# Spatial and temporal analysis of marine invasions in California, Part II:

# Humboldt Bay, Marina del Rey, Port Hueneme, and San Francisco Bay

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# Contents

# Chapter 1: Introduction

**Overview**

The Smithsonian Environmental Research Center (SERC) and Moss Landing Marine Laboratories (MLML) have advanced an extensive program with California Department of Fish and Wildlife (CDFW) to analyze spatial and temporal patterns of nonindigenous species (NIS) invasions in marine and estuarine waters of California, as required by law.

As specified by Section 71211 of the California Public Resources Code, CDFW is responsible for meeting the following requirements in the analysis of NIS in California's coastal waters:

1. Add to its inventory of NIS in open waters, bays, and estuaries, and monitor for new introductions or the spread of existing NIS.

2. Make such data and analysis available to the public using the Internet.

3. Assess the effectiveness of ballast water management in reducing the introduction and spread of NIS.

SERC and MLML have designed and implemented analyses to explicitly (a) assist CDFW in meeting statutory requirements by reporting status, trends, mechanisms, and rates of biological invasions in California waters and (b) test key questions about NIS in California, in order to understand invasion processes and assess strategies for NIS management and prevention.

Our approach combines a statistically robust sampling design, traditional taxonomic and biogeographic analyses, and broad-scale application of genetic tools to understand invasion dynamics in California. First, sampling is designed explicitly to make formal quantitative estimates for both NIS richness and abundance, allowing statistical comparisons across locations and over time for each measure. Second, DNA-based tools are utilized to assure consistent taxonomic assignment and detect cryptic species. The latter approach provides a critical tool and means of taxonomic quality control, providing the necessary groundwork (and baseline) for high-throughput, high-sensitivity, and cost-effective future analyses.

Our sampling design aims specifically to measure and test for spatial, temporal, and taxonomic patterns in NIS diversity (including species richness and abundance). We use a question-driven approach to inform and refine the sampling effort. We seek to evaluate the (a) differences in NIS diversity across habitats, geographic regions, and taxonomic groups and (b) changes in invasion dynamics (NIS detection rate and spread) over time associated with different transfer mechanisms (vectors) and changing management practices, including especially those for ships' ballast water and hull biofouling. We also seek to increase the capacity and sensitivity of detection for NIS, by coupling morphological and molecular analyses.

More specifically, our approach is designed to establish a robust, quantitative baseline and implement a time-series of repeated measures, which serve to assess current status and also to evaluate temporal changes in invasion rate / dynamics associated with management of ballast water and other vectors (Ruiz & Hewitt 2002; Ruiz & Carlton 2003).

In 2012, we launched a multi-year campaign of field-based surveys and associated analyses to characterize NIS in California's coastal waters, as part of a long-term program (hereafter the Program):

- For the initial phase, we designed a 3-part study to focus primarily on bays and estuaries, because (a) these are the primary foci for introduction of NIS and (b) past studies have detected very few NIS along exposed outer coasts, outside of bays, estuaries, and harbors (Wasson *et al*. 2001; Ruiz *et al*. 2009; Zabin *et al*. 2018). Of those NIS present on the outer coast of California (including those reported from recent CDFW-funded surveys), all occur in bays and estuaries and were found at transition zones in close proximity to the mouths of bays and estuaries, suggesting some "spill-over" from estuaries that may not be self-sustaining.

- This initial phase lays the groundwork and establishes the baseline measures to evaluate spatial patterns of invasion in bays and estuaries throughout the state.

- In subsequent phases, continued sampling (repeated measures) in some bays will evaluate temporal changes in invasion dynamics in response to vector management. Additional measures (surveys) may also assess the extent to which NIS are spreading to outer coastal regions that are adjacent to bays.

**Approach**

In this initial phase, we are intensively sampling the invertebrate communities in 10 different estuaries in California. Within each estuary, we are sampling hard-substrate invertebrate communities, soft-sediment communities, and plankton assemblages. The estuaries include those with commercial ports (n=5) and those without commercial ports (n=5), which are distributed throughout the state, allowing us to directly compare (a) differences between the two types of estuary, (b) biogeography of NIS as well as native and cryptogenic species along the axis of the state, and (c) differences among habitat types, including hard-substrate, soft-sediment, and plankton.

For all estuaries, we sample habitats in high salinity (> 20 ppt) waters, which are present in all focal estuaries. In addition, for San Francisco Bay, we include survey sites in low salinity waters, allowing a test of differences across the salinity gradient for each habitat type. Finally, we include survey sites for at least one outer coastal region, which serves as a pilot project for future surveys across a broader number of outer coast sites in out-years, beyond the current project (*i.e*., in subsequent phases of the program).

All surveys occur in summer through mid-fall, to control for possible seasonal differences. This time of year is selected to encompass the season of maximum plankton abundance and larval recruitment, in order to maximize species detection. Each of ten estuaries is surveyed once during a 5-year period, and one estuary (San Francisco Bay) is surveyed in each year.

For each habitat surveyed, we use a stratified sampling design, with replicate samples collected and analyzed to identify the taxonomic composition for each habitat and bay. Although not required as part of our current contract, we also characterize abundances of taxa in samples based on morphological examination. In addition, the following metadata are collected for each of the sites surveyed per estuary: GPS location (latitude and longitude), salinity, temperature, dissolved oxygen, sample date, and weather conditions.

The taxonomic composition of samples is characterized using both morphological and genetic methods for identification of biota. Using established protocols that we have developed over the past decade, we sort and collect voucher specimens for each morpho-species per habitat and bay during field analyses, placing these into individually labeled vials. These "morphological vouchers" are identified subsequently to species (or lowest taxonomic unit) based upon morphological characteristics. A subset of the identifications is verified through additional consultation with taxonomic experts.

Results from morphological analyses are compared to results from genetic analyses, to confirm taxonomic identification and test for cryptic species, using DNA barcoding. Where available, a minimum of five specimens from every newly identified species are collected as "molecular vouchers" from all habitats to be sequenced for mitochondrial cytochrome c oxidase subunit I (COI), which has been highly successful in detecting species-level differences. We augment the standard COI sequence with a second, nuclear locus, a fragment of the large subunit (LSU) ribosomal RNA gene.

**Goals**

The overall goals of the long-term Program are to:

- Measure status and trends of biological invasions in coastal marine ecosystems of California, using statistically robust sampling and DNA-assisted taxonomic analysis;
- Understand geographic distribution, habitat distribution, and patterns of spread for non-native marine and estuarine species in the state;
- Assess the mechanism(s) of introduction and spread of non-native species in California;
- Detect changes in the patterns (rate, spread, prevalence) of non-native marine and estuarine species in response to management strategies, shifts in vector dynamics, and other forcing functions.

**Objectives**

Through intensive field-based surveys, morphological and molecular analyses, and statistical data analyses, the specific objectives of this initial phase of the Program are to:

1. Efficiently characterize native and non-native components of coastal and estuarine waters of California so that analyses can be parsed at regional, biome, landscape, and habitat levels.
2. Test for differences in NIS diversity across different geographic and habitat scales (zones).
3. Estimate total NIS and native species diversity across estuaries.
4. Estimate the relative strength of different vectors to the invasion and spread of NIS in California.
5. Test efficacy (performance) of ballast water control methods by establishing robust baseline data for holoplankton and testing for new invasions.
6. Develop a DNA barcode library for NIS that further advances rapid, sensitive, and cost-effective detection methods for NIS.
7. Maintain and grow a publicly-accessible database incorporating past and concurrent CDFW data, other related data, on NIS in California that uses SERC's National Exotic Marine and Estuarine Species Information System (NEMESIS) framework (Fofonoff *et al*. 2017).

**Structure of this Report**

This is the second of three expected reports for the initial phase, focusing on sampling and analyses from four bays and estuaries in California: Humboldt Bay, Marina del Rey, Port Hueneme, and San Francisco Bay. This expands the analyses presented in our previous report (Ruiz and Geller 2015) -- or Part I of the three-part series that included San Diego Bay, Mission Bay, Morro Bay, San Francisco Bay, and Bodega/Tomales Bay. The next report will include Los Angeles/Long Beach Harbors and Newport Bay under contracts P1675034 (MLML) and P1675035 (SERC).

The results are presented in multiple chapters, which are organized in sections, as follows:

- Section I describes the details for each of the surveys and provides results from the morphological analyses conducted by SERC. These are organized by habitat components, including hard substrate (Chapter 2), soft-sediment (Chapter 3), and zooplankton (Chapter 4). For Chapters 2-4, we include data from each of the four bays, allowing comparisons among bays within community type.

- Section II provides the genetic analyses and results for benthic invertebrates and zooplankton conducted by MLML. Chapter 5 provides results of DNA barcoding of benthic invertebrates collected during the surveys described in Section 1. Chapter 6 reports on analysis of plankton communities across the four bays, using a metagenetic approach. Together, these two chapters demonstrate the application of genetic approaches to evaluate species detection and community composition in coastal waters. Section III provides a brief synthesis, summarizing results to date and next steps for the integrated program of morphological and molecular analyses of NIS in California.

In addition to being reported here, the occurrence records for each NIS will be made accessible through CalNEMO, which was launched as a California-specific portal of NEMESIS (https://invasions.si.edu/nemesis/calnemo/intro.html). This website provides specific georeferenced location and date, both in tabular and mapped format, for each record. A separate electronic archive of the occurrence records by site for this specific study (report) will also be made available through CalNEMO.

**References**


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# Section I: Morphological Detection and Analysis of NIS by Habitat

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# Chapter 2: Hard Substrate Communities

**Introduction**

To detect the presence of non-native invertebrate taxa in hard substrate communities, we sampled four estuaries: Humboldt Bay, Marina del Rey, Port Hueneme, and San Francisco Bay. We sampled 8-10 sites per estuary, and the specific locations and dates are indicated in Appendix 2.1.

For each site, we deployed 10 PVC plates (14 x 14 cm), facing downward and 1 m below MLLW, for a minimum of 3 months. Plates were deployed using a randomized design within site. These plates served as passive collectors for recruitment of marine invertebrates. Upon retrieval, we randomly selected at least 5 plates per site for analysis of biota. In general, our goal was to analyze 50 plates per bay (10 sites x 5 plates). In Port Hueneme, we selected 6-7 plates for analysis at some sites to reach a total of 50 plates for that bay, because there were fewer suitable sites that were available there.

Upon retrieval, all sessile and mobile macroinvertebrates were collected and processed live to generate morphological vouchers for species-level identification on each plate. Molecular vouchers were also collected for each species (at least n=5 per bay, when available), and the molecular vouchers were sent to MLML for DNA barcoding.

For the four estuaries, we surveyed the hard substrate invertebrate community from high salinity waters on a total of approximately 200 plates (4 estuaries x 10 sites x 5 replicates). In addition, we sampled the high salinity portion of San Francisco Bay in identical fashion in 2014 and 2016 (10 sites x 5 replicates x 2 years = 100 additional plates), providing repeated measures for three consecutive years. Thus, our analyses include data from 300 plates across these estuaries from 2014-2016.

**Results**

***A. Spatial Variation in High Salinity Hard Substrate Communities of Four Estuaries.***

The analyses indicate that our sampling program performed well at detecting and characterizing the NIS in the target hard substrate communities of these estuaries, for each the sessile and the mobile marine macroinvertebrates. This performance is shown in a series of figures below that examine the detection of species in high salinity regions among and within the five estuaries using species accumulation curves and richness estimators, calculated using R package vegan 2.3-0 (R Core Team 2015; Oksanen *et al.* 2015). The species accumulation curves show rarefaction of species richness and the associated standard error with sampling effort. Species richness estimators provide statistical estimates of total richness present, based on accumulation curves, and are reported as Chao, Jack1, Jack 2, and Boot values along with standard errors (Canning-Clode *et al.*, 2008).

***Total NIS Richness among Estuaries.***

When we combine samples across all four estuaries, species accumulation for NIS approaches an asymptote (Figure 2.1). We observed (detected) 26 NIS for mobile invertebrates and 46 NIS for sessile invertebrates. The total estimated richness for these two groups was approximately 28 and 48 NIS, respectively (Table 2.1), indicating that our surveys detected between 90-96% of the estimated total pool of NIS present, depending upon which estimator is considered. In contrast, the species accumulation curves for native species are further from their asymptotes, suggesting we detected 56.85% of the estimated total native species pool (Table 2.1).

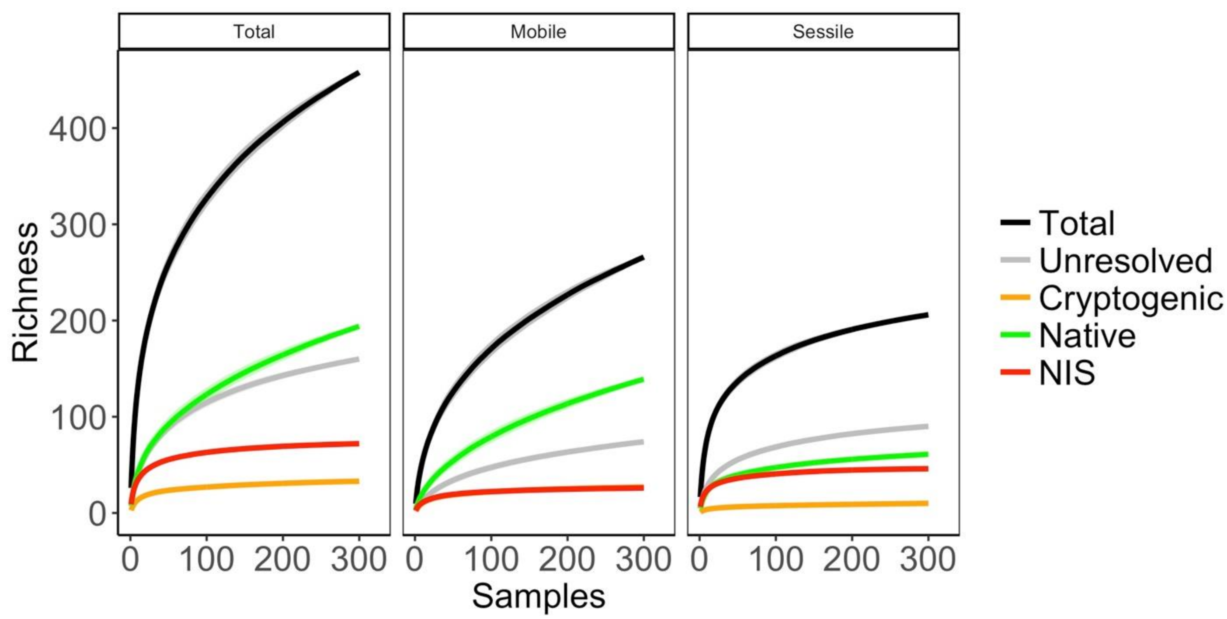


**Figure 2.1. Species accumulation curves by invasion status for high salinity habitats across all four estuaries combined.** Status is designated based on literature and SERC NEMESIS database. Samples (x-axis) represent the number of settlement plates examined across all four bays, including 100 plates in San Francisco and Humboldt Bay and 50 plates in Marina Del Rey and Port Hueneme (n=300 plates total across bays). All bays were sampled in 2015. NIS asymptotes agree strongly with species richness estimators (Table 2.1). Shading around each line represents 1 standard deviation (SD), which is often not visible at this scale due to low variation in estimates.

**Table 2.1. Species richness estimators by invasion status for high salinity sites for all four estuaries (combined).** Column 3 shows observed species richness by category followed by multiple estimators for total species richness, and associated standard errors (except for Jack 2), to show concordance across estimates.

| Data | Status | Species | Chao | Chao SE | Jack1 | Jack1 SE | Jack2 | Boot | Boot SE | n |
|---|---|---|---|---|---|---|---|---|---|---|
| All | Cryptogenic | 33 | 36.11 | 3.65 | 37.98 | 2.23 | 38.99 | 35.48 | 1.30 | 300 |
| | Introduced | 72 | 76.49 | 4.79 | 77.98 | 2.44 | 79.98 | 75.17 | 1.60 | 300 |
| | Native | 194 | 345.87 | 49.03 | 273.73 | 12.05 | 332.41 | 227.17 | 6.30 | 300 |
| | Unresolved | 160 | 213.60 | 21.78 | 203.85 | 7.33 | 229.74 | 179.48 | 3.98 | 300 |
| | Total | 458 | 651.24 | 45.76 | 592.55 | 15.80 | 680.12 | 516.30 | 8.42 | 300 |
| Mobile | Cryptogenic | 27 | 29.66 | 3.48 | 30.99 | 1.99 | 31.99 | 28.98 | 1.17 | 300 |
| | Introduced | 26 | 28.24 | 3.39 | 28.99 | 1.73 | 29.99 | 27.48 | 1.01 | 300 |
| | Native | 139 | 254.21 | 39.49 | 206.77 | 10.83 | 254.52 | 167.34 | 5.62 | 300 |
| | Unresolved | 74 | 126.39 | 27.82 | 102.90 | 5.90 | 123.79 | 86.13 | 3.09 | 300 |
| | Total | 266 | 429.33 | 44.70 | 369.65 | 13.53 | 440.29 | 309.93 | 7.02 | 300 |
| Sessile | Cryptogenic | 10 | 12.99 | 4.48 | 12.99 | 1.73 | 15.97 | 11.16 | 0.90 | 300 |
| | Introduced | 46 | 48.24 | 3.39 | 48.99 | 1.73 | 49.99 | 47.69 | 1.15 | 300 |
| | Native | 61 | 75.04 | 10.37 | 73.96 | 3.59 | 80.93 | 66.86 | 1.98 | 300 |
| | Unresolved | 90 | 103.46 | 8.29 | 107.94 | 4.23 | 113.94 | 98.68 | 2.46 | 300 |
| | Total | 206 | 240.11 | 14.77 | 242.88 | 6.22 | 259.83 | 223.39 | 3.61 | 300 |

***Total NIS Richness within Individual Estuaries.***

A similar pattern exists within the four individual estuaries: NIS detection approaches an asymptote rapidly compared to that for native and other taxa (Figure 2.2, Table 2.2). For mobile biota, we detected 7-21 NIS per estuary, and we detected 15.36 NIS per estuary for sessile invertebrates (Table 2.2). It is also noteworthy that for sessile taxa in San Francisco Bay, our observed NIS richness was 95.100% of total estimated NIS richness values.

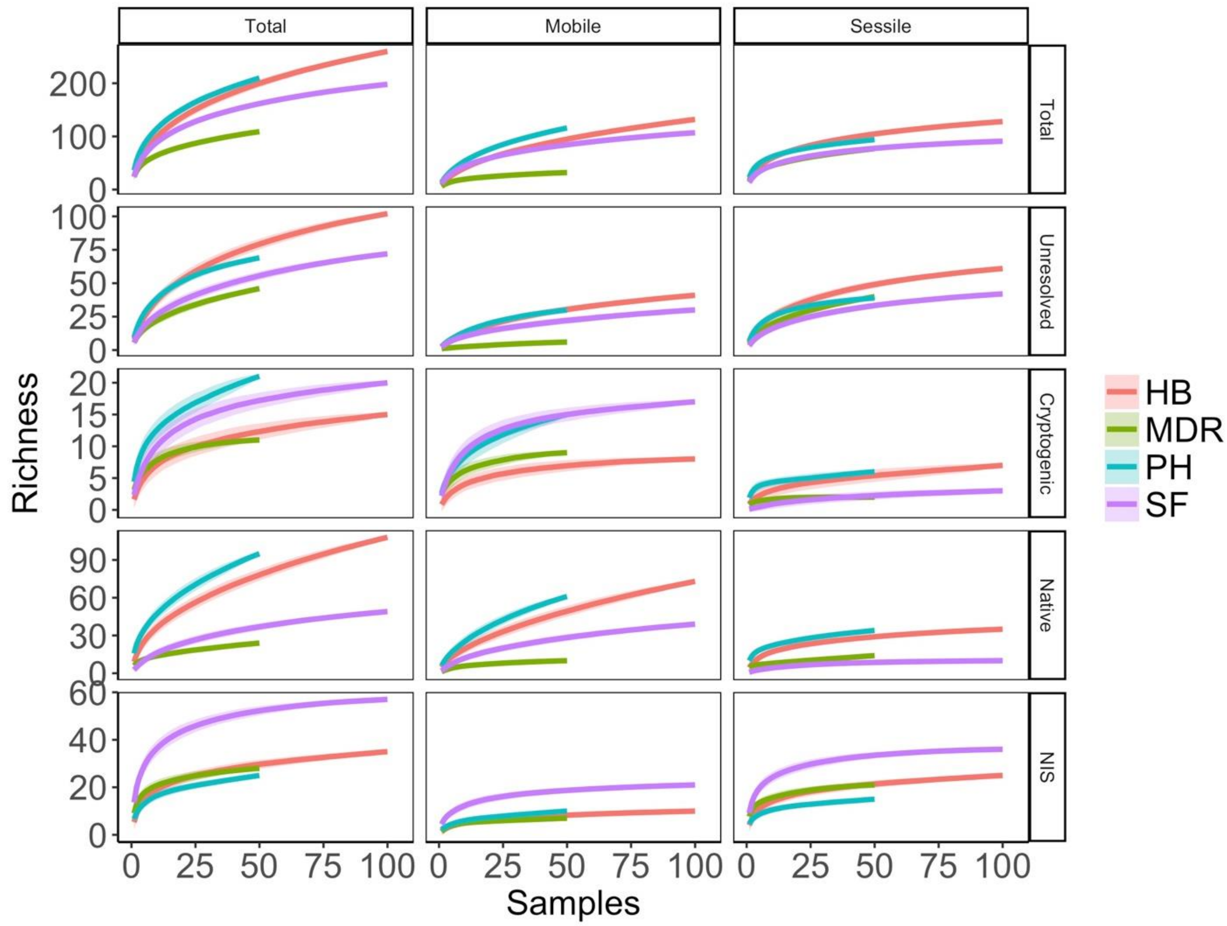


**Figure 2.2. Species Accumulation curves separated by invasion status for high salinity portions of each bay sampled.** Status is designated based on literature and SERC NEMESIS database. Samples (x-axis) represent the number of settlement plates examined among sites for each bay (≤10 plates/site), including 100 plates in San Francisco and Humboldt Bay and 50 plates in Marina Del Rey and Port Hueneme (n=300 plates total). NIS asymptotes agree strongly with species richness estimators (Table 2.2). Shading around each line represents 1 standard deviation (SD), which is often not visible at this scale due to low variation in estimates.

**Table 2.2. Species richness estimators by invasion status for high salinity sites within four estuaries (separately).** Column 3 shows observed species richness by category followed by multiple estimators for total species richness, and associated standard errors (except for Jack 2), to show concordance across estimates.

