship Pier	12	83.61
Dumbarton Bridge	11	96.57
Ferry Terminal Pier	4.2	67.75
Hayward Landing	Low	82.99
Hayward Landing	High	0.89
Hercules Wharf	1.3	30.32
Mare Island Strait - marina	3.7	96.59
Mare Island Strait - Navy	4.7	90.58
Martinez Marina	1.3	85.86
McNears Beach	High	0.00
McNears Beach	Low	8.35
Napa Valley Marina	1.5	89.09
New York Point	2.8	88.79
Oakland Inner Harbor - shipping cranes	16	58.39
Oakland Inner Harbor - small marinas	4.5	98.65
Oakland Outer harbor	11.7	97.94
Pacheco Creek Oil Pier	9.8	30.18
Paradise Area	High	0.00
Paradise Area	Low	2.73
Paradise Cay	2.8	96.00
Petaluma River Turning Basin	4.5	92.11
Pier 39	4	87.90
Pier 45	6.7	66.06
Point Richmond	Low	10.23
Point Richmond	High	10.99
Point Richmond Piers	2.5	80.46
Point San Pablo Yacht Harbor	2	77.65
Port of Oakland Office	7	92.60

Port Sonoma/ Petaluma R.	1.8	91.70
Potrero Point	5.7	93.48
Railroad bridge	2.4	55.38
Redwood Creek - marina	5	89.69
Redwood Creek - shipping	12.5	84.62
Richardson Bay	3.4	92.65
Richmond Marina	6.9	94.00
Rodeo Marina	1.1	82.78
Saint Francis Yacht Harbor	4.2	94.41
San Mateo Bridge	13.6	90.86
San Pablo Bay Pumphouse	3.1	79.96
Santa Fe Channel - back	6.6	60.33
Santa Fe Channel - front	10.5	91.18
Sea Plane Harbor	2.5	76.29
Sea Plane Lagoon	Low	0.54
Sea Plane Lagoon	High	0.34
Sea Plane Lagoon	5.2	83.33
Sierra Point Marina	3	86.34
Tiburon Rhomberg Center	2.8	78.64
Toll Plaza	High	0.00
Toll Plaza	Low	34.99
Treasure Island	2	73.68