| | Bay | Status | Species | Chao | Chao SE | Jack1 | Jack1 SE | Jack2 | Boot | Boot SE | n |
|---|---|---|---|---|---|---|---|---|---|---|---|
| All | Humboldt Bay | Cryptogenic | 15.00 | 18.96 | 5.24 | 18.96 | 1.98 | 20.94 | 16.79 | 1.14 | 100 |
| | | Native | 108.00 | 177.91 | 27.50 | 156.51 | 9.15 | 188.04 | 128.58 | 4.68 | 100 |
| | | NIS | 35.00 | 55.05 | 19.99 | 43.91 | 2.97 | 50.79 | 38.68 | 1.65 | 100 |
| | | Unresolved | 102.00 | 140.15 | 17.50 | 135.66 | 7.56 | 154.43 | 117.04 | 3.94 | 100 |
| | Marina del Rey | Cryptogenic | 11.00 | 11.25 | 0.72 | 11.98 | 0.98 | 11.06 | 11.67 | 0.70 | 50 |
| | | Native | 24.00 | 73.00 | 58.40 | 33.80 | 4.18 | 42.46 | 27.91 | 2.07 | 50 |
| | | NIS | 28.00 | 29.96 | 2.60 | 31.92 | 2.41 | 32.00 | 30.03 | 1.63 | 50 |
| | | Unresolved | 46.00 | 85.20 | 25.57 | 65.60 | 5.56 | 80.10 | 54.18 | 2.93 | 50 |
| | Port Hueneme | Cryptogenic | 21.00 | 45.01 | 30.49 | 27.86 | 2.59 | 33.64 | 23.82 | 1.37 | 50 |
| | | Native | 95.00 | 155.31 | 26.53 | 134.20 | 9.96 | 160.37 | 111.66 | 5.17 | 50 |
| | | NIS | 25.00 | 52.44 | 21.00 | 32.84 | 2.77 | 40.52 | 27.98 | 1.38 | 50 |
| | | Unresolved | 69.00 | 91.11 | 13.64 | 87.62 | 5.48 | 98.34 | 77.49 | 2.94 | 50 |
| | San Francisco Bay | Cryptogenic | 20.00 | 23.96 | 5.24 | 23.96 | 1.98 | 25.94 | 21.81 | 1.10 | 100 |
| | | Native | 49.00 | 69.05 | 12.63 | 66.82 | 4.65 | 76.70 | 57.00 | 2.57 | 100 |
| | | NIS | 57.00 | 59.06 | 2.48 | 61.95 | 2.21 | 61.03 | 59.89 | 1.58 | 100 |
| | | Unresolved | 72.00 | 91.01 | 10.16 | 95.76 | 5.24 | 104.73 | 83.05 | 3.05 | 100 |
| Mobile | Humboldt Bay | Cryptogenic | 8.00 | 8.25 | 0.72 | 8.99 | 0.99 | 8.03 | 8.65 | 0.73 | 100 |
| | | Native | 73.00 | 148.65 | 33.97 | 113.59 | 8.48 | 143.10 | 89.68 | 4.22 | 100 |
| | | NIS | 10.00 | 12.97 | 4.45 | 12.97 | 1.71 | 15.91 | 11.18 | 0.87 | 100 |
| | | Unresolved | 41.00 | 69.61 | 19.62 | 57.83 | 4.54 | 69.64 | 48.14 | 2.33 | 100 |
| | Marina del Rey | Cryptogenic | 9.00 | 9.25 | 0.72 | 9.98 | 0.98 | 9.06 | 9.67 | 0.70 | 50 |
| | | Native | 10.00 | 14.41 | 7.06 | 12.94 | 1.70 | 14.88 | 11.31 | 0.95 | 50 |
| | | NIS | 7.00 | 7.98 | 2.20 | 8.96 | 1.39 | 10.88 | 7.73 | 0.69 | 50 |
| | | Unresolved | 6.00 | 10.41 | 7.06 | 8.94 | 2.20 | 10.88 | 7.27 | 1.16 | 50 |
| | Port Hueneme | Cryptogenic | 15.00 | 27.25 | 16.80 | 19.90 | 2.19 | 23.76 | 17.09 | 1.22 | 50 |
| | | Native | 61.00 | 105.10 | 22.31 | 90.40 | 7.76 | 109.80 | 73.51 | 4.03 | 50 |
| | | NIS | 10.00 | 15.88 | 7.00 | 13.92 | 1.96 | 17.76 | 11.47 | 0.96 | 50 |
| | | Unresolved | 30.00 | 41.86 | 9.55 | 40.78 | 3.81 | 46.64 | 34.93 | 2.09 | 50 |
| | San Francisco Bay | Cryptogenic | 17.00 | 21.46 | 7.12 | 19.97 | 1.71 | 21.94 | 18.31 | 0.94 | 100 |
| | | Native | 39.00 | 54.84 | 10.48 | 54.84 | 4.43 | 62.76 | 46.13 | 2.42 | 100 |
| | | NIS | 21.00 | 23.23 | 3.37 | 23.97 | 1.71 | 24.97 | 22.45 | 1.01 | 100 |
| | | Unresolved | 30.00 | 41.88 | 9.08 | 41.88 | 3.96 | 47.82 | 35.30 | 2.29 | 100 |
| Sessile | Humboldt Bay | Cryptogenic | 7.00 | 9.97 | 4.40 | 9.97 | 1.71 | 12.91 | 8.15 | 0.89 | 100 |
| | | Native | 35.00 | 40.28 | 4.89 | 42.92 | 3.13 | 44.94 | 38.90 | 1.77 | 100 |
| | | NIS | 25.00 | 33.91 | 10.08 | 30.94 | 2.42 | 34.88 | 27.50 | 1.35 | 100 |
| | | Unresolved | 61.00 | 75.31 | 9.11 | 77.83 | 4.32 | 84.79 | 68.90 | 2.46 | 100 |
| | Marina del Rey | Cryptogenic | 2.00 | 2.00 | 0.00 | 2.00 | 0.00 | 2.00 | 2.01 | 0.07 | 50 |
| | | Native | 14.00 | 34.58 | 16.97 | 20.86 | 3.55 | 27.58 | 16.59 | 1.71 | 50 |
| | | NIS | 21.00 | 21.49 | 1.02 | 22.96 | 1.97 | 21.12 | 22.30 | 1.31 | 50 |
| | | Unresolved | 40.00 | 75.40 | 25.37 | 56.66 | 4.50 | 69.22 | 46.92 | 2.36 | 50 |
| | Port Hueneme | Cryptogenic | 6.00 | 6.98 | 2.18 | 7.96 | 1.39 | 9.88 | 6.73 | 0.68 | 50 |
| | | Native | 34.00 | 50.33 | 14.56 | 43.80 | 3.40 | 50.58 | 38.15 | 1.71 | 50 |
| | | NIS | 15.00 | 20.88 | 7.07 | 18.92 | 1.96 | 22.76 | 16.51 | 0.97 | 50 |
| | | Unresolved | 39.00 | 49.45 | 10.08 | 46.84 | 3.11 | 51.70 | 42.56 | 1.79 | 50 |
| | San Francisco Bay | Cryptogenic | 3.00 | 3.50 | 1.31 | 3.99 | 0.99 | 4.00 | 3.50 | 0.59 | 100 |
| | | Native | 10.00 | 10.99 | 2.25 | 11.98 | 1.40 | 13.94 | 10.87 | 0.78 | 100 |
| | | NIS | 36.00 | 36.50 | 1.02 | 37.98 | 1.40 | 36.06 | 37.45 | 1.11 | 100 |
| | | Unresolved | 42.00 | 49.92 | 5.98 | 53.88 | 3.43 | 56.91 | 47.75 | 2.03 | 100 |

***Percent Contribution of NIS to Total Species Richness per Estuary***

NIS contributed 16.40% of total observed species richness per estuary for sessile invertebrates, and the percent contribution was highest in San Francisco Bay and Marina del Rey (Figure 2.3). For mobile invertebrates, NIS species richness accounted for 7-22% among estuaries, being greatest in the same two estuaries. When considering mobile and sessile invertebrates combined, NIS represented 12-29% of the total species richness, again with the highest levels in San Francisco Bay and Marina del Rey. The relative dominance of NIS in San Francisco Bay and Marina del Rey was driven by both high NIS richness and low native species richness in these estuaries compared to Humboldt Bay and Port Hueneme (see red and green respectively in Figure 2.3).

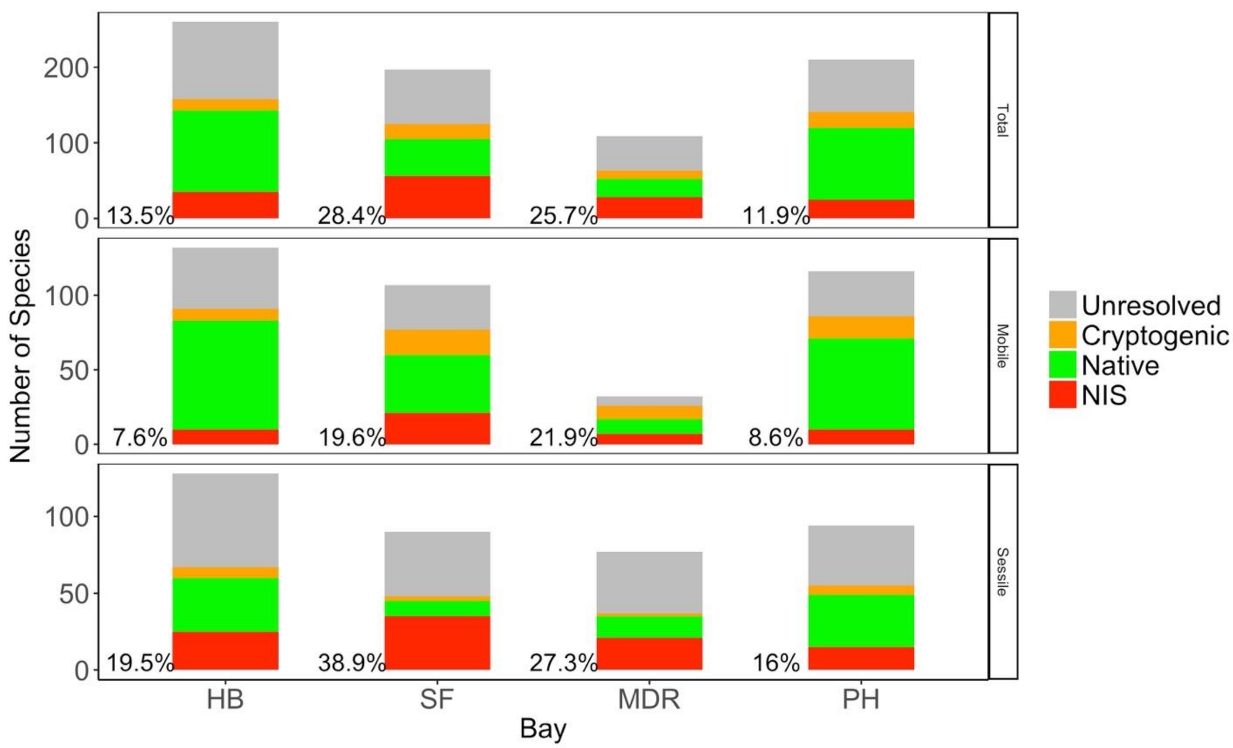


**Figure 2.3. Number of unique species for each bay, functional type, and status.** Status is designated based on literature and SERC NEMESIS database. Percentages to the left of each bar indicate the percentage contribution of NIS to total species richness per bay for each sessile invertebrate, mobile invertebrates, and all invertebrates combined.

***NIS Richness per Plate within Bays.***

The observed mean NIS richness varies >3-fold among sites across the four different estuaries when combining mobile and sessile taxa (Figure 2.4). This was driven largely by variation in sessile species, with sites in San Francisco Bay being at the highest end of the range. While this figure emphasizes differences among sites, the elevated NIS richness per plate in San Francisco Bay was also observed at the bay level when comparing mean NIS richness for all plates within each of the four bays (Figure 2.5). Thus, overall, San Francisco Bay had the highest per-plate NIS richness within individual sites as well as for the entire bay. [An additional analysis of total NIS richness per site (instead of plate) is also presented in Appendix 2.3.]


**Figure 2.4. Mean number of NIS detected per plate within each site.** Error bars equal ±1SD.

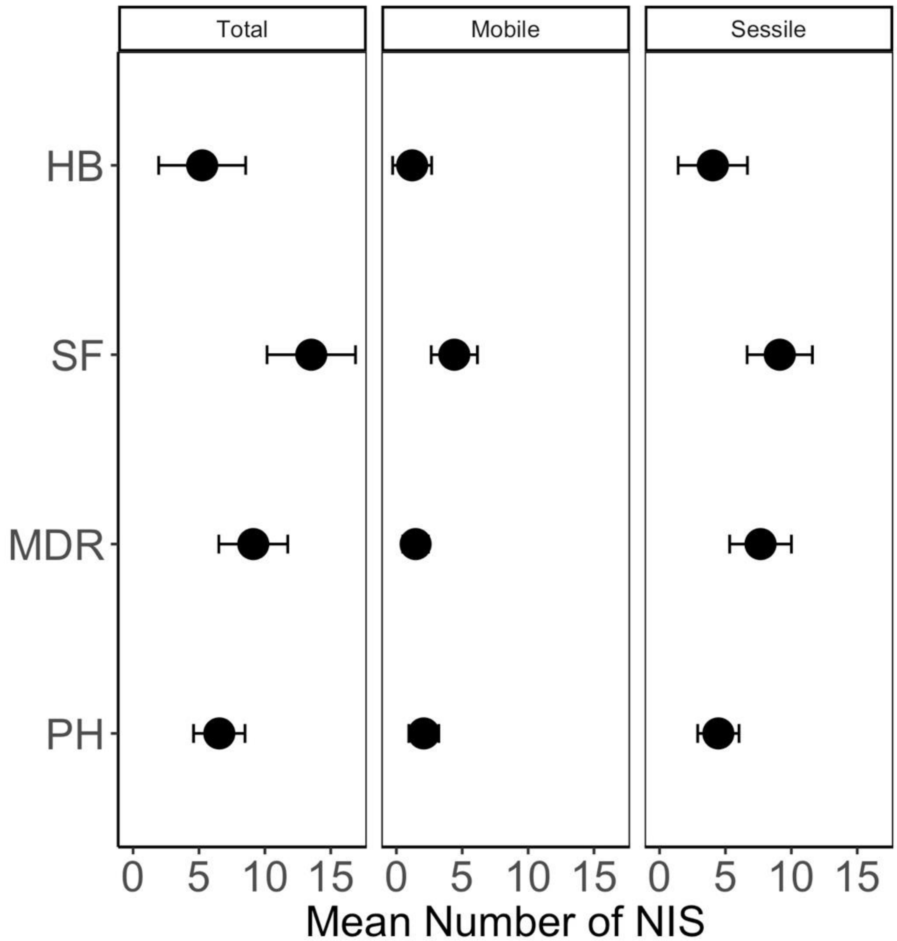


**Figure 2.5. Mean number of NIS detected per plate within each bay.** Error bars equal ±1SD.

***Relative Abundance of Sessile NIS per Plate within Bays.***

For sessile invertebrates alone, excluding mobile taxa, we estimated relative abundance using percent cover based on point count measurements. NIS occupied the highest percent cover in San Francisco Bay, followed by Marina del Rey (Figure 2.6), with median NIS cover exceeding 50% per plate in each bay. Moreover, San Francisco Bay had the lowest percent cover for native species. Thus, sessile invertebrate communities in San Francisco Bay differed from the other three bays in relative abundance of both native species and NIS. In comparison to NIS and native species, cryptogenic and unresolved taxa occupied a relatively small percentage of space in each bay.

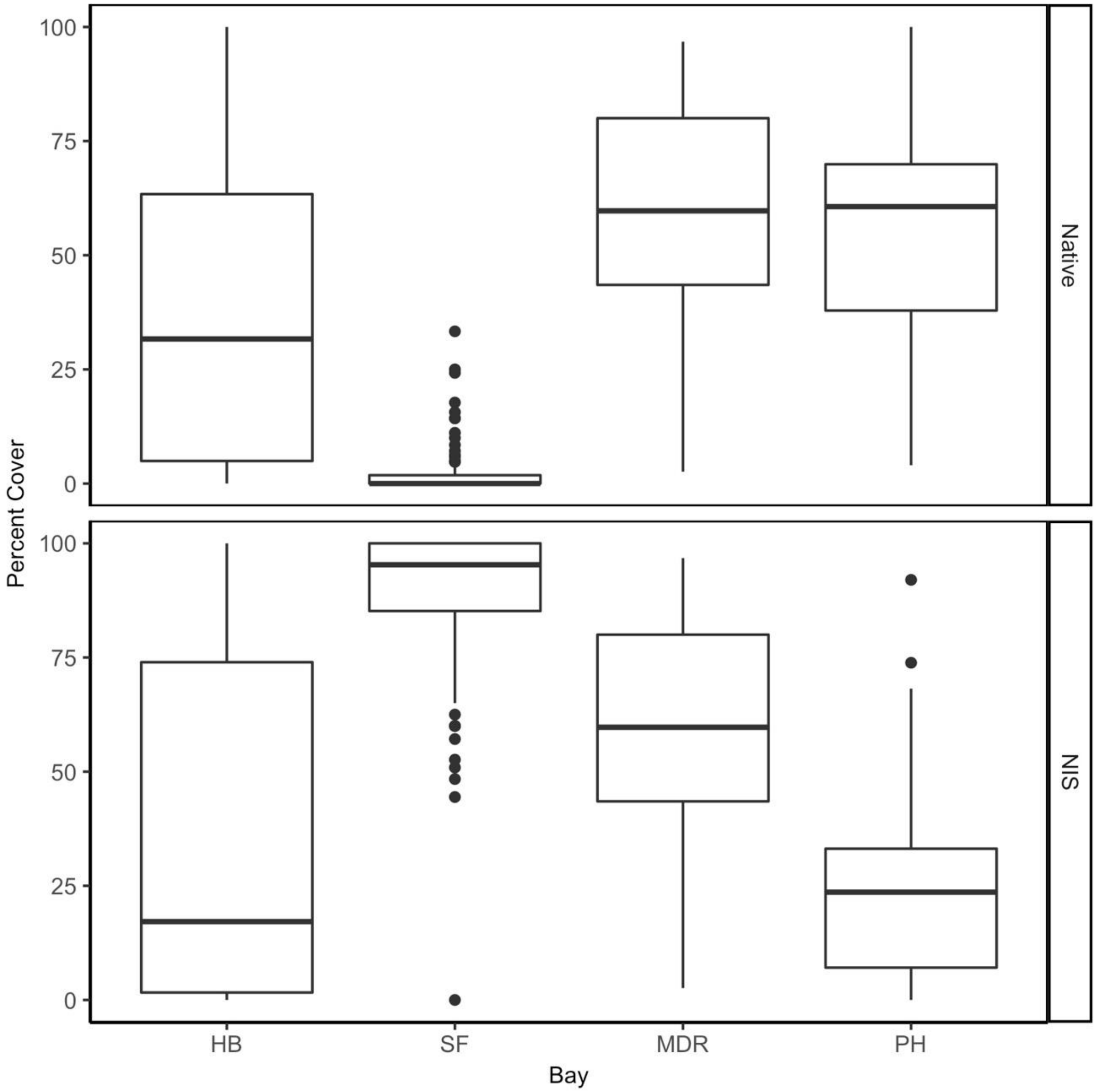


**Figure 2.6. Measures of percent cover of native species (upper) and NIS (lower) on plates in each bay for sessile taxa only.** Percent cover was calculated using point count measurements (50 points/plate and ≥50 plates per estuary), identifying primary (base) space occupation by sessile invertebrate species. Status as native or NIS is designated based on literature and SERC NEMESIS database. The lower and upper hinges of the box plots correspond to the first and third quartiles (the 25th and 75th percentiles); center line with boxes indicates medians, lines indicate 95% confidence limits, and points indicate samples that extended beyond these limits.

***B. Temporal and Salinity Variation in San Francisco Bay: Sessile Invertebrates.***

**Total NIS Richness among Years at High Salinity Sites.**

The results of repeated measures (surveys) among three years shows a high degree of consistency both in the number of NIS detected each year and also in reaching an asymptote, suggesting that these surveys are sampling a high percentage of the total species pool for this focal habitat in San Francisco Bay. Figure 2.7 compares the species accumulation curves for NIS in 2015 (also shown in previous section in Figure 2.2) to that in 2014 and 2016 in San Francisco Bay, using only high salinity sites surveyed with identical methods. Figure 2.8 shows the total number of NIS observed in each year and the percent contribution of NIS to total species richness.

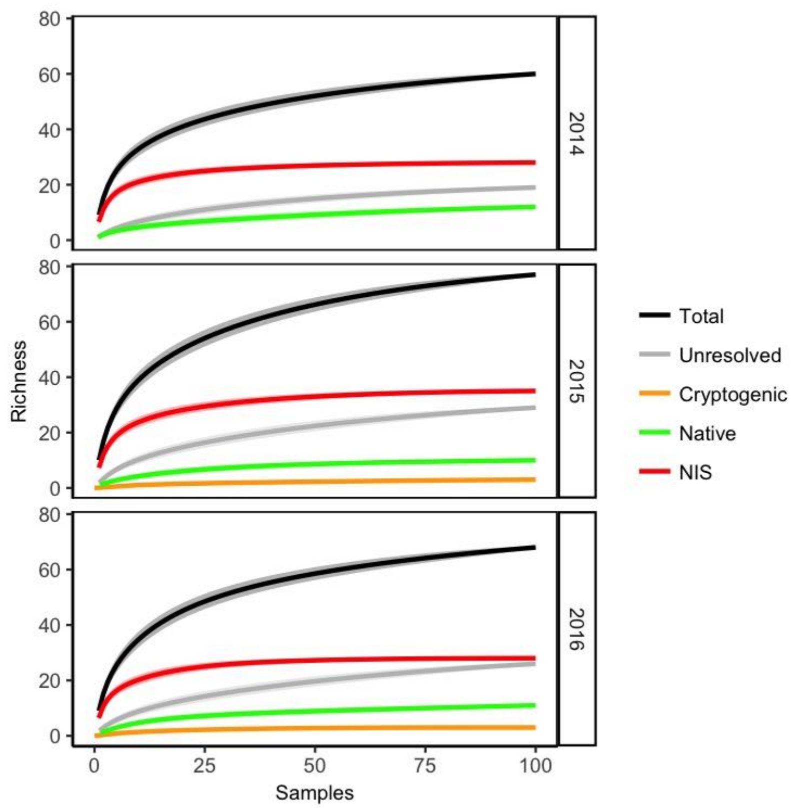


**Figure 2.7. Species accumulation curves (sessile taxa only) by invasion status for high salinity sites in San Francisco Bay in three successive years.** Status is designated based on literature and SERC NEMESIS database. Shading around each line represents 1SD.

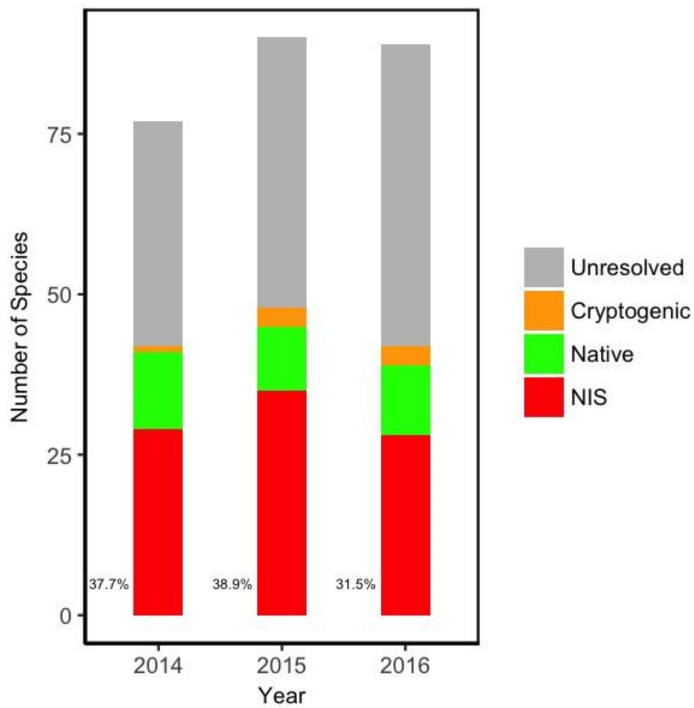


**Figure 2.8. Number of unique species (sessile taxa only) detected in each year by invasion status for high salinity sites in San Francisco Bay in three different years.** Status is designated based on literature and SERC NEMESIS database. Percentages to the left of each bar indicate the percentage contribution of NIS to the total.

***<u>NIS Richness per Plate among Years.</u>***

While the surveys exhibited high consistency in performance and overall (cumulative) detection of NIS among years, there was also considerable variation among years and sites in the mean NIS richness observed per plate (Figure 2.9). We hypothesize that much of this variation was caused by environmental conditions, and especially differences in rainfall (and salinity in the winter and spring, prior to the summer surveys), following previous work (Chang *et al*. 2017). This result suggests that the probability of NIS detection may vary among years when controlling for sampling effort, including the number of sites and number of plates.

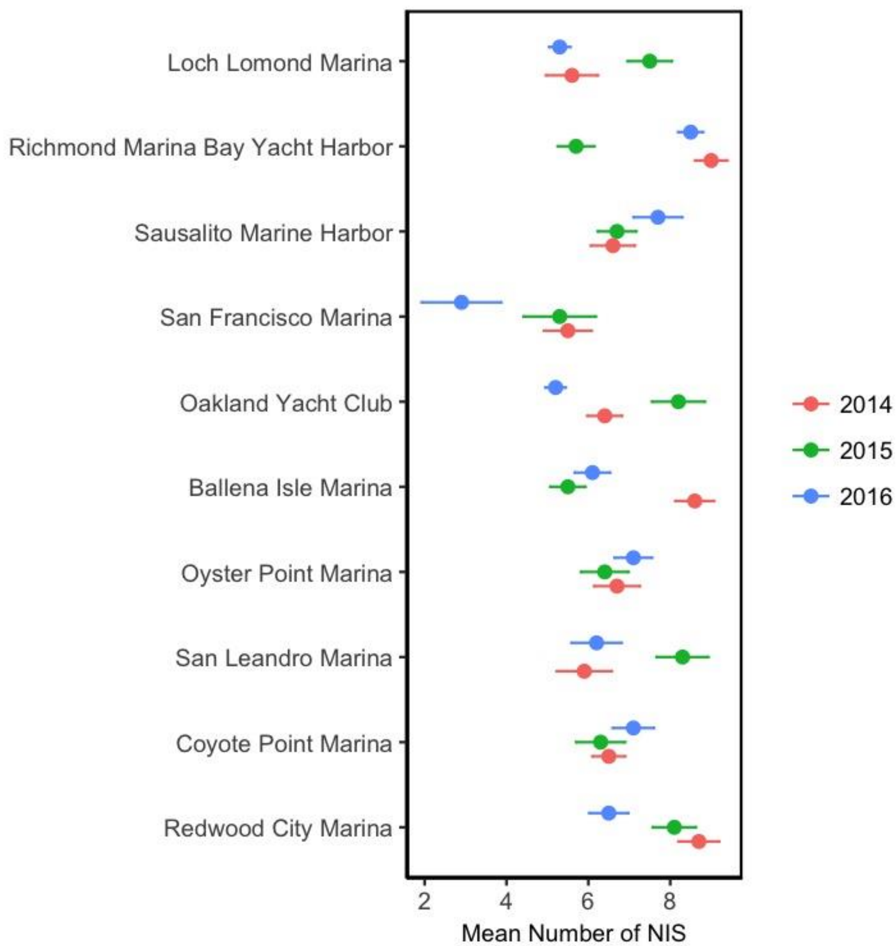


**Figure 2.9. Mean number of NIS (sessile taxa only) detected per plate averaged within site per year in San Francisco Bay.** This shows high salinity sites sampled over time. Error bars equal ±1SD.

***<u>Relative Abundance of NIS per Plate among Years and Sites.</u>***

The mean percent cover of NIS at high salinity sites exceeded 75% for all sites and years (Figure 2.10). Six of the sites showed considerable variation across years, including Richmond Marina Bay Yacht Harbor, Oakland Yacht Club, Ballena Isle Marina, and San Francisco Marina.

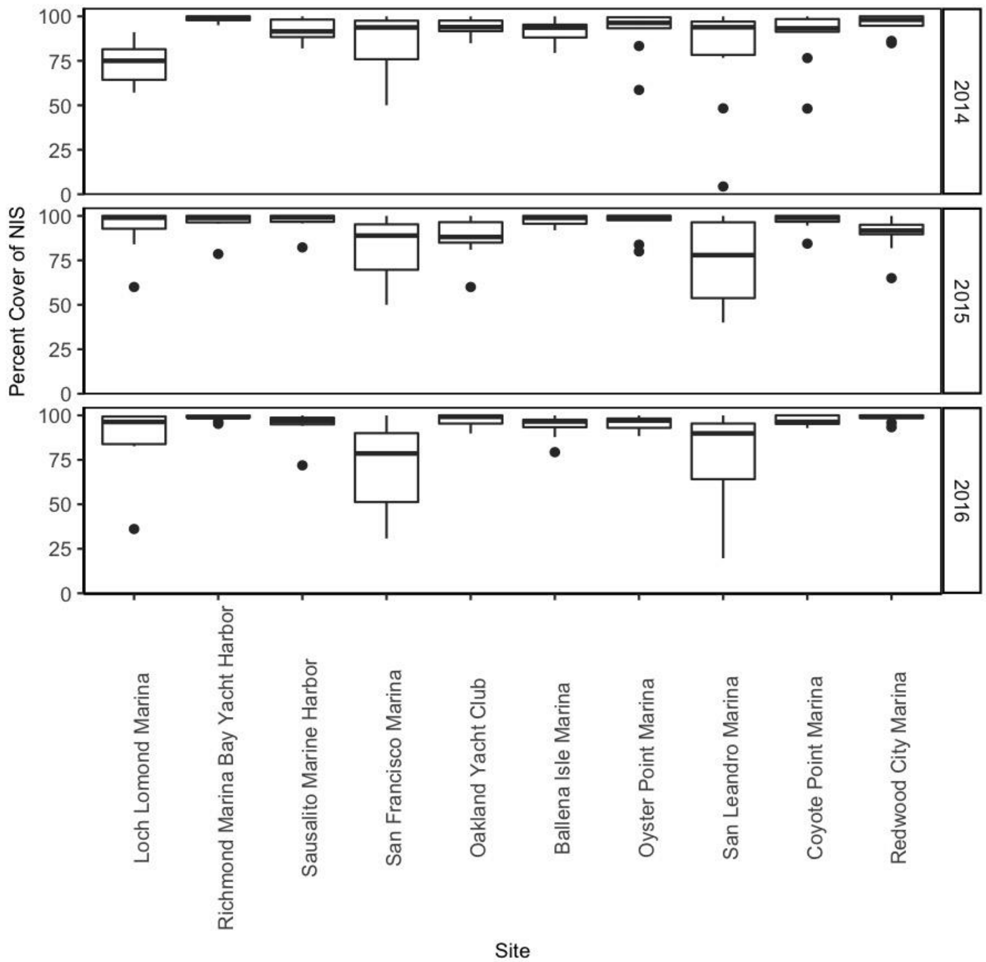


**Figure 2.10. Measures of percent cover of NIS (sessile taxa only) on plates within sites in each year in San Francisco Bay, based on point count measurements.** Approximately 50-point count measurements were made per plate, identifying sessile invertebrates to species. Status is designated based on literature and SERC NEMESIS database. The lower and upper hinges of the box plots correspond to the first and third quartiles (the 25th and 75th percentiles); center line with boxes indicates medians, lines indicate 95% confidence limits, and points indicate samples that extended beyond these limits.

## *C. Newly Detected NIS across Years (2014-2016) in the San Francisco Bay Hard Substrate Community.*

For the hard substrate surveys, we detected ten NIS on panels for the first time in San Francisco Bay, using this repeated measure across years (Table 2.3). Four of these species were tunicates (*Microcosmus squamiger, Molgula ficus, Perophora japonica*, and *Styela canopus*), and the remaining –six were polychaetes. Two of the ten species have been previously reported in San Francisco Bay (but not on panel surveys), and others appear to be new records for San Francisco Bay. However, all these species were reported previously elsewhere in California (Fofonoff *et al*. 2017).

**Table 2.3. Year of first detection in plate surveys for San Francisco Bay**. Asterisks indicate species previously reported for San Francisco Bay, and all species were reported previously elsewhere in California.

| | Year of First Detection for Surveys | | |
|---|---|---|---|
| **Species** | **2014** | **2015** | **2016** |
| *Amblyosyllis speciosa* D | x | | |
| *Branchiomma* sp. 2 | x | | |
| *Myrianida pentadentata* | x | | |
| *Neoamphitrite* sp. A | x | | |
| *Perophora japonica* | x | | |
| *Microcosmus squamiger* | | x | |
| *Molgula ficus** | | x | |
| *Myrianida pachycera* | | x | |
| *Styela canopus* | | x | |
| *Pseudopolydora paucibranchiata** | | | x |

Several of the new tunicate records for San Francisco Bay appear to be northward range expansions from southern California that coincide with unusually warm water, suggesting a change of environmental conditions may have contributed to colonization (Tracy *et al*., 2017). Whether these populations will persist in San Francisco Bay, especially during normal (colder) years, is not yet clear.

While our repeated measures across years suggest new invasions may have occurred recently for San Francisco Bay, some of the newly detected polychaete species may simply reflect an increased search effort for this group, which has received relatively little scrutiny (for plate surveys) until the last four years.

***D. Newly Detected NIS across Other Sampled Bays in the Hard Substrate Community.***

Aside from San Francisco Bay, our surveys of Port Hueneme, Marina del Rey, and Humboldt Bay detected one new NIS: the bryozoan *Cradoscrupocellaria bertholletii*, which was found at two sites in Humboldt Bay in 2015 (Appendix 2.2), representing a first record for the Pacific coast of North America. *C. bertholletii* is widely reported from the Mediterranean. This paucity of new records, despite the extensive survey effort outlined in this report, is noteworthy and discussed further in Section III.

**References**

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Fofonoff P.W., Ruiz G.M., Steves B., Simkanin C., & Carlton J.T. 2017. National Exotic Marine and Estuarine Species Information System. http://invasions.si.edu/nemesis/. Access Date: 15-Jun-2017

Oksanen J., Blanchet F.G., Kindt R., Legendre P., Minchin P.R., O'Hara, R.B., Simpson G., Solymos P., Stevens M. & Wagner H. 2015. vegan: Community Ecology Package. R package version 2.3-0. Retrieved from http://CRAN.R-project.org/package=vegan

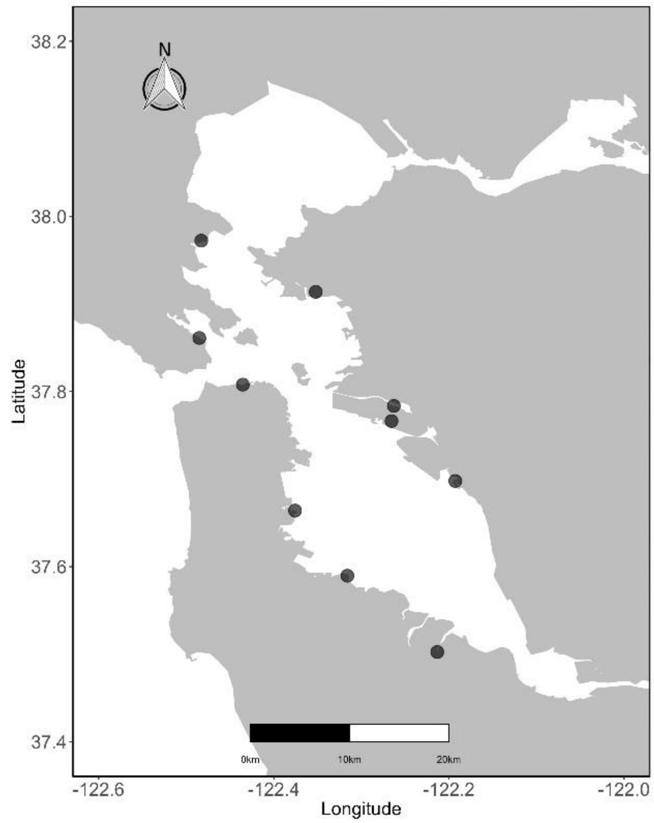
R Core Team. 2015. R: A Language and Environment for Statistical Computing. https://www.R-project.org/

Tracy B, Larson K, Ashton G, Lambert G, Chang AL, &Ruiz GM. (2017) Northward range expansion of three non-native ascidians on the west coast of North America. BioInvasions Records. DOI: 10.3391/bir.2017.6.3.04

## Appendix 2.1: Survey Locations by Estuary and Year

The maps and tables below indicate locations and dates for hard substrate surveys for each estuary and year.

### ***San Francisco Bay (2014-2016)***

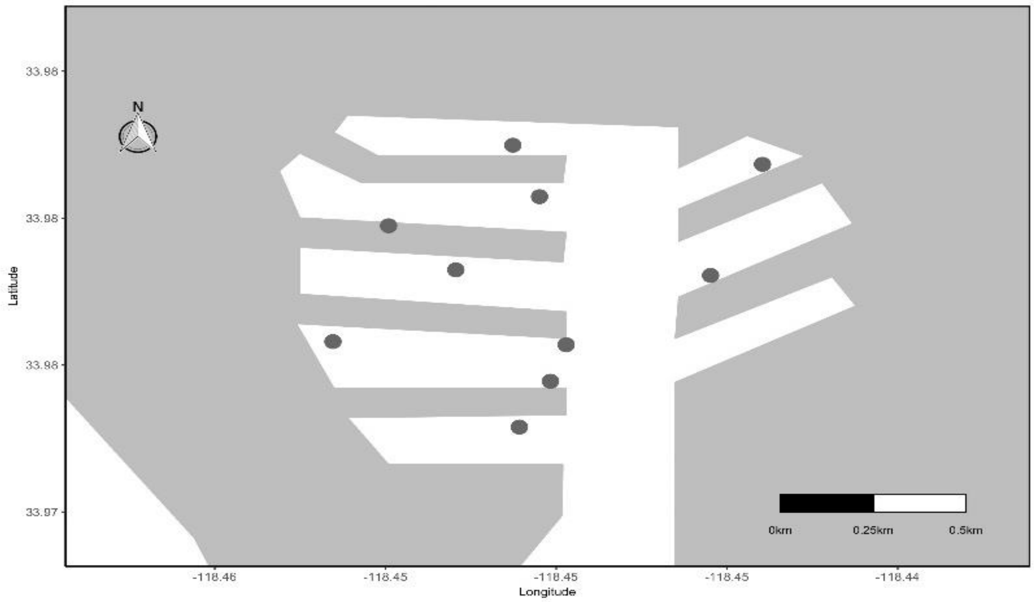



| Site Name | Latitude | Longitude | 2014 Deploy Date | 2014 Retrieval Date | 2015 Deploy Date | 2015 Retrieval Date | 2016 Deploy Date | 2016 Retrieval Date |
|---|---|---|---|---|---|---|---|---|
| San Francisco Marina | 37.80777 | -122.43544 | 6/10/2014 | 9/8/2014 | 6/18/2015 | 9/15/2015 | 6/21/2016 | 9/7/2016 |
| San Leandro Marina | 37.69776 | -122.19279 | 6/11/2014 | 9/9/2014 | 6/11/2015 | 9/16/2015 | 6/13/2016 | 9/14/2016 |
| Sausalito Marine Harbor | 37.86108 | -122.48511 | 6/10/2014 | 9/19/2014 | 6/16/2015 | 9/25/2015 | 6/15/2016 | 9/23/2016 |
| Coyote Point Marina | 37.58952 | -122.31601 | 6/12/2014 | 9/16/2014 | 6/18/2015 | 9/22/2015 | 6/20/2016 | 9/22/2016 |
| Oyster Point Marina | 37.66393 | -122.37583 | 6/12/2014 | 9/17/2014 | 6/18/2015 | 9/23/2015 | 6/20/2016 | 9/21/2016 |
| Redwood City Marina | 37.50243 | -122.2134 | 6/12/2014 | 9/11/2014 | 6/18/2015 | 9/21/2015 | 6/17/2016 | 9/26/2016 |
| Ballena Isle Marina | 37.7662 | -122.26561 | 6/11/2014 | 9/12/2014 | 6/11/2015 | 9/17/2015 | 6/13/2016 | 9/13/2016 |
| Richmond Marina Bay Yacht Harbor | 37.91377 | -122.3522 | 6/9/2014 | 9/10/2014 | 6/17/2015 | 9/14/2015 | 6/17/2016 | 9/12/2016 |
| Loch Lomond Marina | 37.97231 | -122.48293 | 6/10/2014 | 9/15/2014 | 6/16/2015 | 9/18/2015 | 6/15/2016 | 9/8/2016 |
| Oakland Yacht Club | 37.78352 | -122.263 | 6/19/2014 | 9/24/2014 | 6/19/2015 | 9/24/2015 | 6/17/2016 | 9/27/2016 |

***Humboldt Bay 2015***

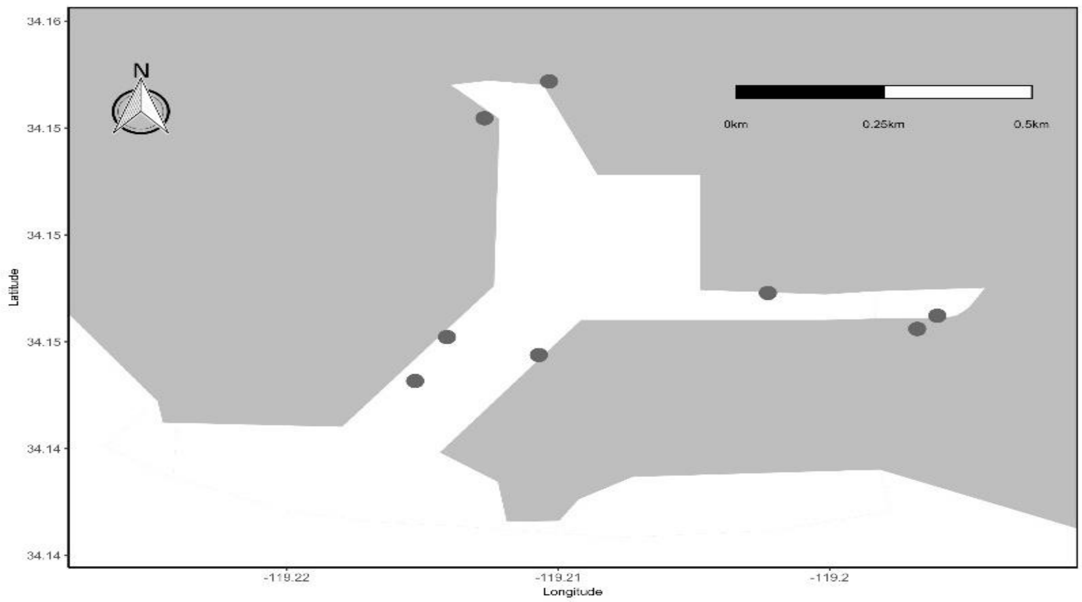

| Site Name | Latitude | Longitude | Deploy Date | Retrieval Date |
|---|---|---|---|---|
| EZ Landing RV Park and Marina | 40.73703 | -124.21757 | 5/18/2015 | 8/17/2015 |
| Coast Guard | 40.76691 | -124.2174 | 5/19/2015 | 8/11/2015 |
| Fairhaven Terminal | 40.78842 | -124.19461 | 5/19/2015 | 8/18/2015 |
| Samoa Pacific | 40.79869 | -124.19067 | 5/19/2015 | 8/19/2015 |
| Redwood Marine Terminal Berth 1 | 40.81733 | -124.18038 | 5/19/2015 | 8/12/2015 |
| Simpson Samoa | 40.80359 | -124.18906 | 5/20/2015 | 8/13/2015 |
| Woodley Island Marina | 40.80784 | -124.16101 | 5/20/2015 | 8/10/2015 |
| Schneider Dock | 40.77746 | -124.1865 | 5/20/2015 | 8/14/2015 |
| Humboldt Bay Forest Products | 40.73262 | -124.21914 | 5/21/2015 | 8/20/2015 |
| Eureka Public Marina | 40.8026 | -124.17892 | 5/21/2015 | 8/15/2015 |

## ***Marina del Rey 2015***




| Site Name | Latitude | Longitude | Deploy Date | Retrieval Date |
|---|---|---|---|---|
| Waves-Tahiti A | 33.97289 | -118.45108 | 4/29/2015 | 7/29/2015 |
| Waves-Tahiti B | 33.97445 | -118.45017 | 4/29/2015 | 7/29/2015 |
| Esprit Marina | 33.97569 | -118.44971 | 4/29/2015 | 7/27/2015 |
| Neptune Marina | 33.9758 | -118.45654 | 4/28/2015 | 7/27/2015 |
| Catalina Yacht Club | 33.98183 | -118.44396 | 4/28/2015 | 7/28/2015 |
| Del Rey Marina-Basin D | 33.98073 | -118.45049 | 4/28/2015 | 7/31/2015 |
| Del Rey Marina-Basin E | 33.98248 | -118.45127 | 4/28/2015 | 7/31/2015 |
| Dolphin Marina | 33.97824 | -118.45294 | 4/26/2015 | 7/30/2015 |
| Holiday Marina | 33.97974 | -118.45491 | 4/26/2015 | 8/1/2015 |
| Santa Monica Yacht Club | 33.97805 | -118.44548 | 4/26/2015 | 7/28/2015 |

## ***Port Hueneme 2015***




| **Site Name** | **Latitude** | **Longitude** | **Deploy Date** | **Retrieval Date** |
|---|---|---|---|---|
| Naval Base floating dock | 34.15369 | -119.20897 | 5/4/2015 | 7/25/2015 |
| Naval Base fiberglass dock | 34.14771 | -119.21085 | 5/4//2015 | 7/23/2015 |
| Naval Base alpha dock | 34.15283 | -119.21016 | 5/4//2015 | 7/23/2015 |
| Naval Base sealion dock | 34.146583 | -119.212639 | 5/4//2015 | 7/24/2015 |
| Port Hueneme site 1 | 34.14729 | -119.20916 | 4/27/2015 | 7/22/2015 |
| Port Hueneme Site 2 | 34.1479 | -119.20219 | 4/27/2015 | 7/20/2015 |
| Port Hueneme Site 3 | 34.14821 | -119.20182 | 4/27/2015 | 7/22/2015 |
| Port Hueneme Site 4 | 34.14874 | -119.20494 | 4/29/2015 | 7/21/2015 |

## Appendix 2.2 Taxa Identified Morphologically by Estuary and Year

### ***Humbolt Bay***

| HUMBOLDT BAY<br>Fouling Panel Species List | BAY SPECIES STATUS | Coast Guard | Eureka Public Marina | EZ Landing RV Park and Marina | Fairhaven Terminal | Humboldt Bay Forest Products | Redwood Marine Terminal Berth 1 | Samoa Pacific | Schneider Dock | | Simpson Samoa | Woodley Island Marina |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **2015** | **2015** | **2015** | **2015** | **2015** | **2015** | **2015** | **2015** | | **2015** | **2015** |
| **ANNELIDA** | | | | | | | | | | | | |
| **Capitellidae** | | | | | | | | | | | | |
| Capitellidae | U | | | 1 | | | | | | | | |
| **Chrysopetalidae** | | | | | | | | | | | | |
| Chrysopetalidae | U | 6 | 1 | | | 2 | 1 | 2 | 1 | | 2 | 2 |
| *Paleanotus bellis* | N | 5 | 2 | 6 | 11 | 9 | 5 | 8 | 4 | | 4 | 1 |
| **Fabriciidae** | | | | | | | | | | | | |
| Fabriciidae | U | | 1 | | | | | | | | | |
| **Nereididae** | | | | | | | | | | | | |
| *Alitta succinea* | I | | | | 2 | 1 | | | | | | 1 |
| Nereididae | U | | 1 | | 2 | | | | 1 | | | |
| *Nereis latescens* | N | | | | | | | | | | | 1 |
| *Platynereis bicanaliculata* | N | 10 | 9 | 10 | 9 | 9 | 8 | 10 | 7 | | 10 | 10 |
| **Opheliidae** | | | | | | | | | | | | |
| *Armandia brevis* | N | | 1 | | | | | | | | | |
| **Orbiniidae** | | | | | | | | | | | | |
| *Naineris dendritica* | N | | | | | | | | | | | 1 |
| **Phoronida** | | | | | | | | | | | | |
| *Phoronis* sp. | N | | 1 | 1 | | | | | | | | |
| **Phyllodocidae** | | | | | | | | | | | | |
| Eteoninae | U | | | | | | | 1 | | | 1 | |
| *Eulalia quadrioculata* | N | 7 | 1 | 1 | 8 | 9 | 6 | 9 | 3 | | 5 | 3 |
| *Eulalia* sp. | U | | | | 2 | 1 | | 1 | | | 1 | |
| *Hypereteone lighti* | N | | | | | 1 | | | | | | |
| *Mystides* sp. | N | | | | | | | 1 | | | | |
| *Phyllodoce* sp. | N | | | | | | | | | | 1 | |
| Phyllodocidae | U | 1 | | | | | | 1 | 1 | | 1 | 1 |
| **Polynoidae** | | | | | | | | | | | | |
| *Halosydna brevisetosa* | N | 4 | 3 | | 2 | 1 | | 2 | 1 | | 2 | 3 |
| *Halosydna johnsoni* | N | | 1 | | 2 | 1 | | 2 | 1 | | | |
| *Halosydna* sp. | N | | 1 | 1 | | | | | | | | |
| *Harmothoe imbricata* | C | | 1 | | | | | | | | | 3 |
| Polynoidae | U | 1 | | | | 1 | | 2 | | | | |
| **Sabellariidae** | | | | | | | | | | | | |
| *Neosabellaria cementarium* | N | | | | | | | | 1 | | | |
| *Sabellaria gracilis* | N | | 1 | | | | | | 1 | | | |
| Sabellariidae | U | | 1 | | | | | | | | | |

| **HUMBOLDT BAY**<br>**Fouling Panel Species List** | **BAY SPECIES STATUS** | Coast Guard<br>**2015** | Eureka Public Marina<br>**2015** | EZ Landing RV Park and Marina<br>**2015** | Fairhaven Terminal<br>**2015** | Humboldt Bay Forest Products<br>**2015** | Redwood Marine Terminal Berth 1<br>**2015** | Samoa Pacific<br>**2015** | Schneider Dock<br>**2015** | | Simpson Samoa<br>**2015** | Woodley Island Marina<br>**2015** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sabellidae** | | | | | | | | | | | | |
| *Chone* sp. | N | 1 | | | | 1 | | | | | | |
| *Myxicola* sp. A | C | | 1 | | | | | | | | | |
| Sabellidae | U | 1 | | | 1 | 3 | | | | | | |
| *Schizobranchia insignis* | U | 2 | | | | | | | 1 | | | |
| **Serpulidae** | | | | | | | | | | | | |
| *Crucigera zygophora* | N | 1 | | 3 | 1 | 3 | | 1 | | | | |
| *Pseudochitinopoma occidentalis* | N | 8 | 5 | 8 | 3 | 10 | | | 5 | | 1 | |
| Serpulidae | U | | 1 | 1 | | 1 | | 1 | 1 | | | 1 |
| **Spionidae** | | | | | | | | | | | | |
| *Dipolydora socialis* | C | | 2 | | | | | | 1 | | | |
| *Polydora narica* | N | | 1 | 1 | | | | | | | | |
| *Polydora* sp. | U | | | 1 | 1 | | | | | | | |
| Spionidae | U | | | | 1 | | | 1 | | | 1 | |
| **Spirorbidae** | | | | | | | | | | | | |
| *Neodexiospira pseudocorrugata* | C | 2 | 8 | 4 | | | | | | | 1 | |
| Spirorbidae | U | 1 | | | | | | | | | | |
| **Syllidae** | | | | | | | | | | | | |
| Eusyllinae | U | | | | 1 | | | | 2 | | | |
| *Eusyllis* sp. | U | | | | | | | | | | 1 | |
| Exogoninae | U | | | | | | | | | | 1 | |
| *Myrianida* sp. | U | 1 | | | | | | | | | | |
| *Odontosyllis phosphorea* | N | | | | 2 | | | | | | | |
| *Sphaerosyllis californiensis* | N | | 2 | 1 | | | | 1 | | | | |
| Syllidae | U | | | | | | | 2 | | | | |
| *Syllis elongata* complex | N | | | | | | | 1 | | | | |
| *Typosyllis* sp. | U | | | | 1 | | | 1 | | | | |
| **Terebellidae** | | | | | | | | | | | | |
| *Eupolymnia heterobranchia* | N | | | 1 | | | | | | | | 1 |
| *Polycirrus* sp. | U | | 6 | 1 | 1 | | 1 | | 1 | | 2 | 2 |
| Terebellidae | U | 1 | | | | | | | | | 1 | |
| **ARTHROPODA** | | | | | | | | | | | | |
| **Amphipoda** | | | | | | | | | | | | |
| *Allorchestes rickeri* | N | | | | | 1 | | | | | | |
| *Ampithoe lacertosa* | C | | | | | | | 1 | | | | |
| *Ampithoe valida* | I | | | | | | | 1 | | | 2 | |
| *Anisogammarus pugettensis* | N | | | 1 | | | | | | | | |
| Aoridae | U | | | | | 1 | | | | | | |
| *Aoroides columbiae* | N | 4 | | | 2 | | | | | | | |
| *Aoroides inermis* | N | 4 | 2 | 5 | 3 | 5 | 5 | 5 | 3 | | 5 | 1 |

| **HUMBOLDT BAY Fouling Panel Species List** | **BAY SPECIES STATUS** | Coast Guard **2015** | Eureka Public Marina **2015** | EZ Landing RV Park and Marina **2015** | Fairhaven Terminal **2015** | Humboldt Bay Forest Products **2015** | Redwood Marine Terminal Berth 1 **2015** | Samoa Pacific **2015** | Schneider Dock **2015** | | Simpson Samoa **2015** | Woodley Island Marina **2015** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Aoroides secunda* | I | | 1 | | | | | | | | | |
| *Ericthonius brasiliensis* | C | | | 1 | | | 1 | | | | | |
| *Gnathopleustes serratus* | N | | | | | | | | | | 1 | 1 |
| *Grandidierella japonica* | I | | 1 | | | | 2 | | | | | 1 |
| Hyalidae | U | | | | | | | | | | 1 | |
| *Incisocalliope derzhavini* | I | 1 | | | | | | | | | | |
| *Jassa slatteryi* | C | 4 | 3 | | 4 | 5 | 5 | 5 | 5 | | 5 | 5 |
| *Jassa* sp. | U | 1 | | | 1 | | | | | | | 3 |
| *Jassa staudei* | N | 4 | 1 | | 2 | | | 2 | 1 | | 1 | |
| *Laticorophium baconi* | N | | | | | 1 | | | | | | |
| *Metopa cistella* | N | | | | | | | | 1 | | | |
| *Microjassa* sp. | N | | | | | 1 | | | | | | |
| *Monocorophium acherusicum* | I | | 4 | 5 | 1 | 3 | 2 | 3 | 5 | | 4 | 5 |
| *Monocorophium californianum* | N | 1 | | | | | | | | | | |
| *Monocorophium insidiosum* | I | 2 | 1 | 1 | | 4 | 1 | 2 | | | | 1 |
| *Monocorophium* sp. | U | | | | 1 | | | | | | | |
| *Paracorophium* sp. | I | | 1 | | | | | | | | | |
| *Photis brevipes* | N | 1 | 3 | 2 | 1 | 4 | | 1 | 4 | | | |
| *Photis* sp. | N | | | | | | | 1 | | | | |
| *Podocerus brasiliensis* | C | | | | 3 | | | | 4 | | | |
| *Podocerus cristatus* | C | 5 | 1 | | 3 | 4 | | | 1 | | | |
| *Pontogeneia rostrata* | N | | | 2 | | | | | | | | |
| *Protohyale frequens* | N | 2 | | | | | | | | | | |
| **Caprellidae** | | | | | | | | | | | | |
| *Caprella alaskana* | N | 1 | | | | | | | | | | |
| *Caprella californica* | N | 3 | 4 | 5 | | 5 | 4 | 2 | 5 | | 3 | 4 |
| *Caprella drepanochir* | I | 2 | 4 | 3 | | 3 | 4 | 4 | 4 | | 2 | 4 |
| *Caprella equilibra* | C | | | | | 1 | 2 | 1 | 5 | | 3 | 4 |
| *Caprella ferrea* | N | | | | 1 | | | | | | | |
| *Caprella laeviuscula* | I | 1 | | | | | | 1 | | | | |
| *Caprella mutica* | I | 4 | 4 | 5 | | 4 | 2 | 3 | 3 | | 2 | 5 |
| *Caprella* sp. | U | 1 | | | | 1 | | 1 | | | | |
| *Caprella* sp. 11 | U | | | | | | | 1 | | | | |
| Caprellidae | U | | | | | | | | 1 | | | |
| *Deutella californica* | N | 1 | | | 3 | 5 | | | | | | |
| *Tritella pilimana* | N | 1 | | | | | | | | | | |
| **Cirripedia** | | | | | | | | | | | | |
| *Amphibalanus amphitrite* | I | 1 | | | | | | | | | | |
| *Amphibalanus improvisus* | I | | | | | | | | 1 | | | |

| HUMBOLDT BAY<br>Fouling Panel Species List | BAY SPECIES STATUS | Coast Guard<br>2015 | Eureka Public Marina<br>2015 | EZ Landing RV Park and Marina<br>2015 | Fairhaven Terminal<br>2015 | Humboldt Bay Forest Products<br>2015 | Redwood Marine Terminal Berth 1<br>2015 | Samoa Pacific<br>2015 | Schneider Dock<br>2015 | | Simpson Samoa<br>2015 | Woodley Island Marina<br>2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Balanidae | U | 2 | | | 1 | 1 | | | | | | |
| *Balanus crenatus* | N | 9 | 10 | 7 | 11 | 9 | 8 | 11 | 7 | | 10 | 6 |
| *Balanus glandula* | N | 9 | | | 1 | | 1 | 3 | 2 | | 8 | 4 |
| *Balanus nubilus* | N | 9 | | | 6 | 3 | 3 | 7 | 2 | | 1 | 2 |
| *Balanus* sp. | U | 1 | | 2 | 1 | | 2 | 3 | 1 | | | 4 |
| Cirripedia | U | | | | | | | | | | | 1 |
| *Megabalanus californicus* | N | 2 | | | | | | | | | | |
| **Decapoda** | | | | | | | | | | | | |
| *Hemigrapsus oregonensis* | N | 1 | | | | | | | | | | |
| *Heptacarpus* sp. | N | | | 1 | | | | | | | | |
| *Pachycheles pubescens* | N | 1 | | | | | | | | | | |
| *Pachycheles rudis* | N | | | | 2 | 1 | | | | | 1 | |
| *Pachycheles* sp. | N | | | | | | | 1 | | | | |
| *Pugettia gracilis* | N | | 1 | | | | | | | | | |
| *Pugettia richii* | N | | | | | 1 | | | | | | |
| *Romaleon branneri* | N | 2 | 1 | | 1 | 1 | 2 | | 1 | | 1 | |
| **Isopoda** | | | | | | | | | | | | |
| *Ianiropsis* sp. | U | | | | | 1 | | | 2 | | | |
| *Idotea rufescens* | N | | | | | | | 1 | | | | |
| *Idotea* sp. | N | | | | | 1 | | | | | | |
| *Limnoria* sp. | U | | | | | | | 1 | | | | |
| *Munna* sp. | U | | | | | 1 | | | | | | |
| *Munna stephenseni* | N | 2 | | | | | | | | | | |
| Oniscidea | U | | | | | | | | 1 | | | |
| *Paracerceis sculpta* | N | | | 2 | | | 1 | | 1 | | | 2 |
| **Pycnogonida** | | | | | | | | | | | | |
| *Achelia* sp. | N | | | | | | | | 1 | | | |
| *Tanystylum occidentalis* | N | | | | | | | | | | 1 | |
| **Tanaidae** | | | | | | | | | | | | |
| *Leptochelia* sp. | C | | | 1 | | | | | | | 1 | |
| *Zeuxo* sp. | U | | | | | | 1 | | 1 | | 5 | 4 |
| **BRYOZOA** | | | | | | | | | | | | |
| **Bryozoa** | | | | | | | | | | | | |
| *Aetea pseudoanguina* | N | | | | | 4 | | | | | | |
| *Alcyonidium* sp. | U | 5 | 4 | 2 | 11 | 7 | 4 | 11 | 4 | | 2 | |
| *Amathia* sp. *bowerbankia* | U | 8 | 10 | 10 | 7 | 9 | 1 | 4 | 4 | | 6 | |
| *Anguinella palmata* | I | | 1 | | | | | | | | | |
| *Bugula neritina* | I | 3 | 9 | 10 | 3 | 10 | 6 | 1 | 4 | | 2 | 10 |
| Bugulidae | U | | | | | | | | 1 | | | |

| HUMBOLDT BAY<br>Fouling Panel Species List | BAY SPECIES STATUS | Coast Guard 2015 | Eureka Public Marina 2015 | EZ Landing RV Park and Marina 2015 | Fairhaven Terminal 2015 | Humboldt Bay Forest Products 2015 | Redwood Marine Terminal Berth 1 2015 | Samoa Pacific 2015 | Schneider Dock 2015 | | Simpson Samoa 2015 | Woodley Island Marina 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Bugulina californica* | N | | 1 | | | | | | | | | |
| *Bugulina longirostrata* | N | | 10 | | 2 | 6 | | | 3 | | 1 | |
| *Bugulina stolonifera* | I | | 5 | 5 | 5 | 4 | 3 | | 3 | | | 9 |
| Candidae | U | 1 | 2 | | | | 1 | | | | | |
| *Celleporaria brunnea* | N | | | | | | | | 1 | | | |
| *Celleporaria* sp. | U | | | | | | | | 1 | | | |
| *Celleporella hyalina* | C | 1 | 10 | 5 | 4 | 7 | 7 | 8 | 4 | | 8 | 5 |
| *Conopeum* sp. | U | | | | | 1 | 1 | | 2 | | 1 | 1 |
| *Conopeum tenuissimum* | I | | 1 | | 1 | | 1 | 1 | 3 | | 1 | 1 |
| *Copidozoum adamantum* | N | 1 | | | | | | | | | | |
| *Cradoscrupocellaria bertholletii* | U | | 2 | | 1 | | | | | | | |
| *Crisia occidentalis* | N | 6 | 3 | | 5 | 8 | 1 | 2 | 4 | | | 1 |
| *Crisularia pacifica* | N | 1 | 3 | 9 | | 9 | | | | | | |
| *Cryptosula pallasiana* | I | | 5 | 4 | | 2 | | | | | | 7 |
| Electridae | U | | | | | | | | 1 | | | |
| *Fenestrulina delicia* | C | | 6 | 2 | | 1 | | | | | | 1 |
| *Fenestrulina* sp. | U | | 3 | 1 | | | | | 2 | | 1 | 1 |
| *Filicrisia franciscana* | N | 2 | 5 | | | 6 | | | 2 | | | |
| *Filicrisia* sp. | U | | | | | 1 | | | | | | |
| Hippothoidae | U | | | | | | 1 | | | | | |
| *Licornia diegensis* | N | 1 | 5 | 1 | 2 | 2 | 3 | 1 | 4 | | 1 | |
| *Microporella californica* | N | | 2 | 1 | 1 | 7 | 7 | | 3 | | 1 | 1 |
| *Parasmittina collifera* | N | | 5 | | 1 | 5 | 3 | | 3 | | 1 | |
| *Parasmittina* sp. | U | | | | | | | | 1 | | | |
| *Pomocellaria varians* | N | | 6 | 1 | | | | | | | | |
| *Rhynchozoon spicatum* | N | | | | | | | | 1 | | | |
| *Schizoporella errata* | I | | 2 | | | | | | | | | |
| *Schizoporella japonica* | I | 1 | 9 | 10 | | 4 | 1 | | 2 | | 1 | 2 |
| *Schizoporella* sp. | U | | 1 | | | | 2 | | | | | 1 |
| *Scruparia ambigua* | C | | | | 1 | | | | | | | |
| *Smittoidea prolifica* | N | | 2 | | | | | | 1 | | | 2 |
| *Tubulipora* sp. | U | 2 | | | 1 | | | | | | | |
| *Watersipora* sp. | I | 3 | | | | | 3 | | | | 3 | |
| *Watersipora subtorquata* complex | I | 3 | 10 | 10 | 1 | 10 | 8 | | 8 | | 3 | 10 |

| **HUMBOLDT BAY Fouling Panel Species List** | **BAY SPECIES STATUS** | Coast Guard | Eureka Public Marina | EZ Landing RV Park and Marina | Fairhaven Terminal | Humboldt Bay Forest Products | Redwood Marine Terminal Berth 1 | Samoa Pacific | Schneider Dock | | Simpson Samoa | Woodley Island Marina |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **2015** | **2015** | **2015** | **2015** | **2015** | **2015** | **2015** | **2015** | | **2015** | **2015** |
| **CNIDARIA** | | | | | | | | | | | | |
| **Anthozoa** | | | | | | | | | | | | |
| Actiniaria | U | 2 | | | | | 2 | 1 | | | | |
| Anthozoa | U | 1 | | | | | | | | | 1 | |
| *Diadumene* sp. | U | | | 1 | 1 | 2 | | | 1 | | | |
| *Metridium* sp. | N | 2 | | | 5 | 1 | | 1 | | | | 1 |
| **Hydrozoa** | | | | | | | | | | | | |
| Athecata | U | | 1 | | 3 | | 2 | 1 | | | 4 | |
| Corynidae | U | 2 | | | | | | | | | | |
| Hydrozoa | U | | | | | | | | 2 | | | |
| Hydrozoa sp. A | U | 11 | 3 | 8 | 10 | 10 | 11 | 11 | 4 | | 5 | 9 |
| Hydrozoa sp. C | U | 1 | | | | 1 | | | 2 | | 1 | |
| Hydrozoa sp. D | U | | | | | | | | | | | 1 |
| Plumularioidea | U | 4 | 1 | | | 1 | 2 | | 3 | | 3 | |
| Thecata | U | | 2 | | | 1 | | | | | 1 | 1 |
| Tubulariidae | U | | | | | | | 1 | | | | |
| **ECHINODERMATA** | | | | | | | | | | | | |
| **Asteroidea** | | | | | | | | | | | | |
| Asteroidea | U | 1 | | | | | 1 | 1 | | | | |
| **Echinodermata** | | | | | | | | | | | | |
| Echinodermata | U | | | 1 | | | | | | | | |
| Echinoidea | U | 1 | | | | | | | | | | |
| *Ophiopholis kennerlyi* | N | 1 | | | | | | | | | | |
| *Ophiothrix spiculata* | N | | | | | | 2 | | 2 | | | |
| **ENTOPROCTA** | | | | | | | | | | | | |
| **Kamptozoa** | | | | | | | | | | | | |
| Kamptozoa | U | | 2 | | | | | | 2 | | | |
| **MOLLUSCA** | | | | | | | | | | | | |
| **Bivalvia** | | | | | | | | | | | | |
| Anomiidae | N | | | | | 1 | | | | | | |
| Bivalvia | U | 1 | | | | | 1 | | 1 | | | |
| Cardiidae | U | 1 | | | | | | | | | | |
| Heterodonta | U | 1 | | | 1 | | | 1 | 3 | | | |
| *Hiatella arctica* | C | 1 | | | | | | | | | | |
| *Modiolus modiolus* | N | | | | | | 1 | | | | | |
| *Modiolus* sp. | N | 3 | | | | | | | | | | |
| Mytilidae | U | 7 | 5 | 1 | 9 | 7 | 6 | 9 | 3 | | 5 | 6 |
| *Mytilus californianus* | N | | | | 1 | | | | | | 1 | 1 |
| *Mytilus galloprovincialis/trossulus* complex | U | | 1 | | 1 | | | | | | 1 | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Mytilus* sp. | U | 3 | 1 | 2 | 1 | | 1 | | 1 | | 3 | 1 |
| *Ostrea lurida* | N | | | | | | 1 | | | | | |
| Ostreidae | U | | 1 | | | | | | | | | |
| Pectinidae | U | 2 | | 1 | 2 | | | | | | | |
| *Pododesmus* sp. | N | | | | 1 | 3 | | | 1 | | | |
| Pteriomorphia | U | 1 | 2 | | 3 | | | | 1 | | | |
| **Gastropoda** | | | | | | | | | | | | |
| *Alia carinata* | N | | | | | | | | | | 1 | |
| *Alia gouldi* | N | | | | | | 1 | | | | | |
| *Alia* sp. | N | | 1 | | | | 1 | | | | | |
| *Alia tuberosa* | N | | | | | | | | | | | 1 |
| *Alvania* sp. | N | | 1 | | | | | | | | | |
| Columbellidae | U | | | | | 1 | 1 | | 2 | | 1 | |
| Gastropoda | U | | 1 | | 1 | 3 | | | 1 | | 1 | |
| **Nudibranchia** | | | | | | | | | | | | |
| *Acanthodoris rhodoceras* | N | | | | 3 | | | | | | | |
| *Dendronotus* sp. | N | | | | | | | | 1 | | | |
| *Dendronotus venustus* | N | | | | | | | 3 | 1 | | | |
| *Diaphorodoris lirulatocauda* | N | | 1 | | | 1 | | | | | | |
| Doridacea | U | | 1 | | 1 | | | | | | | |
| *Doto* form A of Goddard | N | | | | | | | | | | | 1 |
| *Doto* sp. | N | | | | | | | | | | | 1 |
| *Eubranchus doriae* | N | | | | | | 1 | | | | | |
| *Hermissenda* sp. | N | 2 | 6 | | 7 | 6 | 1 | 4 | 5 | | 3 | 3 |
| Nudibranchia | U | 2 | | | | 1 | 2 | 2 | | | 2 | |
| *Onchidoris bilamellata* | N | 1 | | | 1 | | | | | | | |
| *Onchidoris muricata* | N | | | | 1 | | | | | | | |
| *Polycera* sp. | N | | 1 | | | | | | | | | |
| **Opisthobranchia** | | | | | | | | | | | | |
| *Stiliger fuscovittatus* | N | 1 | | | | | | | | | | |
| **Polyplacophora** | | | | | | | | | | | | |
| Chitonida | N | | | | | 1 | | 1 | | | | |
| Ischnochitonidae | U | | | | | | | 1 | | | | |
| *Mopalia hindsii* | N | | | | | | | 1 | | | | |
| Polyplacophora | U | | | | | 1 | | 1 | | | | |
| **NEMERTEA** | | | | | | | | | | | | |
| **Nemertea** | | | | | | | | | | | | |
| Nemertea | U | 2 | 1 | | 1 | 1 | 1 | | 1 | | 1 | 2 |
| *Tubulanus* sp. | N | | | | | | 1 | | | | | |

| **HUMBOLDT BAY Fouling Panel Species List** | **BAY SPECIES STATUS** | Coast Guard **2015** | Eureka Public Marina **2015** | EZ Landing RV Park and Marina **2015** | Fairhaven Terminal **2015** | Humboldt Bay Forest Products **2015** | Redwood Marine Terminal Berth 1 **2015** | Samoa Pacific **2015** | Schneider Dock **2015** | | Simpson Samoa **2015** | Woodley Island Marina **2015** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **PLATYHELMINTHES** | | | | | | | | | | | | |
| **Platyhelminthes** | | | | | | | | | | | | |
| *Acanthozoon lepidum* | N | | | | | | | 2 | 1 | | | |
| *Acerotisa* sp. | U | | | | | 1 | | | | | | |
| Leptoplanoidea | U | | | | | | | 1 | | | | |
| Platyhelminthes | U | 2 | 1 | 2 | 6 | 7 | 7 | 3 | 2 | | 6 | 8 |
| *Pleioplana inquieta* | N | | | | | 1 | | | | | | |
| *Pseudoceros* sp. | N | | | | | | 1 | | 1 | | | 1 |
| **PORIFERA** | | | | | | | | | | | | |
| **Porifera** | | | | | | | | | | | | |
| Porifera | U | | | 1 | | | | | | | | |
| Porifera sp. A | U | 3 | 7 | 2 | 1 | 1 | | 4 | 3 | | | 3 |
| Porifera sp. B | U | 1 | | | 1 | | | | | | | |
| Porifera sp. C | U | 2 | 7 | | 5 | 10 | 1 | | 1 | | | |
| **UROCHORDATA** | | | | | | | | | | | | |
| **Tunicata** | | | | | | | | | | | | |
| *Aplidium* sp. | U | 1 | | | | 1 | | 1 | | | | |
| Aplousobranchia | U | 3 | 3 | 3 | 2 | | 2 | 1 | 4 | | 4 | |
| Botryllinae | I | 6 | 3 | 2 | 1 | 8 | 5 | 1 | 3 | | 4 | 3 |
| *Botrylloides* sp. | I | | 2 | 2 | | | | | 1 | | | 1 |
| *Botrylloides violaceus* | I | 2 | 5 | 8 | | 2 | 8 | | 5 | | 2 | 10 |
| *Botryllus schlosseri* | I | | | 5 | | 2 | | | 2 | | | 6 |
| *Botryllus* sp. | I | | | 1 | | | | | | | | |
| *Botryllus* sp. A | I | | | | | | | | 1 | | | 3 |
| *Ciona savignyi* | I | | | | | | | | | | | 4 |
| *Ciona* sp. | I | | 4 | | 2 | 2 | 5 | 3 | 2 | | 4 | 2 |
| *Corella inflata* | I | 7 | | | | | | | | | | |
| *Corella* sp. | U | | 2 | | | | | | | | | |
| Didemnidae | U | 1 | 5 | 2 | 4 | 8 | 5 | 6 | 3 | | 4 | 4 |
| *Didemnum* cf. *vexillum* | I | | | | | | 1 | 2 | 1 | | 2 | 2 |
| *Diplosoma listerianum* | I | 6 | 1 | | 1 | 6 | 6 | | 2 | | 3 | 3 |
| *Diplosoma* sp. | U | | 1 | | 5 | 3 | | 3 | 1 | | | |
| *Distaplia occidentalis* | N | 2 | 1 | 5 | | 1 | 1 | 4 | 2 | | | 7 |
| *Distaplia* sp. | U | | 4 | 3 | 7 | 8 | | 5 | 4 | | | 1 |
| *Molgula manhattensis* | I | | 1 | | | | | | | | | 1 |
| *Perophora* sp. | U | | | 1 | | 1 | | | | | | |
| Phlebobranchia | U | 1 | | | 2 | 1 | | | | | | |
| Stolidobranchia | U | 5 | 4 | 3 | | 1 | 2 | 1 | 2 | | 5 | 2 |
| *Styela clava* | I | | | | | | | | | | | 1 |
| *Styela* sp. | U | | 1 | 4 | 4 | 4 | | 1 | 1 | | | |
| Tunicata | U | | 2 | | | | | | | | | |

## *Marina del Rey*

| **MARINA DEL REY**<br>**Fouling Panel Species List** | **BAY SPECIES STATUS** | Catalina Yacht Club **2015** | Del Rey Marina Basin D **2015** | Del Rey Marina Basin E **2015** | Dolphin Marina **2015** | Esprit Marina **2015** | Holiday Marina **2015** | Neptune Marina **2015** | Santa Monica Yacht Club **2015** | Waves Tahiti A **2015** | Waves Tahiti B **2015** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **ANNELIDA** | | | | | | | | | | | |
| **Capitellidae** | | | | | | | | | | | |
| *Capitella capitata* complex | C | | 1 | | 1 | 2 | | | | 1 | |
| **Cirratulidae** | | | | | | | | | | | |
| *Cirriformia* sp. | N | | | | | | | | | | 1 |
| **Dorvilleidae** | | | | | | | | | | | |
| *Schistomeringos longicornis* | N | | | | | | | | 3 | | |
| **Eunicidae** | | | | | | | | | | | |
| *Marphysa* sp. | C | | 1 | 1 | | | | | | | |
| **Nereididae** | | | | | | | | | | | |
| *Neanthes acuminata* complex | C | | | | | | 1 | | | | 1 |
| **Sabellidae** | | | | | | | | | | | |
| *Parasabella* sp. | N | 5 | 5 | 5 | 4 | 5 | 5 | 3 | 5 | 4 | 5 |
| **Serpulidae** | | | | | | | | | | | |
| *Hydroides elegans* | I | 4 | 5 | 5 | 2 | 1 | 3 | 1 | 4 | 4 | 4 |
| *Hydroides gracilis* | N | | | | | | | | | | 1 |
| *Hydroides* sp. | U | 1 | 1 | | 1 | | 1 | | | | 2 |
| *Salmacina tribranchiata* | N | 3 | 3 | 4 | 4 | | 5 | 5 | 5 | 5 | 4 |
| **Spionidae** | | | | | | | | | | | |
| *Boccardiella* sp. | U | 1 | | | | | | | | | |
| **Spirorbidae** | | | | | | | | | | | |
| Januini | U | | 1 | | | | | | | | |
| *Neodexiospira brasiliensis* | I | | | | 2 | | | | | | |
| *Neodexiospira pseudocorrugata* | C | 3 | 3 | 4 | 3 | 2 | 4 | 4 | 5 | 3 | 4 |
| *Pileolaria* sp. | N | | | | | 1 | | | | | |
| *Simplaria pseudomilitaris* | N | 4 | 5 | 5 | 4 | 3 | 4 | 5 | 5 | 5 | 5 |
| **Syllidae** | | | | | | | | | | | |
| *Megasyllis nipponica* | I | | | | 1 | | | | | | |
| *Myrianida pachycera* | I | | | 1 | 1 | 1 | 1 | | 1 | | |
| *Salvatoria californiensis* | N | | | | | | | | | 1 | |
| Syllidae | U | | | | | 1 | | | | | |
| *Syllis gracilis* complex | C | | | | | 1 | | | 1 | 1 | |
| **ARTHROPODA** | | | | | | | | | | | |
| **Amphipoda** | | | | | | | | | | | |
| *Aoroides secunda* | I | 4 | 4 | 3 | 3 | 2 | 2 | 1 | 3 | 1 | 3 |

| MARINA DEL REY<br>Fouling Panel Species List | BAY SPECIES STATUS | Catalina Yacht Club 2015 | Del Rey Marina Basin D 2015 | Del Rey Marina Basin E 2015 | Dolphin Marina 2015 | Esprit Marina 2015 | Holiday Marina 2015 | Neptune Marina 2015 | Santa Monica Yacht Club 2015 | Waves Tahiti A 2015 | Waves Tahiti B 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Elasmopus bampo* | C | 4 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 4 |
| *Ericthonius brasiliensis* | C | 3 | 5 | 2 | 4 | 5 | | 4 | 5 | 5 | 4 |
| *Laticorophium baconi* | N | | 2 | 1 | 1 | 3 | 1 | | 2 | 3 | 4 |
| *Leucothoe alata* | C | | | | 1 | 2 | | | 2 | 2 | 1 |
| *Monocorophium acherusicum* | I | | | | 1 | 3 | 1 | 2 | | 2 | 1 |
| *Paradexamine* sp. 1 | I | | | | 1 | | | | | | |
| *Podocerus brasiliensis* | C | | | | | 4 | | 1 | | 4 | 2 |
| *Podocerus cristatus* | C | | 1 | 1 | 1 | 1 | 2 | | | 2 | 2 |
| *Stenothoe valida* | I | | 1 | 4 | | 3 | 3 | 1 | | 2 | 1 |
| **Caprellidae** | | | | | | | | | | | |
| *Caprella equilibra* | C | | | | | 1 | | | | | |
| **Cirripedia** | | | | | | | | | | | |
| *Amphibalanus* sp. | U | | | | | | 1 | | | | |
| **Isopoda** | | | | | | | | | | | |
| *Paracerceis sculpta* | N | | | | 1 | | | | | | |
| *Paranthura japonica* | I | 1 | 3 | | 2 | | 2 | 1 | 4 | | 2 |
| **Tanaidae** | | | | | | | | | | | |
| *Zeuxo* sp. | U | 5 | 3 | 4 | 4 | 4 | 4 | 4 | 5 | 5 | 4 |
| **BRYOZOA** | | | | | | | | | | | |
| **Bryozoa** | | | | | | | | | | | |
| *Bugula neritina* | I | 2 | 3 | | 3 | 3 | 2 | 1 | 2 | 5 | 5 |
| Bugulidae | U | | | | | 1 | | | | | |
| *Bugulina stolonifera* | I | 5 | 4 | 1 | 1 | 1 | 1 | 3 | 5 | 3 | 4 |
| *Celleporaria brunnea* | N | 5 | 5 | 4 | 3 | 5 | 4 | 5 | 5 | 4 | 5 |
| *Crisia* sp. A | U | | | | | 1 | | | 1 | | |
| *Crisulipora occidentalis* | N | 5 | 3 | 2 | 4 | 5 | | 3 | 5 | 4 | 3 |
| *Cryptosula pallasiana* | I | 4 | 3 | 5 | | 4 | 3 | 1 | 4 | 4 | 4 |
| Cyclostomatida | U | | | | | | 1 | | | 1 | 1 |
| *Diaperoforma californica* | N | | | | | | | 1 | | | |
| *Disporella* sp. | N | | | | | | | | | 1 | |
| *Thalamoporella californica* | N | 1 | 1 | | 1 | 5 | 3 | 2 | 1 | 5 | 3 |
| *Tubulipora* sp. | U | | | | | | | | | 1 | |
| *Watersipora* sp. | I | | | | 1 | 1 | | | | | |
| *Watersipora subtorquata* complex | I | 5 | 5 | 3 | 4 | 5 | 3 | 4 | 3 | 5 | 4 |

| **MARINA DEL REY**<br>**Fouling Panel Species List** | **BAY SPECIES STATUS** | Catalina Yacht Club **2015** | Del Rey Marina Basin D **2015** | Del Rey Marina Basin E **2015** | Dolphin Marina **2015** | Esprit Marina **2015** | Holiday Marina **2015** | Neptune Marina **2015** | Santa Monica Yacht Club **2015** | Waves Tahiti A **2015** | Waves Tahiti B **2015** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Watersipora subtorquata* sensu Vieira *et al*. 2014 | I | 1 | | 1 | | | 2 | | 1 | | |
| **CNIDARIA** | | | | | | | | | | | |
| **Anthozoa** | | | | | | | | | | | |
| Actiniaria | U | | 2 | 1 | 1 | | | 2 | 2 | | 1 |
| Anthozoa | U | | | | 1 | | | | | | |
| *Diadumene franciscana* | I | | | | | 1 | | | | | |
| *Diadumene leucolena* | I | | | | | 1 | | | | | |
| *Diadumene lineata* | I | | | 1 | 1 | | 3 | 1 | | | |
| *Diadumene* sp. | U | | | 2 | 2 | 1 | 3 | 2 | 1 | | 2 |
| **Hydrozoa** | | | | | | | | | | | |
| Athecata | U | 1 | | | | 1 | 2 | 1 | | | |
| Hydrozoa | U | | | | | | | | 1 | 1 | |
| Hydrozoa sp. A | U | | | | | 1 | | | | | |
| Hydrozoa sp. D | U | 2 | 4 | 4 | 1 | 1 | 6 | 2 | 2 | 3 | 5 |
| Plumularioidea | U | | | | | 1 | | | | | |
| Tubulariidae | U | | 3 | 4 | | 4 | 1 | 2 | | 4 | 3 |
| **ENTOPROCTA** | | | | | | | | | | | |
| **Kamptozoa** | | | | | | | | | | | |
| Kamptozoa | U | 1 | | | | | | | | | |
| **MOLLUSCA** | | | | | | | | | | | |
| **Bivalvia** | | | | | | | | | | | |
| Mytilidae | U | | | | | 1 | | | | | |
| *Mytilus californianus* | N | | | | 1 | | | | 1 | 1 | |
| *Mytilus galloprovincialis/trossulus* complex | U | | | | | 3 | | | | | 1 |
| *Mytilus* sp. | U | 1 | 2 | | | | | | | 1 | |
| *Ostrea lurida* | N | | | | | | | | | | 1 |
| **Nudibranchia** | | | | | | | | | | | |
| *Polycera atra* | N | 1 | | | | | | | | 2 | |
| *Tenellia adspersa* | I | | | 1 | | | | | | | |
| **NEMERTEA** | | | | | | | | | | | |
| **Nemertea** | | | | | | | | | | | |
| Nemertea | U | | | | | 1 | | | | 1 | |
| Palaeonemertea | U | | | | | 1 | | | | | |

| MARINA DEL REY<br>**Fouling Panel Species List** | **BAY SPECIES STATUS** | Catalina Yacht Club<br>**2015** | Del Rey Marina Basin D<br>**2015** | Del Rey Marina Basin E<br>**2015** | Dolphin Marina<br>**2015** | Esprit Marina<br>**2015** | Holiday Marina<br>**2015** | Neptune Marina<br>**2015** | Santa Monica Yacht Club<br>**2015** | Waves Tahiti A<br>**2015** | Waves Tahiti B<br>**2015** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **PLATYHELMINTHES** | | | | | | | | | | | |
| **Platyhelminthes** | | | | | | | | | | | |
| *Acerotisa californica* | N | | | | 2 | 1 | 1 | 3 | 1 | 2 | 2 |
| *Eurylepta aurantiaca* | N | | 2 | | 1 | 2 | 2 | | | 4 | 1 |
| *Hoploplana californica* | N | 2 | | | | | | | | | |
| *Notocomplana acticola* | N | | 1 | | | 1 | 2 | 1 | | 3 | 2 |
| Platyhelminthes | U | | | | 1 | 1 | | | | | 1 |
| *Pseudoceros* sp. | N | | | | 1 | | | | | | |
| **PORIFERA** | | | | | | | | | | | |
| **Porifera** | | | | | | | | | | | |
| Porifera sp. A | U | 3 | 3 | 4 | 1 | 3 | 5 | 2 | 3 | 1 | 3 |
| Porifera sp. B | U | | | | | | 1 | | | | |
| Porifera sp. C | U | | | | | | | 1 | 1 | | |
| Sycon sp. | U | | | | | | | | 1 | | |
| **UROCHORDATA** | | | | | | | | | | | |
| **Tunicata** | | | | | | | | | | | |
| *Aplidium* sp. | U | 1 | 2 | | 3 | | | 2 | 3 | 4 | 3 |
| *Aplidium* sp. A | U | | | | | | | | | 2 | |
| Aplousobranchia | U | 1 | 1 | | 1 | 1 | | 2 | 2 | | 1 |
| *Ascidia* sp. | U | | | | 1 | | | | | | |
| *Ascidia zara* | I | 1 | | | 1 | | | | | | |
| Ascidiidae | U | | | | | | | | | 1 | |
| Botryllinae | I | 4 | 1 | 1 | 5 | 4 | 1 | 2 | 4 | 2 | 2 |
| *Botrylloides diegensis* | I | | | | | 1 | | | | | 1 |
| *Botrylloides giganteum* | I | | | | | 2 | | | | 1 | |
| *Botrylloides* sp. | I | | 1 | 1 | 1 | | | | 2 | 1 | 2 |
| *Botrylloides violaceus* | I | 1 | | | 2 | 1 | | | 1 | 1 | |
| *Botryllus schlosseri* | I | 5 | 5 | 3 | 5 | 5 | 2 | 2 | 4 | 5 | 5 |
| *Ciona robusta* | I | 3 | 4 | 3 | 4 | 4 | 1 | 3 | 5 | 5 | 4 |
| *Ciona* sp. | U | 4 | 1 | 3 | 2 | 2 | 1 | 3 | 3 | 1 | 1 |
| *Diplosoma listerianum* | I | 3 | 4 | 4 | 5 | 5 | | 4 | 5 | 5 | 5 |
| *Diplosoma* sp. | U | 2 | | | 2 | | | | | | |
| *Distaplia occidentalis* | N | | | | | | | | | 1 | |
| *Distaplia* sp. | U | | | | | | | | | 1 | |

| MARINA DEL REY<br>Fouling Panel Species List | BAY SPECIES STATUS | Catalina Yacht Club 2015 | Del Rey Marina Basin D 2015 | Del Rey Marina Basin E 2015 | Dolphin Marina 2015 | Esprit Marina 2015 | Holiday Marina 2015 | Neptune Marina 2015 | Santa Monica Yacht Club 2015 | Waves Tahiti A 2015 | Waves Tahiti B 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Microcosmus* sp. | U | | | | | | | | | 1 | |
| *Molgula* sp. | U | | | | | | | | 1 | | |
| *Perophora* sp. | U | 2 | 1 | | | | | | 3 | | |
| *Polyandrocarpa zorritensis* | I | 4 | 5 | 4 | 2 | 1 | 5 | 1 | 5 | 1 | 1 |
| Stolidobranchia | U | 2 | | | 1 | | | | | 1 | |
| *Styela plicata* | I | 1 | 2 | | 1 | 4 | | 1 | | 4 | 3 |
| *Styela* sp. | U | | 2 | 2 | 2 | 2 | | 3 | 3 | 3 | 3 |
| Styelidae | U | | | 1 | 1 | | | | | 1 | 2 |
| Tunicata | U | 1 | | | 2 | | | | | | |

## ***Port Hueneme***

| PORT HUENEME<br>Fouling Panel Species List | BAY SPECIES STATUS | Naval Base Alpa Dock 2015 | Naval Base Fiberglass Dock 2015 | Naval Base Floating Dock 2015 | Naval Base Sealion Dock 2015 | Port Hueneme Site 1 2015 | Port Hueneme Site 2 2015 | Port Hueneme Site 3 2015 | Port Hueneme Site 4 2015 |
|---|---|---|---|---|---|---|---|---|---|
| **ANNELIDA** | | | | | | | | | |
| **Chrysopetalidae** | | | | | | | | | |
| Chrysopetalidae | U | | | 1 | | | | | 1 |
| *Paleanotus bellis* | N | 5 | 4 | 5 | 2 | 3 | 2 | 3 | 5 |
| **Cirratulidae** | | | | | | | | | |
| Cirratulidae | U | | | | | 1 | | | |
| **Nereididae** | | | | | | | | | |
| *Platynereis bicanaliculata* | N | 1 | | 3 | 1 | 3 | 1 | 2 | 1 |
| **Opheliidae** | | | | | | | | | |
| *Polyophthalmus* sp. | N | | | | 1 | | | | |
| **Phyllodocidae** | | | | | | | | | |
| *Eulalia quadrioculata* | N | | | | | 1 | | 1 | |
| Phyllodocidae | U | | | | | 1 | | | |
| *Pterocirrus burtoni* | N | | 1 | | | | | | |

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|---|---|---|---|---|---|---|---|---|---|
| **Polynoidae** | | | | | | | | | |
| *Halosydna brevisetosa* | N | | 1 | 1 | | | | | 1 |
| *Halosydna johnsoni* | N | | | 1 | | | | | |
| **Sabellariidae** | | | | | | | | | |
| *Neosabellaria cementarium* | N | | 1 | | | | | | |
| **Sabellidae** | | | | | | | | | |
| *Paradialychone ecaudata* | N | 2 | 2 | 1 | 3 | 2 | 3 | 3 | 1 |
| *Parasabella* sp. | N | | | | | | | 1 | |
| **Serpulidae** | | | | | | | | | |
| *Hydroides gracilis* | N | 6 | | 6 | 5 | 5 | 5 | 6 | 6 |
| *Hydroides* sp. | U | | 2 | | | | | | |
| *Pseudochitinopoma occidentalis* | N | 5 | | | 1 | | 5 | 6 | 6 |
| *Salmacina tribranchiata* | N | | | | | | 2 | | |
| **Spionidae** | | | | | | | | | |
| *Boccardiella* sp. | U | | | | 1 | | | | |
| *Polydora narica* | N | 1 | | | | | | | |
| **Spirorbidae** | | | | | | | | | |
| *Neodexiospira pseudocorrugata* | C | 4 | | 4 | 7 | | 6 | 6 | 5 |
| *Pileolaria berkeleyana* | N | 2 | | | 2 | | | | |
| *Pileolaria* sp. | N | | | 1 | | | | | |
| *Protolaeospira eximia* | N | 7 | 3 | 3 | 1 | 4 | 5 | 4 | 3 |
| *Simplaria pseudomilitaris* | N | 4 | 3 | 4 | 7 | 5 | 5 | 6 | 5 |
| Spirorbidae | U | | | | 2 | | | | |
| **Syllidae** | | | | | | | | | |
| *Amblyosyllis speciosa* D | I | | | | 1 | | | | |
| Eusyllinae | U | | 2 | | | 1 | 1 | 1 | 1 |
| *Eusyllis* sp. | U | 1 | | 1 | | 1 | | | 1 |
| *Eusyllis* sp. 1 | U | 1 | | | 2 | | | 1 | |
| *Exogone lourei* | C | | 1 | | 1 | | | | 1 |
| Exogoninae | U | 2 | | | | 1 | | | |
| *Megasyllis nipponica* | I | 2 | | 3 | 2 | | | | |
| *Myrianida* sp. | U | 1 | | | | | | | |
| *Odontosyllis parva* | N | | | | | 1 | | | |
| *Odontosyllis phosphorea* | N | | 1 | | | | | 1 | |

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|---|---|---|---|---|---|---|---|---|---|
| *Salvatoria californiensis* | N | | 1 | | | 1 | | | |
| Syllidae | U | | | | | | | 2 | |
| *Syllis gracilis* complex | C | | | | | | 1 | | 2 |
| *Typosyllis* sp. | U | | 1 | 1 | | | 1 | 1 | 1 |
| **Terebellidae** | | | | | | | | | |
| *Eupolymnia* sp. | N | | | 1 | | 2 | | | |
| *Nicolea* cf. *amnis* | U | | | | | | | | 1 |
| **ARTHROPODA** | | | | | | | | | |
| **Amphipoda** | | | | | | | | | |
| *Ampithoe lacertosa* | C | | | 1 | | | | | |
| *Ampithoe* sp. | U | | | | | 1 | | | |
| *Aoroides secunda* | I | 4 | 2 | 5 | 6 | 3 | 3 | 3 | 2 |
| *Coboldus hedgpethi* | N | | 1 | | | | | | |
| *Elasmopus bampo* | C | | | | | | 1 | | |
| *Elasmopus* sp. | U | | | | | | 2 | 1 | |
| *Ericthonius brasiliensis* | C | 2 | 5 | 4 | 2 | 5 | 3 | 5 | 6 |
| *Gammaropsis shoemakeri* | N | | | 5 | | | | | |
| *Gammaropsis* sp. | N | | | | | | | | 2 |
| *Grandidierella japonica* | I | | | | | | | | 1 |
| *Hourstonius vilordes* | N | | 1 | | | 1 | | 2 | |
| *Incisocalliope derzhavini* | I | | 1 | | | | | | |
| Ischyroceridae | U | | 1 | | | | | | |
| *Jassa* cf. *pusilla* | N | | | | 1 | | | | |
| *Jassa slatteryi* | C | 7 | 5 | 6 | 5 | 6 | 6 | 6 | 3 |
| *Jassa* sp. | U | | 1 | | 2 | 3 | 1 | | 4 |
| *Jassa* sp. 3 | C | | | | 1 | 1 | | | 1 |
| *Jassa staudei* | N | | | | | | 1 | | |
| *Laticorophium baconi* | N | 7 | 4 | 4 | 7 | 4 | 6 | 6 | 7 |
| *Metopa cistella* | N | 1 | | 2 | | 1 | 1 | 1 | |
| *Microjassa* sp. | N | | 1 | | | 1 | | | |
| *Monocorophium acherusicum* | I | 3 | 2 | | 2 | | 1 | 1 | |
| *Paradexamine* sp. | I | | | | 3 | | | | |
| *Paradexamine* sp. 1 | I | | 1 | | 1 | | 1 | | |
| *Peramphithoe tea* | N | | | | | | 1 | | |

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|---|---|---|---|---|---|---|---|---|---|
| *Photis brevipes* | N | | 4 | | | 2 | 1 | 1 | 2 |
| *Podocerus brasiliensis* | C | | 4 | | | 6 | | 1 | |
| *Podocerus cristatus* | C | | 4 | | | | | 1 | |
| *Podocerus* sp. | C | | | | | | | | 1 |
| *Protohyale frequens* | N | | | | | 1 | | | |
| *Stenothoe valida* | I | | 2 | 1 | | | 1 | | |
| **Caprellidae** | | | | | | | | | |
| *Caprella californica* | N | 7 | 5 | 6 | 3 | 5 | 5 | 5 | 7 |
| *Caprella equilibra* | C | | | 6 | 1 | | 1 | | |
| *Caprella mutica* | I | 3 | | 1 | 2 | 1 | | | 1 |
| *Caprella natalensis* | C | | | 1 | | | 1 | | |
| *Caprella penantis* | C | 1 | 2 | | 1 | 3 | 2 | 2 | 3 |
| *Caprella simia* | I | 6 | 3 | 5 | 6 | 5 | 6 | 6 | 7 |
| *Caprella* sp. | U | | | | 1 | | 1 | | |
| *Caprella verrucosa* | N | | | | | 1 | | | |
| *Deutella californica* | N | | | | | 2 | | | |
| **Cirripedia** | | | | | | | | | |
| Balanidae | U | 1 | 2 | | | | 2 | | |
| *Balanus crenatus* | N | | 1 | 1 | | | 1 | | |
| *Balanus glandula* | N | | 1 | 2 | | | | 1 | |
| *Balanus* sp. | U | | | | 1 | 1 | | 1 | |
| *Balanus trigonus* | N | 6 | 2 | 5 | 6 | 2 | 6 | 6 | 5 |
| *Megabalanus californicus* | N | 7 | 3 | 5 | 1 | 5 | 4 | 3 | 4 |
| *Megabalanus* sp. | N | | | | | | | 1 | |
| **Decapoda** | | | | | | | | | |
| Decapoda | U | | | | | | 1 | | |
| *Hemigrapsus oregonensis* | N | | | | 1 | | | | |
| *Hemigrapsus* sp. | U | | | | 2 | | | | |
| *Heptacarpus* sp. | N | | | | 1 | | | | |
| *Palinurus* sp. | N | | | 1 | | | | | |

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|---|---|---|---|---|---|---|---|---|---|
| **Isopoda** | | | | | | | | | |
| *Ianiropsis* sp. | U | 3 | 1 | 3 | | | 4 | 4 | 5 |
| *Paracerceis* sp. | N | 1 | | 1 | | 1 | | | |
| *Paranthura japonica* | I | 1 | | | | | | | |
| **Pycnogonida** | | | | | | | | | |
| *Achelia chelata* | N | | | | | | | | 1 |
| *Ammothella biunguiculata* | N | | | | | | | | 2 |
| *Anoplodactylus pacificus* | N | | 1 | | | | | | |
| **Tanaidae** | | | | | | | | | |
| *Leptochelia* sp. | C | | | | | | | | 1 |
| *Zeuxo* sp. | U | 6 | 2 | 5 | 7 | 3 | 5 | 5 | 5 |
| **BRYOZOA** | | | | | | | | | |
| **Bryozoa** | | | | | | | | | |
| *Aetea pseudoanguina* | N | | | | | 1 | | | |
| *Amathia* sp. *bowerbankia* | U | 6 | 2 | 5 | | 6 | 2 | 6 | 7 |
| *Bugula neritina* | I | 6 | 5 | 4 | 6 | 4 | 6 | 5 | 7 |
| *Bugulina longirostrata* | N | | 2 | 1 | 1 | | | 1 | 6 |
| *Bugulina stolonifera* | I | | | 4 | 1 | 3 | 1 | 1 | 1 |
| *Celleporaria brunnea* | N | 7 | 5 | 6 | 7 | 6 | 6 | 6 | 7 |
| *Celleporella hyalina* | C | | | | | 4 | | 4 | 4 |
| *Crisia occidentalis* | N | 7 | 2 | 3 | 7 | 5 | 4 | 6 | 4 |
| *Crisia* sp. | U | | 1 | 1 | | | | | 1 |
| Crisiidae | U | 2 | | | 1 | 1 | 3 | 1 | 3 |
| *Crisulipora occidentalis* | N | 5 | | 3 | 4 | | 3 | 4 | 4 |
| *Cryptosula pallasiana* | I | 7 | 2 | 3 | 2 | 4 | 4 | | 6 |
| *Fenestrulina delicia* | C | | | | | | | 1 | |
| *Fenestruloides eopacifica* | N | 6 | 2 | 3 | 4 | 2 | 2 | | 2 |
| *Filicrisia franciscana* | N | 3 | 2 | | 3 | 5 | | 2 | 5 |
| *Filicrisia* sp. | U | | | | | 1 | | | |
| *Licornia diegensis* | N | 5 | 2 | | | 3 | | | 4 |
| *Membranipora villosa* | N | | | | | 1 | | | |
| *Schizoporella japonica* | I | 6 | | 2 | 3 | 3 | 5 | 5 | 2 |
| *Scruparia ambigua* | C | 2 | 1 | 2 | | 4 | | 2 | 4 |
| *Tegella circumclathrata* | N | 3 | 3 | | 2 | | | | |

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|---|---|---|---|---|---|---|---|---|---|
| *Thalamoporella californica* | N | | 1 | | | 1 | | | |
| *Tubulipora aliciae* | N | | | | | | | 1 | |
| *Tubulipora pacifica* | N | 7 | 2 | 5 | 7 | 4 | 6 | 6 | 4 |
| *Tubulipora* sp. | U | 3 | 1 | 2 | 2 | 2 | 1 | | 2 |
| *Tubulipora* sp. 2 | U | | 1 | | | | | | |
| Tubuliporidae | U | | | | | 1 | | | |
| *Watersipora arcuata* | I | 1 | | 1 | 1 | | | | |
| *Watersipora* sp. | I | | | | | 1 | | | |
| *Watersipora subtorquata* complex | I | 7 | 5 | 6 | 7 | 5 | 6 | 6 | 7 |
| **CNIDARIA** | | | | | | | | | |
| **Anthozoa** | | | | | | | | | |
| Actiniaria | U | | | 1 | 1 | | 1 | | |
| **Hydrozoa** | | | | | | | | | |
| Hydrozoa | U | | | | | | | | 1 |
| Hydrozoa sp. A | U | | 2 | | | 1 | 1 | 1 | 2 |
| Hydrozoa sp. D | U | | 1 | | | | | | 4 |
| Plumularioidea | U | | 3 | 5 | | 5 | | | |
| Tubulariidae | U | 4 | 2 | 4 | 1 | | | | |
| **ECHINODERMATA** | | | | | | | | | |
| **Echinodermata** | | | | | | | | | |
| *Amphipholis squamata* | C | | | | | | | 1 | |
| Amphiuridae | U | 1 | | | | | | 1 | |
| Ophiuroidea | U | | 1 | | | | | | |
| *Strongylocentrotus purpuratus* | N | 1 | 1 | 1 | 1 | 1 | 1 | | |
| **ENTOPROCTA** | | | | | | | | | |
| **Kamptozoa** | | | | | | | | | |
| Kamptozoa | U | | 3 | | | 3 | | | |
| **MOLLUSCA** | | | | | | | | | |
| **Bivalvia** | | | | | | | | | |
| Anomiidae | N | | | | | | 2 | | |
| Bivalvia | U | | 2 | | 2 | 1 | 1 | | |
| *Crassadoma gigantea* | N | | | | | | | 1 | |
| *Hiatella arctica* | C | 5 | 4 | 4 | 4 | 4 | 5 | 4 | 1 |
| *Hiatella* sp. | C | | | | 1 | | | | |
| *Leptopecten latiauratus* | N | | | 3 | | | | | 1 |

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|---|---|---|---|---|---|---|---|---|---|
| *Mytilus galloprovincialis/trossulus* complex | U | 4 | 2 | 5 | 2 | 5 | 2 | 3 | 4 |
| *Mytilus* sp. | U | 4 | | 2 | 3 | 1 | 1 | 2 | 3 |
| Pectinidae | U | 1 | | 1 | 4 | | 1 | | |
| *Pododesmus* sp. | N | | 2 | | 6 | | 3 | 1 | |
| **Gastropoda** | | | | | | | | | |
| *Barleeia californica* | N | | | | 1 | | | | |
| *Barleeia* sp. | N | | 2 | | | | | | |
| Caenogastropoda | U | 1 | | | | | | | |
| Calyptraeidae | U | | | | 1 | | | | 1 |
| *Crepidula convexa* | I | 5 | | 6 | 4 | 1 | 4 | 4 | 5 |
| *Crepidula* sp. | U | 1 | | 1 | | | 1 | 1 | |
| *Lacuna* sp. | N | | | | | | 1 | | |
| *Lacuna unifasciata* | N | 1 | | 1 | | | | 1 | |
| *Lottia* sp. | N | | | | | | | 1 | |
| *Odostomia astricta* | N | | 1 | | | | | | |
| *Odostomia* sp. | U | | | | | | | 1 | |
| *Serpulorbis* sp. | N | | | | | | | 1 | |
| **Nudibranchia** | | | | | | | | | |
| *Aegires albopunctatus* | N | | | | 1 | | | | |
| Aeolidiidae | U | | | | 1 | | | | |
| *Corambe steinbergae* | N | | 1 | | | | | | |
| *Cuthona* sp. | U | | | | | | | | 1 |
| *Dendronotus venustus* | N | | | | | 1 | | | 1 |
| *Dirona picta* | N | | | | 1 | | | | |
| *Doto amyra* | N | | | | | 1 | | | |
| *Doto* form A of Goddard | N | | 3 | | | 3 | | | 1 |
| *Doto kya* | N | | 1 | | | 2 | | | |
| *Eubranchus rupium* | N | | 1 | | | | | | |
| *Eubranchus rustyus* | N | | 1 | | | | | | |
| *Eubranchus* sp. | U | | 1 | | | | | | |
| *Hermissenda* sp. | N | | | 2 | | 1 | | | |
| *Okenia angelensis* | N | 3 | | 3 | | 6 | | 5 | 3 |

| **PORT HUENEME**<br>**Fouling Panel Species List** | **BAY SPECIES STATUS** | Naval Base Alpa Dock **2015** | Naval Base Fiberglass Dock **2015** | Naval Base Floating Dock **2015** | Naval Base Sealion Dock **2015** | Port Hueneme Site 1 **2015** | Port Hueneme Site 2 **2015** | Port Hueneme Site 3 **2015** | Port Hueneme Site 4 **2015** |
|---|---|---|---|---|---|---|---|---|---|
| *Polycera atra* | N | 2 | | 1 | | 3 | 2 | 4 | 5 |
| *Polycera hedgpethi* | N | 2 | | | | 1 | | | 1 |
| **NEMERTEA** | | | | | | | | | |
| **Nemertea** | | | | | | | | | |
| *Lineus torquatus* | N | | | | 1 | | | | |
| Nemertea | U | 1 | | | | 1 | | | 1 |
| **PLATYHELMINTHES** | | | | | | | | | |
| **Platyhelminthes** | | | | | | | | | |
| *Acerotisa californica* | N | 2 | 1 | 3 | 1 | | 1 | | 4 |
| *Hoploplana californica* | N | 1 | 2 | 1 | | | 1 | | |
| *Notocomplana acticola* | N | | 1 | | | | | 1 | |
| Platyhelminthes | U | | 1 | 1 | 1 | | | 1 | 1 |
| *Polycystididae* sp. HYP1 | N | | | | | | | 1 | |
| *Pseudoceros mexicanus* | N | | | 1 | | | | | |
| *Pseudoceros* sp. | N | | | | | | | | 1 |
| **PORIFERA** | | | | | | | | | |
| **Porifera** | | | | | | | | | |
| Porifera | U | | | | | | | 1 | 1 |
| Porifera sp. A | U | 2 | 2 | 3 | 7 | 1 | 4 | 5 | |
| Porifera sp. B | U | 5 | 4 | 5 | 7 | 4 | 7 | 4 | 5 |
| Porifera sp. C | U | 1 | 1 | 1 | 3 | 2 | 2 | 5 | |
| *Sycon* sp. | U | 1 | 1 | 3 | 1 | 1 | 2 | 2 | 1 |
| **UROCHORDATA** | | | | | | | | | |
| **Tunicata** | | | | | | | | | |
| *Aplidium* sp. | U | | | | | | | | 1 |
| Aplousobranchia | U | | | | | 1 | 1 | | 2 |
| *Ascidia ceratodes* | N | | | | 1 | | | | |
| *Ascidia* sp. | U | | 1 | 3 | 2 | | 2 | | 3 |
| Botryllinae | I | | 1 | 3 | 1 | 1 | 3 | | 1 |
| *Botrylloides diegensis* | I | | | | | | | | 1 |
| *Botrylloides violaceus* | I | | | 2 | | | | | 5 |
| *Botryllus schlosseri* | I | | | | | | 1 | | 4 |
| *Ciona savignyi* | I | | | | 1 | | | | |
| *Ciona* sp. | U | 1 | 1 | 4 | 5 | 1 | 2 | | 5 |

| **PORT HUENEME**<br>**Fouling Panel Species List** | **BAY SPECIES STATUS** | Naval Base Alpa Dock **2015** | Naval Base Fiberglass Dock **2015** | Naval Base Floating Dock **2015** | Naval Base Sealion Dock **2015** | Port Hueneme Site 1 **2015** | Port Hueneme Site 2 **2015** | Port Hueneme Site 3 **2015** | Port Hueneme Site 4 **2015** |
|---|---|---|---|---|---|---|---|---|---|
| Didemnidae | U | | | | | | 1 | | 5 |
| *Didemnum* cf. *vexillum* | I | | | | | | 1 | | |
| *Diplosoma listerianum* | I | | 1 | 1 | 1 | | | | 5 |
| Phlebobranchia | U | 1 | | | | | 1 | 1 | |
| Stolidobranchia | U | 2 | | | | 2 | | | |
| *Styela* sp. | U | 1 | 1 | 1 | 4 | 1 | 4 | 2 | 4 |
| Tunicata | U | | 1 | | 1 | 1 | | | 1 |

***San Franscisco Bay***

| **SAN FRANCISCO BAY Fouling Panel Species List** | **BAY SPECIES STATUS** | Ballena Isle Marina | | | Coyote Point Marina | | | Loch Lomond Marina | | | Oakland Yacht Club | | | Oyster Point Marina | | | Redwood City Marina | | | Richmond Marina Bay Yacht Harbor | | | San Francisco Marina | | | San Leandro Marina | | | Sausalito Marine Harbor | | |
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| | | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** |
| **ANNELIDA** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Arenicolidae** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Branchiomaldane* sp. | N | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | |
| **Capitellidae** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Capitella capitata* complex | C | | 2 | 1 | 1 | 3 | 1 | | 1 | 2 | | | 1 | | 4 | 3 | | | 1 | | 1 | 1 | | 1 | | | 1 | | | 2 | 2 |
| Capitellidae | U | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | | | | 1 |
| **Chrysopetalidae** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Paleanotus bellis* | N | | | | | | | | | | | | | | | | | | | | | | 2 | | | | | | | | |
| **Cirratulidae** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Cirratulidae | U | | 3 | | | 1 | | | | | | 1 | | | 3 | | 1 | | 1 | | 1 | | | 1 | | | 1 | | | | |
| *Cirratulus dillonensis* | N | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | |
| *Cirratulus multioculatus* | N | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | |
| *Cirriformia* sp. | N | | | | | | | | | 1 | | 2 | 2 | | | 2 | 2 | | 1 | 1 | | | | | 2 | 2 | | 1 | | | |
| *Cirriformia* sp. A SERC | U | | | | 2 | | 4 | | | 8 | | | 2 | | 2 | | 1 | | 3 | | | 1 | | | | | 1 | 3 | | | 1 |
| *Cirriformia spirabrancha* | N | 1 | 3 | 1 | 1 | 2 | 1 | | 4 | | 1 | | 1 | 4 | 1 | 2 | 5 | 2 | | 1 | 1 | | | | | 4 | 5 | 1 | | | |
| *Ctenodrilus serratus* | C | | 1 | 1 | | | 2 | | | 1 | | | 1 | | | | | | | | 2 | | | | | | 2 | | | | 1 |
| *Protocirrineris* sp. | U | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

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| | | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 |
| **Dorvilleidae** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Dorvilleidae | U | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | |
| *Ophryotrocha* sp. | U | 1 | 3 | 2 | | 1 | 2 | 1 | | 2 | 1 | 1 | 4 | 1 | 1 | 1 | 7 | 2 | 6 | 1 | | | | | | | | | | | |
| *Schistomeringos annulata* | N | | 2 | | | | | | 1 | | | | | 1 | | | | | | 1 | | | | | | 1 | | | | | |
| *Schistomeringos longicornis* | N | | 2 | 1 | | | | | | | | | 1 | | 1 | | | | | | | 1 | | | | | | | | | |
| *Schistomeringos* sp. | N | | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | |
| **Lumbrineridae** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Lumbrineris* sp. | N | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | 1 |
| **Nereididae** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Alitta succinea* | I | | | | | | | | | | | | | 1 | 1 | | 1 | | | | | | | | | | | | | | |
| *Neanthes acuminata* complex | C | | | | | | | | | | 6 | 5 | 6 | | | 3 | 2 | 9 | 8 | | | | | | | | | 1 | | | |
| Nereididae | U | | | | | | | | | | | 1 | | | | | | 1 | | | | | | | | | | | | | |
| *Nereis latescens* | N | | | | | | | | | | | | | | 1 | | | | | | | 1 | 4 | 3 | | | | | 1 | 1 | |
| *Platynereis bicanaliculata* | N | | | | | | | | | | | | | | 2 | | | | | 1 | 4 | | 5 | 5 | | | | | 8 | 4 | 3 |
| **Oligochaeta** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Oligochaeta | U | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | 1 | | | |
| **Orbiniidae** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Naineris dendritica* | N | | | | | | | | | | | | | | | | | | | 1 | | | | | | | | | | 1 | |
| Orbiniidae | U | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | |
| **Phyllodocidae** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Eumida longicornuta* | N | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | |
| *Eumida* sp. | U | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | | |

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| | | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 |
| **Polynoidae** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Halosydna brevisetosa* | N | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | | 3 |
| *Halosydna johnsoni* | N | | | | | | | | | | | | | 1 | | | | | | | | | 1 | | | | | | 1 | | |
| *Halosydna* sp. | N | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | |
| *Harmothoe imbricata* | C | 6 | | 4 | 4 | 2 | 3 | 1 | 3 | | 5 | 7 | 9 | 10 | 6 | 6 | | | 3 | 2 | | 4 | 2 | 1 | 4 | 2 | 1 | 1 | 2 | 1 | 7 |
| Polynoidae | U | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | |
| **Sabellidae** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Branchiomma* sp. | U | | 4 | 6 | | | 1 | | | | | 8 | 10 | | | 3 | | | | | | | | | | | | | | | 1 |
| *Branchiomma* sp. 2 | U | | | | | | | | | | 2 | | | | | | | | | | | | | | | | | | | | |
| *Parasabella* sp. | N | | 2 | 5 | | 2 | 3 | | | | 1 | 2 | 5 | | | 1 | | 6 | 2 | | 5 | | | | | | 6 | | 3 | | 1 |
| Sabellidae | U | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | |
| **Serpulidae** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Ficopomatus enigmaticus* | I | | | | | | | | 6 | 5 | | 4 | | | | | 10 | 8 | 3 | | | | | | | | 4 | 2 | | | |
| *Hydroides elegans* | I | | 1 | | | | | | | | | 4 | | | | | | | | | 1 | | | | | | | | | | |
| *Hydroides gracilis* | N | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | 1 | |
| *Hydroides* sp. | U | | | | | | | | | | | 1 | | | | | | | | 1 | | | | | | | | | | | |
| *Pseudochitinopoma occidentalis* | N | | | | | | | | | | | | | | | | | 2 | | | | | | | 1 | | | | | | |
| *Salmacina tribranchiata* | N | | 1 | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | | |
| *Serpula* sp. | N | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | | |
| Serpulidae | U | | | | | | | 1 | | | | 1 | | | | | | | | | | | | | | | | | | | 1 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 |
| **Spionidae** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Dipolydora socialis* | C | 1 | | | | | | | | | | | | | | | | | | | | | 4 | 2 | 1 | | | | 5 | 4 | 2 |
| *Polydora cornuta* | I | | 1 | 1 | 1 | 2 | 1 | 2 | 1 | 3 | | 1 | 2 | 2 | 4 | 1 | 6 | 2 | 3 | | | | 2 | 2 | | 1 | | | 3 | | 5 |
| *Polydora narica* | N | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | 1 | 1 | |
| *Polydora nuchalis* | N | | | | | | | | | 1 | | | | | | | | 1 | | | | | | | | | | | | | |
| *Polydora* sp. | U | | | | | | | | | | | | | | | | 1 | 1 | | | | | 1 | | | | | | | 1 | |
| *Pseudopolydora paucibranchiata* | I | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | |
| **Spirorbidae** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Neodexiospira alveolata* | C | | 2 | 8 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Neodexiospira pseudocorrugata* | C | | 6 | 3 | | | 1 | | 2 | | 1 | 2 | 5 | | | 1 | | | | 1 | | | | | 2 | | | 1 | | | 1 |
| Spirorbidae | U | | | | | 1 | | | | | | 2 | | | | | | | | | | | | | | | 3 | | | | |
| **Syllidae** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Amblyosyllis speciosa* D | I | 2 | | | | 1 | | | | | | 3 | 1 | | | | | 4 | | | | 2 | | | | | 1 | | | | |
| Autolytinae | U | | | | | | | | | | | | 1 | | | | 1 | | | | | | 1 | | | | | | 3 | 3 | 2 |
| *Erinaceusyllis* sp. | N | | 2 | | 1 | | 2 | 1 | | 1 | | 1 | 1 | | | | 1 | 1 | 2 | | | | | | | 1 | 3 | | 1 | 1 | |
| *Exogone lourei* | C | 2 | 3 | 3 | 4 | 2 | 4 | | | | | | 1 | 2 | 2 | 1 | 1 | 2 | | | 1 | | 1 | | 1 | 3 | 1 | 4 | 5 | 5 | 9 |
| *Exogone* sp. | N | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | |
| Exogoninae | U | | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| *Megasyllis nipponica* | I | 7 | 8 | 9 | 7 | 6 | 6 | 9 | 9 | 1 | 7 | 8 | 8 | 10 | 10 | 9 | 2 | 2 | 6 | 9 | 10 | 5 | 6 | 8 | 8 | 3 | 2 | 4 | 1 | 5 | 7 |
| *Myrianida pachycera* | I | | 2 | | | 1 | 1 | | | | | | | | 1 | | | 3 | 3 | | | | | | | | | | | | |
| *Myrianida pentadentata* | I | | | 1 | | | | | 1 | | | | 2 | | | 2 | | 1 | | | | | 1 | | | | | | 3 | 8 | 5 |
| *Myrianida* sp. | U | | 1 | | | | | | | 1 | 1 | | | | | | 3 | | | 1 | | | | | | | | | 6 | | |

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| | | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** |
| *Salvatoria californiensis* | N | | | 1 | | | 1 | | | | | | 6 | | | 1 | | | | | | | | | | | | | | | |
| *Salvatoria heterocirra* | N | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Salvatoria* sp. | N | | | | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | |
| Syllinae | U | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Typosyllis* sp. | U | | | | | | 1 | 6 | 3 | 4 | 1 | | | | 3 | 1 | 1 | 4 | 1 | | 1 | | | | | | 1 | | 1 | | |
| **Terebellidae** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Neoamphitrite* sp. A | I | 1 | 1 | | | 4 | 1 | | 2 | | 2 | 3 | 1 | 4 | 2 | | 7 | 2 | 3 | 1 | 1 | 2 | | | | 1 | | | | | |
| *Nicolea* cf. *amnis* | U | 9 | 9 | 9 | 3 | 2 | | | | 1 | 9 | 8 | 10 | 1 | 1 | 1 | | | | 10 | 10 | 6 | 3 | 7 | 1 | | 1 | | 2 | 6 | 4 |
| Terebellidae | U | | | | | | | | | | | 1 | | | 1 | | | | | | | | | | 1 | | | | | | |
| **ARTHROPODA** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Amphipoda** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Amphipoda | U | | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | |
| *Ampithoe lacertosa* | C | 7 | 6 | 8 | 2 | 3 | 1 | 1 | 3 | | 4 | 3 | | 4 | 5 | 6 | 10 | 7 | 3 | 9 | 3 | 10 | | 1 | 3 | | 5 | 1 | | | 1 |
| *Ampithoe* sp. | U | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | | | |
| *Aoroides secunda* | I | 5 | 8 | 8 | 7 | 5 | 2 | 10 | 8 | 1 | 3 | 4 | 2 | 2 | 7 | 3 | 2 | 10 | 9 | 9 | 7 | 9 | 7 | 7 | 5 | | 5 | | 9 | 6 | 7 |
| *Aoroides* sp. | U | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | |
| Corophiidae | U | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | |
| *Ericthonius brasiliensis* | C | | | | | | | | | | | | | | | | | | | | | | 2 | 4 | | | | | 1 | | |
| Eusiridae | U | | | | | | | | | 4 | | | | | | | | | | | | | | | | | | | | | 1 |
| *Grandidierella japonica* | I | 1 | | | 1 | | 1 | 1 | | 2 | | 2 | | | | | 8 | | | | 1 | | 1 | 1 | 1 | | | 2 | 3 | | 1 |
| Hyalidae | U | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |

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| | | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 |
| Isaeidae | U | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | |
| *Jassa slatteryi* | C | | | | | | | | | | | | | | | | | | | | 2 | | 2 | | | | | | | 3 | 1 |
| *Jassa* sp. | U | | | | | | | | | | | | | | | | | | | | | | | | 2 | | | | 1 | 2 | |
| *Jassa* sp. 1 | U | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| *Laticorophium baconi* | N | 1 | 1 | | | | | | | | 7 | 4 | 2 | | | 1 | 9 | 3 | 1 | 4 | 4 | 7 | 6 | 4 | 1 | | 1 | | 9 | 9 | 3 |
| *Leucothoe alata* | C | 9 | 7 | 10 | 9 | 9 | 6 | 8 | 10 | 1 | 9 | 9 | 9 | 9 | 8 | 8 | 6 | 9 | 8 | 8 | 8 | 5 | 1 | 1 | 2 | 7 | 6 | 7 | | 2 | 2 |
| *Liljeborgia geminata* complex | C | | 3 | 1 | | 5 | 1 | | | | 5 | 4 | 3 | | | | | | | | | | | | | | | | | | |
| Lysianassoidea | U | 7 | 8 | 1 | | | | | | | 5 | 2 | 3 | | | 2 | | | 7 | | | 1 | | | | | | | 1 | | |
| *Melita oregonensis* | N | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | | 1 | 2 | |
| *Melita rylovae* | I | | 1 | | | | | | 1 | | | | | | | | 2 | | | 6 | | 8 | | | | 1 | | | 2 | | 2 |
| Melitidae | U | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | |
| *Metopa cistella* | N | | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | |
| *Monocorophium acherusicum* | I | 1 | | | | | 2 | 1 | | 3 | | | | 1 | | | | | | | 2 | 4 | | | 1 | | | | | | |
| *Monocorophium insidiosum* | I | | | | | | | 3 | | | | | | | 1 | | 1 | | | | 1 | | | | | 1 | | | | 2 | |
| *Monocorophium* sp. | U | | | | | | | | | | | | | | | | 2 | | | | | | | | | | | 1 | | | |
| *Paradexamine* sp. | I | 2 | | 2 | | | 2 | | | | 3 | | | | | 2 | | | 7 | | | | 3 | | 2 | 1 | | 2 | 4 | | 2 |
| *Paradexamine* sp. 1 | I | 1 | 5 | | | 4 | | 4 | 1 | | 4 | 4 | | 2 | 1 | | | 5 | | | | | | 1 | | 3 | 3 | | 4 | 1 | |
| *Photis brevipes* | N | | | | | | | | | | | | | | | | | | | | | | 2 | | | | | | | | |
| *Photis* sp. | N | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| *Polycheria osborni* | N | | | | | | | | | | | | | | | | | | | | | | 3 | 1 | | | | | | | |
| *Stenothoe valida* | I | | | | | | | | | | | 1 | | | | | | | | | | | | | 1 | | | | | | |

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| | | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 |
| **Caprellidae** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Caprella californica* | N | | | | | | 1 | 1 | | | | | | | 1 | | | | | | | | 5 | 8 | | | | | 7 | 9 | 3 |
| *Caprella* cf. *ferrea* | N | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | | | | |
| *Caprella equilibra* | C | | | | | | | | | | | | | | | | | | | | | | 3 | 3 | | | | | | | |
| *Caprella mutica* | I | 5 | 3 | 9 | | | 3 | 3 | 1 | 1 | 4 | 5 | | 1 | | 7 | 6 | 1 | 3 | 10 | 10 | 10 | 5 | 6 | 6 | | | 2 | 9 | 10 | 9 |
| *Caprella penantis* | C | | | | | | | | | | | | | | | | | | | | | | 4 | 1 | | | | | 1 | | |
| *Caprella scaura* | I | | 2 | | | 3 | 3 | | 3 | | 4 | 4 | | 3 | 5 | 7 | | 2 | | 1 | 3 | | | | | | 1 | | | 1 | 2 |
| *Caprella simia* | I | 7 | 9 | 6 | 7 | 8 | 6 | 1 | 3 | 2 | 10 | 10 | 6 | 7 | 9 | 9 | 10 | 7 | 8 | 5 | 9 | 1 | 10 | 7 | 9 | 4 | 4 | 2 | 10 | 10 | 10 |
| *Caprella* sp. | U | | | | | | 1 | | | | | | | | | 1 | | 1 | | 1 | | | | | | | | | | | |
| *Caprella* sp. 11 | U | | | | | | | | | | | | | | | | | | | | 2 | | | | | | | | | | |
| *Metacaprella anomala* | N | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | | |
| **Cirripedia** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Amphibalanus amphitrite* | I | 2 | | | | | | | | | 7 | | | | | | 10 | 4 | 6 | | | | | | | | | | | | |
| *Amphibalanus improvisus* | I | 4 | | | | | | | | | 5 | 1 | 1 | 2 | | | 7 | | 1 | 6 | 2 | 3 | 3 | 4 | 2 | 2 | 2 | | | 3 | |
| *Amphibalanus* sp. | U | | | | | | | | | 1 | | | | | 1 | 1 | | 1 | | | | | | | | | | | | | 1 |
| Balanidae | U | | | | | | | | | | | | | | 1 | | | | | | | | | 1 | | | | | | | 1 |
| *Balanus crenatus* | N | | | | | | | | | | | | | | | | | 1 | | 2 | | | 10 | 2 | 1 | | | | 10 | 5 | |
| *Balanus trigonus* | N | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | | |
| Cirripedia | U | | | | | | | | | | | | | | | 2 | | | | | | | | | | | | | | | |

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| | | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 |
| **Decapoda** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Hemigrapsus oregonensis* | N | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | |
| *Pugettia producta* | N | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | |
| *Romaleon branneri* | N | | | | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | |
| **Isopoda** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Gnorimosphaeroma oregonensis* | N | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | |
| *Ianiropsis* sp. | U | 5 | 8 | 6 | 2 | 2 | 1 | | 3 | | 6 | 2 | 6 | 1 | 2 | 1 | | 7 | 5 | 10 | 10 | 8 | | 6 | 3 | | 1 | 1 | 5 | 8 | 9 |
| *Munna* sp. | U | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | |
| *Munna stephenseni* | N | 2 | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | 1 | | |
| Munnidae | U | | | | | | | | | | | | | | 2 | | | | | | | | | | | | | | | | |
| *Paracerceis sculpta* | N | | 1 | | | | | | | | | 7 | | | | | | | | | | | | | | | | | | | |
| *Paranthura japonica* | I | 8 | 10 | 9 | 9 | 9 | 7 | 10 | 8 | 10 | 8 | 9 | 9 | 8 | 6 | 10 | 10 | 10 | 10 | 10 | 7 | 3 | 1 | 1 | 2 | 7 | 8 | 5 | 7 | 9 | 8 |
| *Sphaeroma quoianum* | I | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | | | |
| *Uromunna* sp. | U | | | 4 | | 1 | 2 | | | | | | 1 | | | 3 | | | | | | | | | 1 | | 3 | 1 | 1 | 3 | 4 |
| *Uromunna* sp. A | I | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Pycnogonida** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Ammothea hilgendorfi* | N | | | | | | | | | | | | 1 | | | | | | | | | 1 | | | | | | | | | |
| *Ammothella biunguiculata* | N | | | | 1 | 1 | | | | | | | | | | | | | | | | | | | | 1 | 1 | | | 1 | |
| *Anoplodactylus erectus* | C | | | | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | |
| *Anoplodactylus* sp. | U | | | | | | | 1 | 2 | | | | | | | | | | | | | | | | | 1 | | | | | |
| Pycnogonida | U | | | | | 2 | | | | | | | | | | | | | | | | | | | | | | | | | |

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| | | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** |
| *Crisularia pacifica* | N | | | | | | | | | 3 | | | | | | 1 | | | | 1 | | | | | | | | | | | |
| *Crisulipora occidentalis* | N | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | |
| *Cryptosula pallasiana* | I | 3 | 7 | 4 | | | 2 | | 2 | | | | 1 | | 1 | | | 7 | 4 | 10 | 2 | 10 | 7 | 5 | 2 | 4 | 9 | 6 | 6 | 7 | 9 |
| Ctenostomatida | U | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 2 |
| Cyclostomatida | U | | | | | | | | | | | 2 | | | | | | | | | | | | | | | | | | | |
| *Electra* sp. | U | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| *Fenestrulina delicia* | C | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | 1 | 3 |
| *Fenestrulina* sp. | U | | | | | | | | | | | | | | | | | | | 2 | | | 1 | | | | | | | 1 | |
| *Licornia diegensis* | N | | | | | | | | | | | | | | | 4 | | | | | | | | | | | | | | | 7 |
| *Schizoporella errata* | I | | | | | | | | | | | | | | | | | | | | | | | | | | 2 | | | | |
| *Schizoporella japonica* | I | | | | | | | | | | | | | | | | | | | | | | 2 | 4 | 1 | 1 | 1 | | | | 1 |
| *Schizoporella* sp. | U | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | |
| *Smittoidea prolifica* | N | 5 | 1 | 1 | 2 | | 3 | | | 1 | | | | 2 | | 1 | | | | 1 | | | | | | 3 | 1 | | | 1 | |
| *Thalamoporella californica* | N | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | |
| *Tricellaria occidentalis* | N | | | | | | | | 1 | 1 | 3 | | 3 | | | | | 1 | 1 | 1 | | 9 | | | | | 1 | | 8 | 1 | 1 |
| *Victorella pavida* | I | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | |
| *Watersipora* sp. | I | 3 | 1 | | | 1 | | | | | | 3 | 2 | | | 1 | | | | | 1 | 1 | | 2 | | | 3 | | | | |
| *Watersipora subtorquata* complex | I | 2 | 7 | 10 | 2 | 4 | 4 | 1 | 1 | 8 | 2 | 1 | 6 | 2 | 2 | 6 | | 2 | 2 | 7 | 7 | 9 | 9 | 5 | 5 | 4 | 5 | 9 | 9 | 10 | 10 |

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| | | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** |
| **CNIDARIA** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Anthozoa** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Actiniaria | U | | | | | | | | | | | 2 | | | | | | | | | | | | | | | 1 | 2 | | 2 | 2 |
| Anthozoa | U | | | | | 1 | | | 1 | | | 1 | | | | | | | | | | | | | | | | | | 1 | |
| *Diadumene franciscana* | I | | | | | | | | | | | | | | | | | | | | 1 | | | | | | 1 | | | | |
| *Diadumene leucolena* | I | | | | | | | | | | | | | | | | | 3 | | | | | | | | | | | | | |
| *Diadumene lineata* | I | | | 1 | | 1 | | | 1 | 1 | | | | | | | | 2 | | | 3 | | | 1 | | | 4 | 1 | | 3 | |
| *Diadumene* sp. | U | 2 | | | | 5 | | | 3 | 1 | | 5 | 1 | | 1 | | 1 | 8 | | | 5 | | | | | | 5 | 8 | 1 | 5 | 3 |
| **Hydrozoa** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Athecata | U | | | 1 | | | 1 | | 3 | | | 1 | | | | 1 | 1 | | | | | | | 1 | | | 3 | 2 | | 1 | |
| *Bougainvillia* sp. | U | | | | 6 | | 1 | 6 | | | 2 | | | 1 | | | | | | | | | | | | | | | | | |
| Bougainvilliidae | U | | | | | | | | | | | | | | 1 | 1 | | 1 | | | | | | | | | 2 | | | | |
| *Cordylophora* sp. | U | | | | | | | 1 | | | | | | | | | | | | | | | | | | 2 | | | | | |
| *Ectopleura crocea* | U | | | | | | | | | | | | | 2 | 1 | 1 | | | | | | | 1 | | | | | | | | |
| *Garveia franciscana* | U | | | | 2 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Hydrozoa | U | | | | | | 2 | 1 | | 1 | | | 1 | | | | | | | | | | | | | 1 | | 1 | | | |
| Hydrozoa sp. A | U | | | | | | | | | | | | | | | 1 | | | | | 1 | | | | 1 | | 1 | | | | |
| Hydrozoa sp. B | U | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | |
| Hydrozoa sp. D | U | | | | | 2 | 2 | | | 1 | | | | | | | | | | | | | | | | | 2 | | | 1 | |
| Hydrozoa sp. E | U | | | | | | | | | | | | 1 | | | | | | 1 | | | | | | | | | 1 | | | |
| *Obelia* sp. | U | | | | | | 1 | 1 | | | | | | 1 | | 2 | | | | 1 | | | | | | 8 | | | | | |
| Thecata | U | | | 2 | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | |

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| | | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** |
| **ECHINODERMATA** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Echinodermata** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Amphipholis squamata* | C | | | | | | | | | | | 1 | 7 | | | 1 | | | | | | 1 | | | | | | 2 | | | |
| Ophiuroidea | U | | | | | | | | | | | 3 | | | | | | | | | | | | | | | | | | | |
| **ENTOPROCTA** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Kamptozoa** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Barentsia benedeni* | U | 1 | | | 2 | | 2 | | | | | | | 1 | | | 1 | | 1 | | | | | | | 7 | | 2 | | | |
| *Barentsia* sp. | U | | | | | | 1 | | | | | | | | | | | | | | | | | | | | 1 | | | | |
| Kamptozoa | U | | | | | | | | | | 2 | | | 1 | | | | 1 | | | | | | | | 1 | 3 | 5 | | | |
| **MOLLUSCA** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Bivalvia** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Anomiidae | U | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Bivalvia | U | | | 1 | | | | | | | | | 2 | | | | 1 | 2 | | | | | | | | | | | | | |
| Heterodonta | U | | | | | | | | | | | 1 | 3 | | | | | | | | | 1 | | | | | | | | 1 | |
| *Leptopecten latiauratus* | N | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | |
| *Modiolus* sp. | N | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | | |
| *Musculista senhousia* | I | 2 | 2 | | 4 | 4 | | 1 | | | 9 | 10 | 8 | 7 | 6 | 3 | 10 | 4 | 2 | 1 | 1 | | 1 | 1 | | | | 1 | | | |
| Mytilidae | U | | | | 1 | 1 | | | 2 | | | 2 | 1 | | 2 | | | 4 | | | 1 | | | 2 | | | | | | | |
| *Mytilus galloprovincialis/trossulus* complex | U | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | |
| *Mytilus* sp. | U | | | | | | | | | | | | | | | | | | | 1 | | | 4 | 1 | | | | | 7 | | |
| *Ostrea lurida* | N | 7 | | | 9 | 6 | | 8 | 3 | | 10 | 10 | 4 | 9 | 6 | 1 | 2 | 3 | | 6 | | | 7 | 6 | | 3 | | | 1 | 3 | |
| Ostreidae | U | | 4 | 3 | | 1 | 3 | | | 1 | | | 4 | | 4 | 3 | | 1 | 1 | 1 | | | | 3 | | | | | | 2 | 1 |
| *Pododesmus* cf. *macrochisma* | N | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | |
| Veneridae | U | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | | | |

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| **GASTROPODA** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Alia carinata* | N | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | |
| *Crepidula plana* | I | | | | | | | | | | 1 | | | 1 | | | | | | | | | 1 | | | | | | | | |
| *Crepidula* sp. | U | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | |
| Gastropoda | U | | 1 | | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | |
| *Haminoea japonica* | I | | 1 | | 1 | 1 | 2 | 1 | | | | | | | | | 2 | 3 | 1 | | | | | | | 2 | 3 | 3 | | | |
| *Iselica ovoidea* | N | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | |
| *Marseniopsis sharonae* | N | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | |
| *Odostomia* sp. | U | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Odostomia* sp. SF1 Phillips | N | | | | | | | 2 | | | | | | 1 | | | | | | | | | | | | | | | | | |
| *Urosalpinx cinerea* | I | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | | |
| **NUDIBRANCHIA** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Cuthona albocrusta* | N | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Cuthona perca* | I | | | | | | | | | | | | | | | | | 3 | | | | | | | | | | | | | |
| *Dirona picta* | N | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | |
| *Eubranchus* sp. | U | | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | |
| *Flabellina verrucosa* | N | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | |
| *Janolus barbarensis* | N | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | |
| *Polycera atra* | N | | | | | | | | | | | | | | | | | | | | | | | | | | | | 4 | | |
| *Polycera hedgpethi* | N | | | | | | | | | | 1 | 2 | | 1 | | | | | | 3 | | 1 | | | | | | | 1 | | |

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| **Opisthobranchia** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Aplysiopsis enteromorphae* | N | | | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | | |
| *Placida dendritica* | C | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **NEMATODA** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Nematoda** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Nematoda | U | | | | | | 2 | | | | | | | | | 4 | | 1 | | | | 1 | | | 1 | | 1 | 5 | | | |
| **Nemertea** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Nemertea** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Cephalothrix* sp. | U | | | | | 2 | 3 | | 4 | | | | | | 1 | 1 | | 2 | | | | | | 2 | | | 10 | 1 | | 1 | 3 |
| *Lineus ruber* | N | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | |
| Nemertea | U | | | | | | | | 1 | 2 | | | | | | | 1 | | | | | | | | | | | 1 | | | |
| Tubulanidae | U | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **PLATYHELMINTHES** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Platyhelminthes** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Acanthozoon lepidum* | N | | | | | | | | | | | | | | | | | | | | | | | | 3 | | | | | | 1 |
| *Acerotisa alba* | N | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | 4 |
| *Acerotisa californica* | N | | | | | | | | | | | | | | | | | | | | | | 2 | 5 | 1 | | | | | 6 | |
| *Cycloporus* sp. | N | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| *Eurylepta aurantiaca* | N | | | | | 3 | 1 | | 1 | | | 1 | 2 | | 1 | | 1 | 4 | | | | | | | | | | | | | |
| Leptoplanidae | U | | | | | | | | | | | | | | | | | | | | | 2 | 1 | | | | | | | | |
| *Notocomplana acticola* | N | | | | | | | | | | | 4 | | | | | | | | | | | | | | | | | | | |
| Platyhelminthes | U | | | | | 1 | | | | | | | | | | | | | | | 1 | 1 | | | | | | | | | 5 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** |
| Prosthiostomidae | U | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | |
| *Pseudoceros* sp. | N | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | 1 | |
| **PORIFERA** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Porifera** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Euplectella* sp. | U | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | |
| *Grantia* sp. | U | | | | | | | 1 | | | 1 | | | | | | | | | 1 | | | | | | 1 | | | | | |
| *Halichondria* sp. | U | 5 | | | 6 | 1 | | 8 | | 1 | 1 | | 1 | 3 | | 2 | 9 | | | 8 | | 1 | 3 | 1 | | 6 | | | 5 | | 2 |
| *Haliclona* sp. | U | 2 | | | 2 | | 2 | 5 | | | | | 1 | 2 | | 2 | 3 | | 1 | 2 | | 1 | | | | | | | 2 | | 1 |
| *Microciona prolifera* | U | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Porifera | U | 5 | 1 | | | | | 3 | | | 2 | | 3 | 4 | | | 3 | | 1 | 2 | | | 1 | | | | | | | | |
| Porifera sp. A | U | | 5 | 7 | | 11 | 6 | | 9 | 9 | | 9 | 7 | | 4 | 9 | | 12 | 9 | | | 9 | | 3 | | | 6 | 6 | | 5 | 5 |
| Porifera sp. B | U | | | | | 2 | 2 | | 1 | 3 | | 1 | 4 | | 2 | | | 5 | | | 1 | 2 | | | | | | | | | |
| Porifera sp. C | U | | | | | | | | | | | 10 | 2 | | 1 | 1 | | | 3 | | 4 | | | | 1 | | 1 | | | | |
| *Sycon* sp. | U | 7 | 1 | | | 2 | 2 | 9 | 1 | | 3 | 6 | 1 | 5 | 6 | 1 | | 7 | | 3 | | | | | | 1 | 5 | 1 | | 2 | |
| **UROCHORDATA** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Tunicata** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Aplidium* sp. | U | 1 | | | | | | | | | | | | | | 1 | | | | 1 | | | | | | | | | | | |
| *Aplidium* sp. A | U | | | | | | | 1 | | | | | | | | | | | | 1 | | | | | | | | | | | |
| Aplousobranchia | U | | | | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | |
| *Ascidia* sp. | U | | | | 1 | | | | | 1 | | | 1 | | | | | 1 | 1 | 2 | | 2 | | | | | | | 1 | 1 | |
| *Ascidia zara* | I | 10 | 9 | 10 | 7 | 9 | 9 | 7 | 10 | 5 | 10 | 9 | 6 | 9 | 10 | 10 | 10 | 8 | 9 | 6 | 4 | 8 | 1 | 4 | 2 | 7 | 10 | 5 | 5 | 3 | 4 |
| Ascidiacea | U | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** | **2014** | **2015** | **2016** |
| Botryllinae | I | 6 | 8 | 2 | 4 | 7 | | 3 | 7 | 4 | 7 | 8 | 7 | 7 | 8 | 3 | 2 | 9 | 6 | 7 | 8 | 1 | 5 | 9 | 3 | | 5 | 1 | 8 | 8 | 1 |
| *Botrylloides diegensis* | I | 3 | 7 | 9 | | 7 | 10 | | 5 | 1 | | 1 | 5 | | 8 | 10 | 1 | 6 | 6 | 3 | 4 | 9 | | 5 | 4 | 1 | 3 | 4 | 1 | 8 | 9 |
| *Botrylloides* sp. | I | 3 | 1 | 2 | 4 | 7 | 1 | 1 | 3 | 3 | 1 | 4 | 1 | 2 | 7 | 2 | 2 | 1 | 3 | 4 | 2 | 7 | 2 | 2 | 5 | 1 | 1 | 1 | 3 | 8 | 3 |
| *Botrylloides violaceus* | I | 10 | 3 | 5 | 7 | 3 | 4 | 8 | 4 | 1 | 4 | | | 5 | 3 | 3 | 1 | 1 | | 9 | 2 | 6 | 7 | 6 | 3 | | 3 | 1 | 7 | 5 | 9 |
| *Botryllus schlosseri* | I | 8 | 6 | 7 | 5 | 8 | 6 | 3 | 6 | 10 | 4 | 9 | | 10 | 9 | 9 | 1 | 4 | 4 | 9 | 5 | 10 | 5 | 6 | 2 | 2 | 3 | 2 | 4 | 7 | 10 |
| *Botryllus* sp. A | I | 4 | | | | | | | | | 2 | | | 2 | | | 1 | | | 1 | | | | | | 1 | | | | | |
| *Ciona robusta* | I | 3 | | 3 | 5 | 3 | | 4 | | | 8 | 9 | 3 | 7 | 6 | 4 | 9 | 5 | 3 | 10 | 4 | 7 | 3 | 5 | 2 | 3 | 1 | | 7 | | 2 |
| *Ciona savignyi* | I | 10 | 10 | 9 | 7 | 10 | 9 | 6 | 8 | 3 | 10 | 10 | 8 | 9 | 9 | 10 | 9 | 9 | 8 | 10 | 8 | 10 | 2 | 4 | 1 | 4 | 5 | 3 | 4 | 4 | 8 |
| *Ciona* sp. | I | 1 | 2 | 2 | 2 | 4 | 1 | 2 | | 1 | 1 | | 7 | 3 | 4 | 1 | | 5 | 5 | | 2 | 1 | | | 1 | 1 | 1 | 1 | 3 | 3 | |
| Didemnidae | U | 1 | | 4 | 2 | 5 | 8 | | 2 | 2 | | 1 | 4 | 4 | 3 | 9 | | 3 | 9 | | 5 | 10 | | 8 | 8 | | 7 | 3 | | 2 | 6 |
| *Didemnum vexillum* | I | 5 | | 1 | 7 | 3 | 3 | 1 | 1 | | | | | 1 | 1 | | 1 | | | 10 | | 1 | 9 | | | 3 | | 1 | 10 | 8 | 5 |
| *Diplosoma listerianum* | I | 9 | 10 | 10 | 7 | 4 | 10 | 3 | 6 | 1 | 8 | 10 | 10 | 3 | 6 | 10 | 7 | 9 | 1 | 10 | 10 | 9 | 8 | 8 | 7 | 2 | 7 | 3 | 8 | 10 | 10 |
| *Distaplia occidentalis* | N | 1 | | | | | 1 | | | | | | | | | | | | | | | | | | 7 | | | | 1 | 3 | 10 |
| *Distaplia* sp. | U | | | | | | 2 | | | | | | | | | | | | | 1 | | | | 3 | 1 | | | | 1 | | 1 |
| *Microcosmus* sp. | U | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | |
| *Microcosmus squamiger* | I | | | | | | | | | | | 3 | | | | | | | | | | | | | | | | | | | |
| *Molgula ficus* | I | | | | | | 1 | | | | | 2 | | | | 1 | | | | | | | | | | | | | | | |
| *Molgula manhattensis* | I | 6 | 1 | 3 | 8 | 6 | 7 | 8 | 10 | 7 | 2 | 1 | | 1 | 5 | 8 | 9 | 5 | 6 | 1 | 1 | 8 | 4 | 3 | 3 | 8 | 8 | 9 | | | 4 |
| *Molgula* sp. | U | 2 | 1 | | 1 | | 1 | | | 3 | 1 | 1 | | | 1 | | 1 | 1 | 3 | | | | | 1 | 1 | 1 | 1 | | | | 1 |
| *Perophora annectens* | N | 3 | 4 | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

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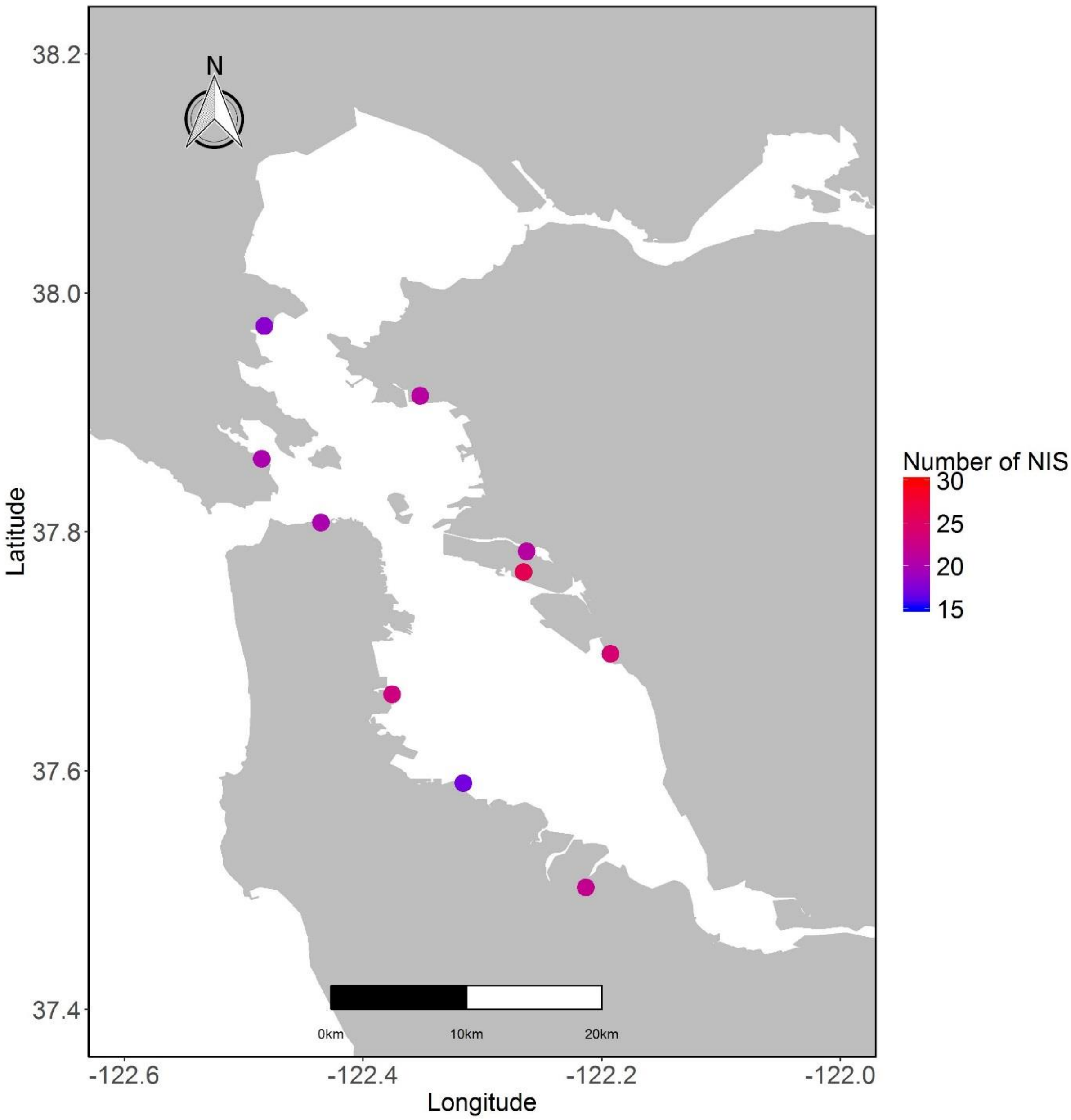
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 |
| *Perophora japonica* | I | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Perophora* sp. | U | 1 | 1 | 1 | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | |
| Phlebobranchia | U | | | | | | 1 | | | 1 | | | 1 | | | | | | | | | 2 | | | 1 | | | | | | |
| Stolidobranchia | U | | 2 | 2 | | | 3 | | | | | 1 | 6 | | 2 | 4 | | 1 | 4 | | 3 | 4 | | 1 | | | 1 | | | 1 | 1 |
| *Styela canopus* | I | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | | |
| *Styela* cf. *canopus* | I | | | | | | | | | | | 4 | | | | | | | | | | | | | | | | | | | |
| *Styela clava* | I | | 2 | | 3 | 3 | 4 | 5 | 2 | | | | | 3 | 1 | 1 | | 2 | 1 | 2 | 1 | 1 | | | | 3 | 5 | | 3 | 1 | |
| *Styela* sp. | U | 5 | | | 3 | 2 | 3 | 1 | 5 | | 4 | 2 | 1 | 4 | 4 | 5 | 4 | | 1 | 8 | | 1 | 5 | 1 | | | 3 | 2 | 3 | 2 | 2 |
| Styelidae | U | | 1 | | | 2 | | | 3 | | | 3 | | | 1 | | | 8 | 2 | | 3 | 3 | | 2 | | | 2 | | | 2 | |

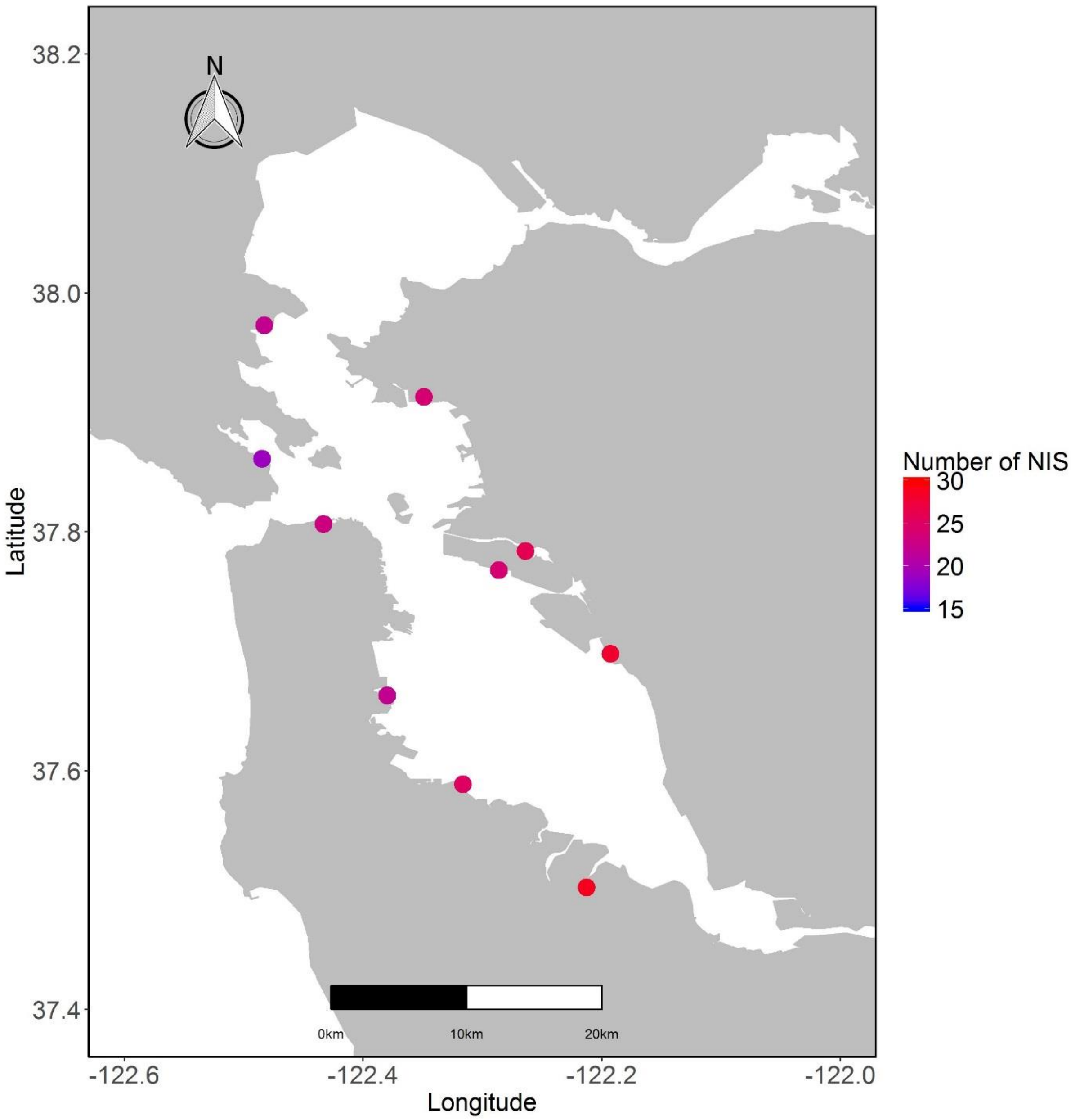
**Appendix 2.3: Non-Native Species Richness by Estuary and Year**

The heat maps below show non-native invertebrate species richness detected in hard substrate samples for each bay and year surveyed. Taxonomic identification is based on morphological characteristics.

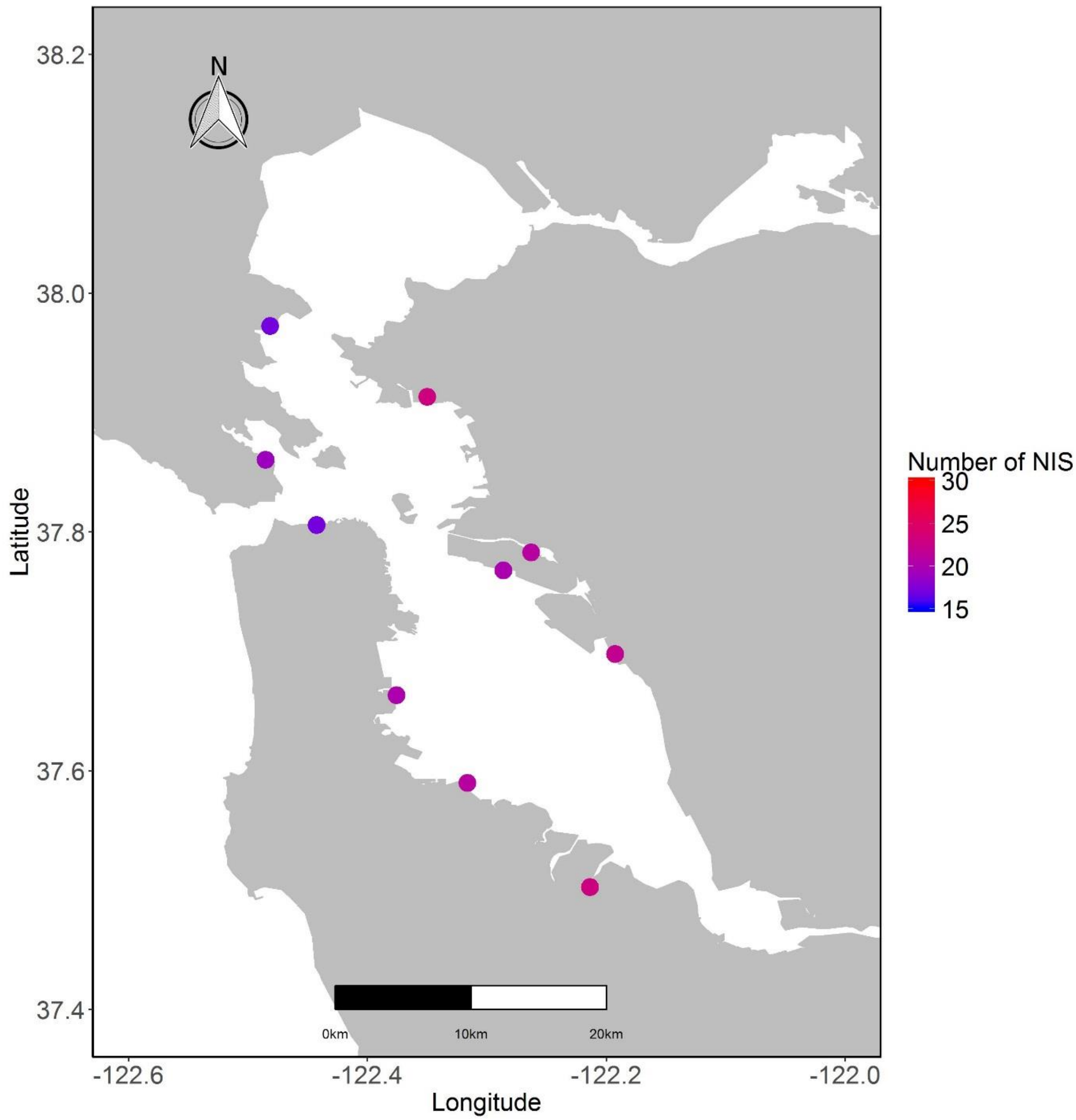
***San Francisco Bay 2014***



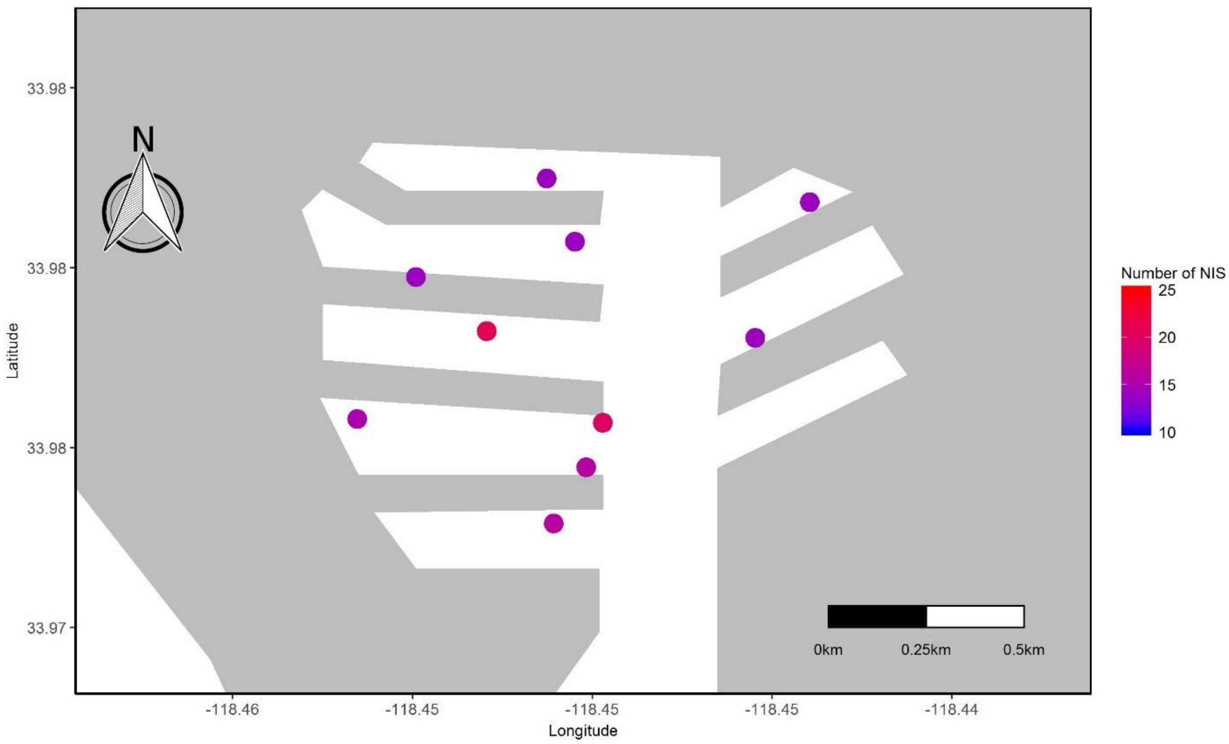
***San Francisco Bay 2015***



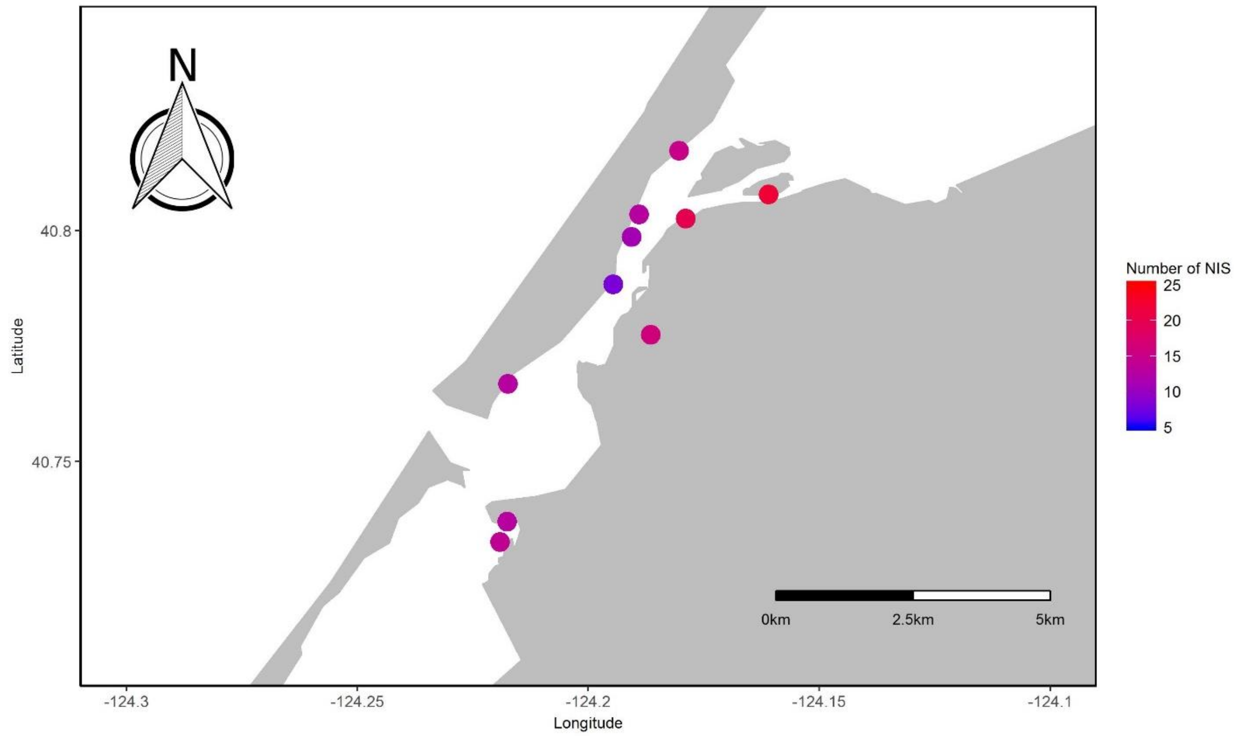
***San Francisco Bay 2016***



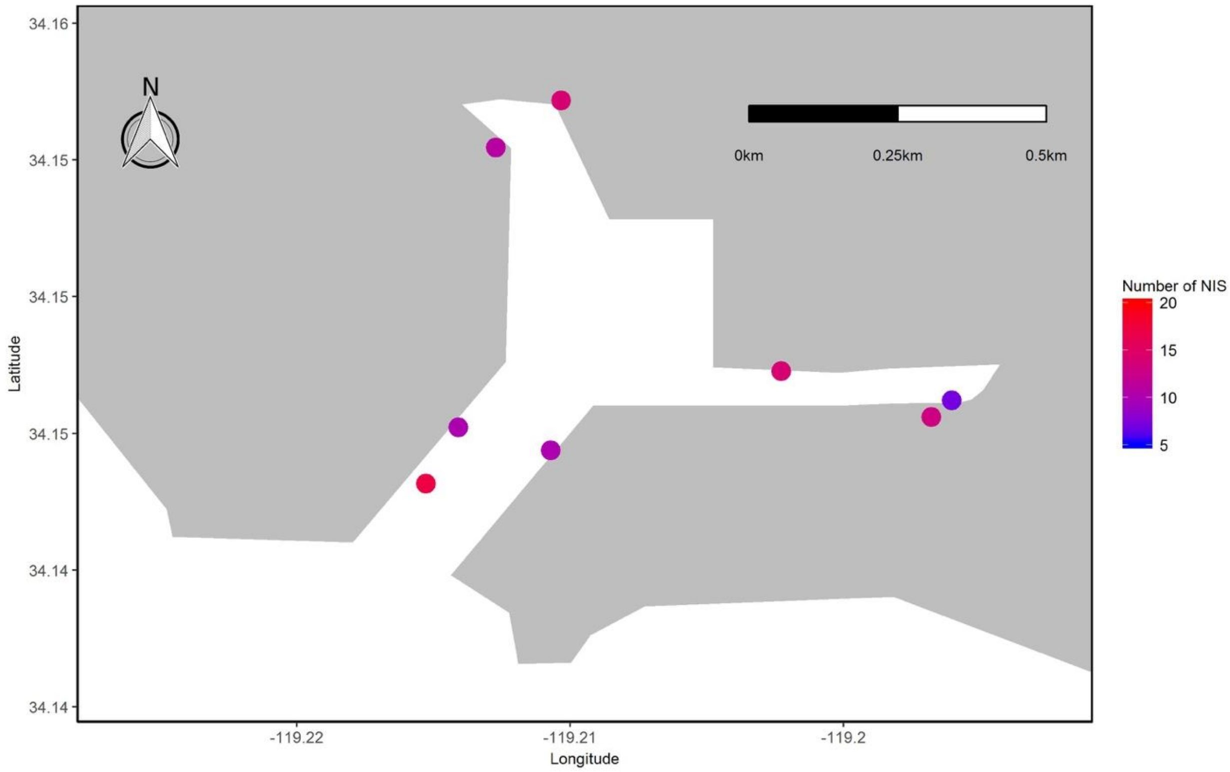
***Marina del Rey 2015***



***<u>Humboldt Bay 2015</u>***



***Port Hueneme 2015***



# Chapter 3: Soft Sediment Communities

## Introduction

### *A. Field Collections*

Surveys of invertebrate communities in soft sediment habitats were conducted in San Francisco Bay (2014, 2015, 2016) and Humboldt Bay (2015). We used a stratified sampling scheme to sample at ten stations in the high salinity region in each Bay. At each station, five replicate grab samples were collected at 200m intervals at each depth sampled, as described below. Salinity and temperature were collected using a YSI Model 85 (Yellow Springs Instrument Co.) meter, and depth was recorded using a depth sensor on the boat.

In San Francisco Bay each year (2014, 2015, 2016), we sampled shallow subtidal depths (2m below MLLW) at ten stations in the higher salinity region of the Bay. Five replicate grab samples were collected at 200m intervals at each station and depth, generating a total of 50 samples (replicates x 10 stations).

In Humboldt Bay in 2015, we sampled five stations in the higher-salinity region of the Bay at intertidal, shallow subtidal (2m below MLLW), and deep (5m below MLLW) depths, and five additional stations at shallow subtidal (2m below MLLW) only. Five replicate grab samples were collected at 200m intervals at each station and depth generating 100 samples (5 replicates x 3 depths x 5 stations, and 5 replicates x 1 depth x 5 stations).

We used a standard Young-modified Van Veen grab (Dauer & Lane 2005, US EPA 2009) with shovels capturing grab samples with a surface area of $0.1m^2$ deployed via hydraulic winch to collect all samples. The entire grab sample was sieved on a 1mm mesh screen, and the retained organisms were preserved in 95% ethanol (except for polychaetes and soft-bodied organisms that were preserved in 10% formalin).

### *B. Sample Analyses*

Morphological analyses for soft sediment taxa proceeded through several steps, and all collected organisms were sorted and identified to the lowest taxonomic level, as follows:

Coarse sorting and removal of polychaete taxa in the field followed by examination under dissecting microscopes, with vouchers taken for genetics and preserved in 95% ethanol.

1. Laboratory sorting of grab samples using dissecting microscopes where necessary and identification by in-house experts to the lowest taxonomic level using California fauna identification keys (Kozloff 1996, Carlton 2007) and consultation with taxonomic experts.

2. Verification of morphological voucher identification. A subset of samples was selected randomly for independent verification, based on morphological characters, by recognized taxonomic experts. Unique or unusual specimens, or potential first records of a species, were subject to additional scrutiny, including additional examination of morphological characters, consultation with additional taxonomic experts, and targeted genetic analyses as possible to confirm or revise morphological identifications.

Voucher specimens of each morphotaxon were taken from each sample. Where possible, based on size and species constraints, the same organisms were split into a paired morphological and DNA sample, to provide direct comparisons of genetic and morphological identifications. All voucher specimens were labeled with a unique identification number, and genetic vouchers were sent to MLML for analyses.

***C. Data Analyses***

The morphological identifications of specimens produced a list of taxa identified to the lowest possible taxonomic level for each sample, along with their abundances (number of individuals). For each taxon, we classified the invasion status in the bay in question, based upon previous analyses and using a synthesis of information in the National Exotic Marine and Estuarine Species Information System (Fofonoff *et al.*, 2017). Four categories were used for this classification: NIS, native, cryptogenic (of uncertain status, *sensu* Carlton 1996), and undetermined (where species-level identification could not be made because specimens were juveniles or in poor condition). Putative records of new species were examined closely and compared to available databases and literature in consultation with taxonomic experts to evaluate their invasion status.

From these data, we compiled the number of NIS detected at each depth for each Bay and sampling year.

**Results**

***A. Overall Summary***

**San Francisco Bay 2014**

Seventy-five morphospecies were detected for the 2014 soft sediment community survey in San Francisco Bay: 37 native, 21 NIS, 5 cryptogenic and 12 unresolved species. Native species accounted for a total of 1713 individuals (27% of the community), NIS species for 4530 individuals (71% of the community), cryptogenic for a total of 39 individuals (0.61% of the community) and unresolved species for 119 individuals (2% of the community).

**San Francisco Bay 2015**

Sixty-three morphospecies were detected for the 2015 soft sediment community survey in San Francisco Bay: 29 native, 23 NIS, 5 cryptogenic and 6 unresolved species. Native species accounted for a total of 197 individuals (7% of the community), NIS species for 2356 individuals (88% of the community), cryptogenic for a total of 89 individuals (3% of the community) and unresolved species for 48 individuals (2% of the community).

**San Francisco Bay 2016**

Seventy-two morphospecies were detected for the 2016 soft sediment community survey in San Francisco Bay: 29 native, 23 NIS, 5 cryptogenic and 15 unresolved taxa. Native species accounted for a total of 1905 individuals (25% of the community), NIS for 5035 individuals (66% of the community), cryptogenic for a total of 54 individuals (0.7% of the community) and unresolved taxa for 635 individuals (8% of the community).

**Humboldt Bay 2015**

A total of 136 morphospecies were detected for soft sediment community survey in Humbodlt Bay: 84 native, 13 NIS, 5 cryptogenic and 34 unresolved. Native species accounted for a total of 4927 individuals (57% of the community), NIS species for 910 individuals (13% of the community), cryptogenic for a total of 36 individuals (0.4% of the community) and unresolved for 2799 individuals (34% of the community).

***B. Detection of NIS in San Francisco and Humboldt Bays.***

Our analyses indicate that our sampling program performed well in detecting and characterizing the NIS in the soft sediment community in both San Francisco and Humboldt Bays. The figures below show the detection of species in the high salinity portion of both bays (2014–2016 for San Francisco, and 2015 for Humboldt). The accumulation curves show the rarefaction of species richness. Calculations were performed using the R package vegan 2.4 (R Core Team 2017; Oksanen *et al.* 2015).

***Total NIS Richness in San Francisco and Humboldt Bays.***

NIS richness approached an asymptote rapidly in shallow water subtidal habitats in San Francisco Bay in all three years sampled (Figures 3.1, 3.2, 3.3), and in Humboldt Bay in 2015 (Figure 3.3). We observed 22 NIS in San Francisco Bay in 2014 and 24 NIS in both 2014 and 2015, while we found a total of 14 NIS in Humboldt Bay in 2015. The accumulation curves suggest that we have detected > 90% of the estimated total NIS in Humboldt Bay and 84-100% of the estimated total NIS in San Francisco Bay across each of the three years (Table 3.1).

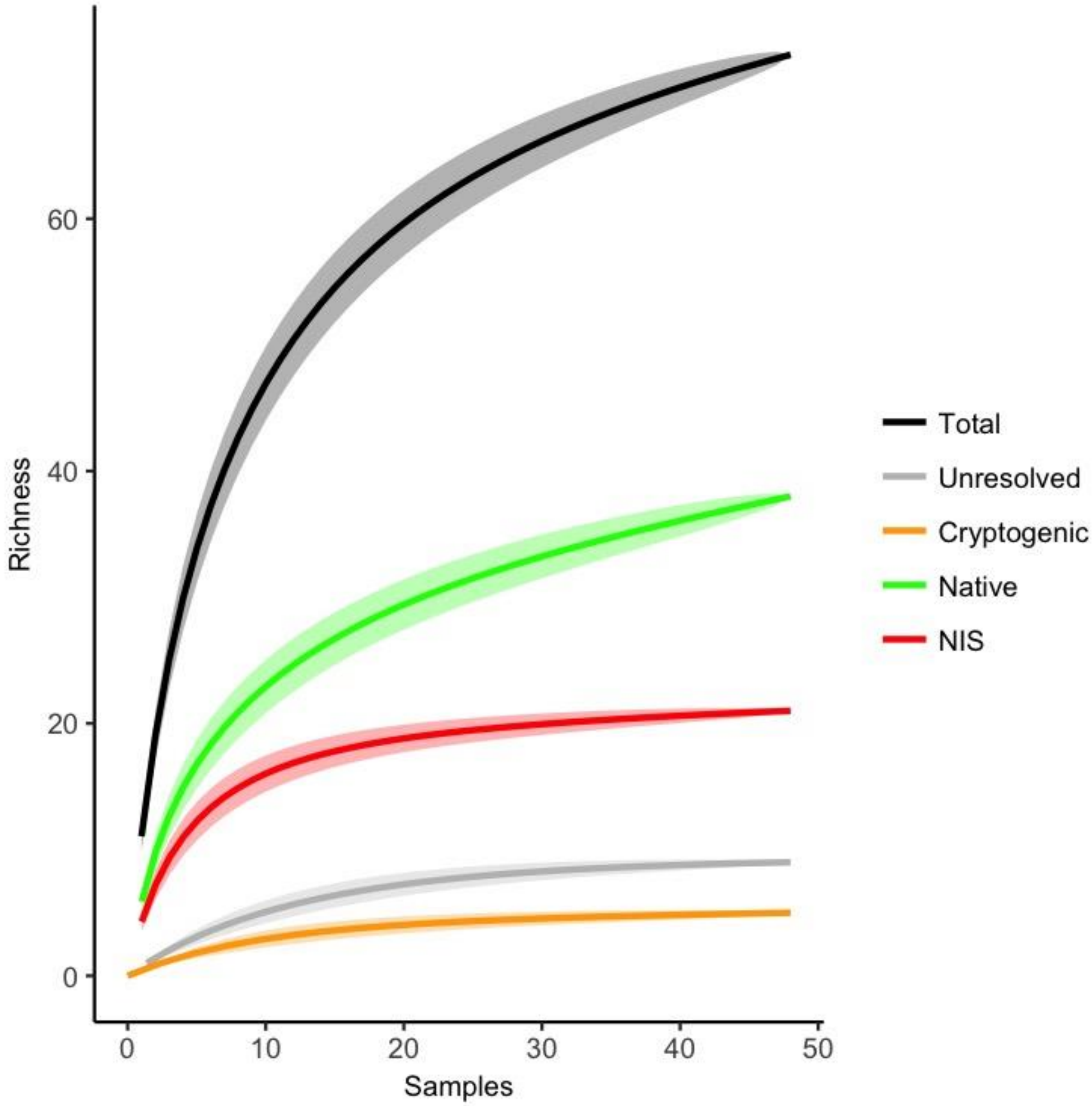



**Figure 3.1**. **Species accumulation curves by invasion status for San Francisco Bay, 2014.** Status is designated based on literature and SERC NEMESIS database. Here, a sample represents a grab taken at 5 locations in each of 10 sites in the high salinity region of the Bay (n=50 grabs total). NIS asymptote agrees with species richness estimators (see Table 3.1). Shading around each line represents 1SD.

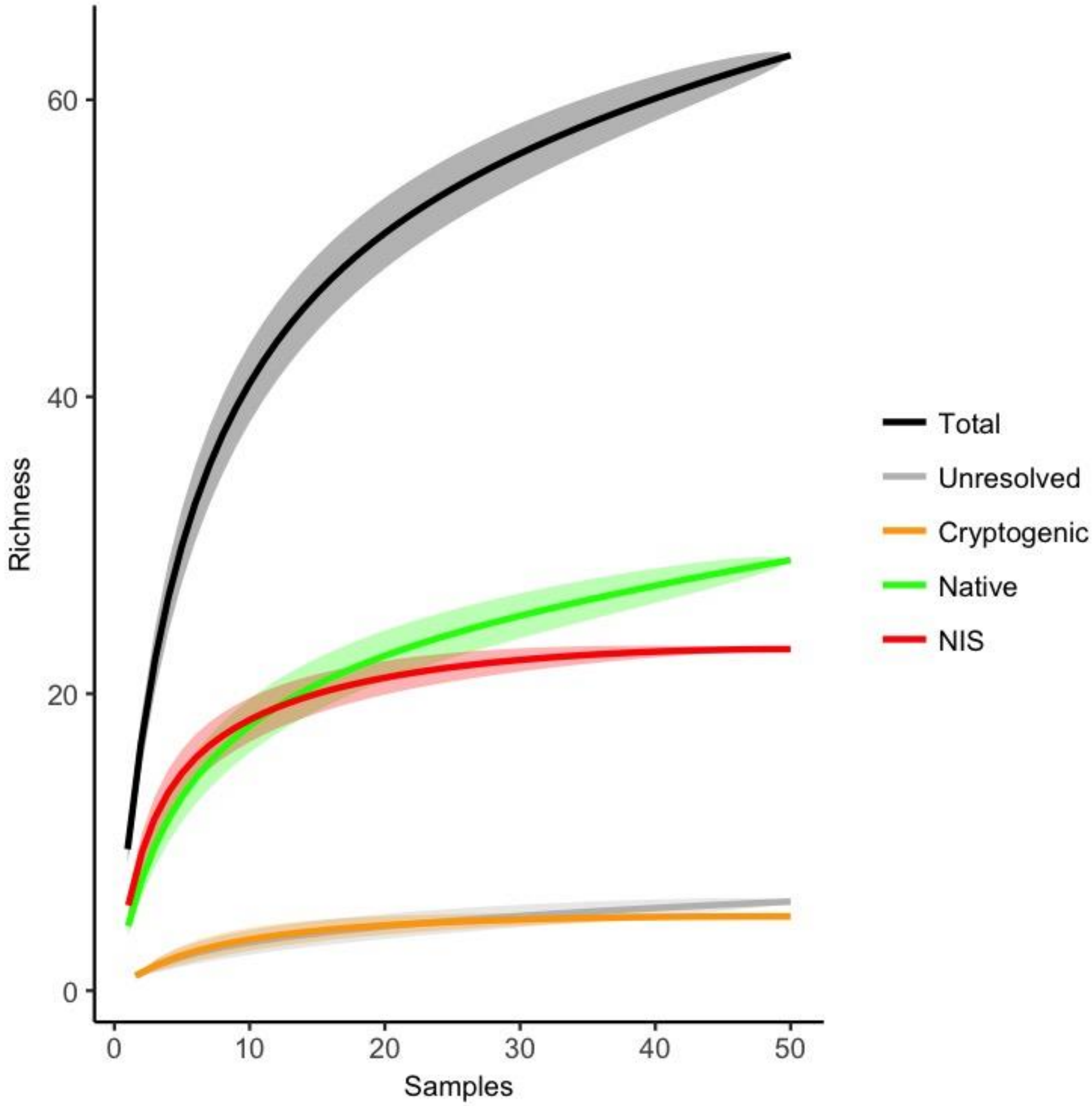



**Figure 3.2**. **Species accumulation curves by invasion status for San Francisco Bay, 2015.** Status is designated based on literature and SERC NEMESIS database. Here, a sample represents a grab taken at 5 locations in each of 10 sites in the high salinity region of the Bay (n=50 grabs total). NIS asymptote agrees with species richness estimators (see Table 3.1). Shading around each line represents 1SD.

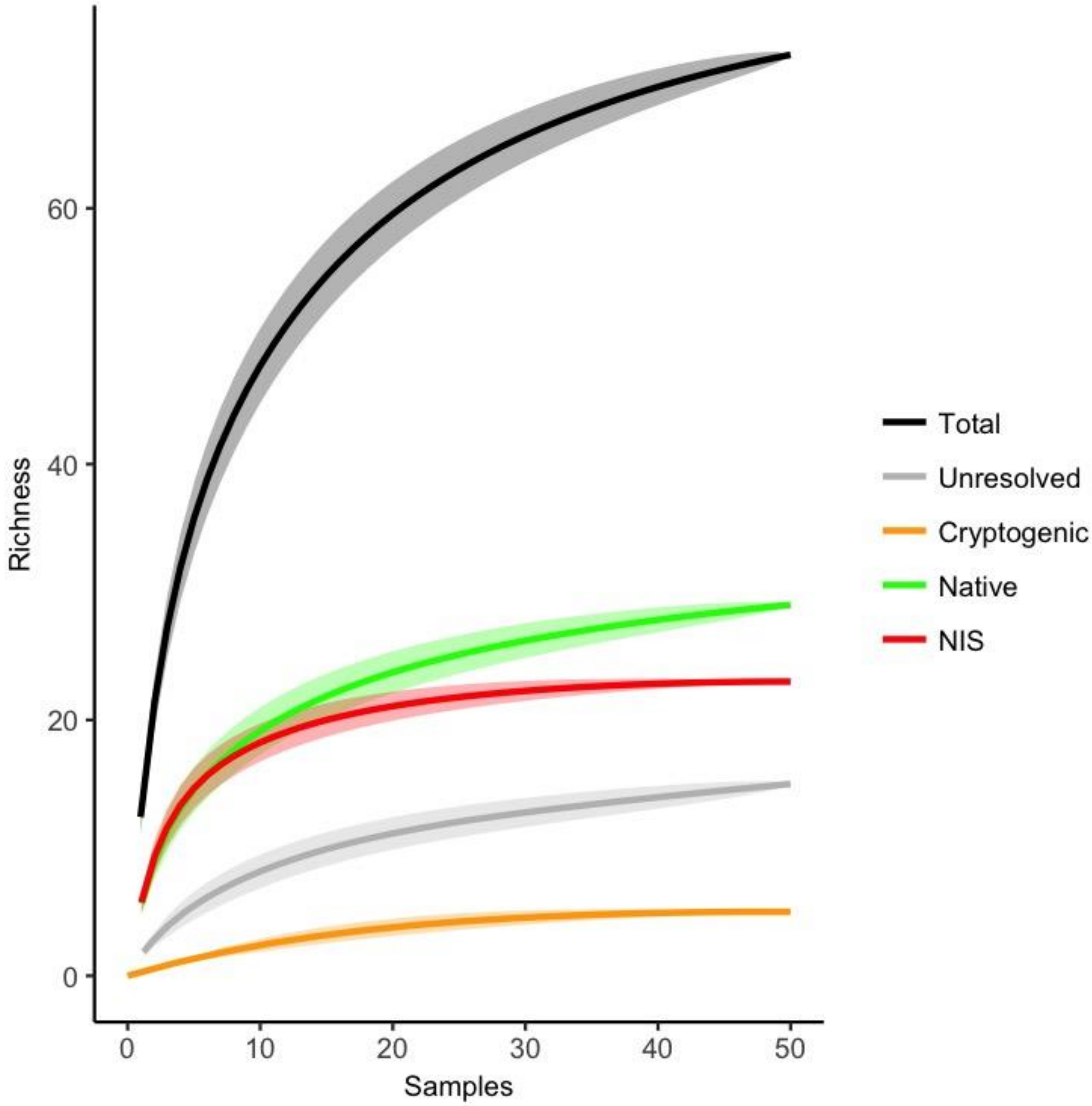



**Figure 3.3. Species accumulation curves by invasion status for San Francisco Bay, 2016.** Status is designated based on literature and SERC NEMESIS database. Here, a sample represents a grab taken at five locations in each of 10 sites in the high salinity region of the Bay (n=50 grabs total). NIS asymptote agrees with species richness estimators (see Table 3.1). Shading around each line represents 1SD.

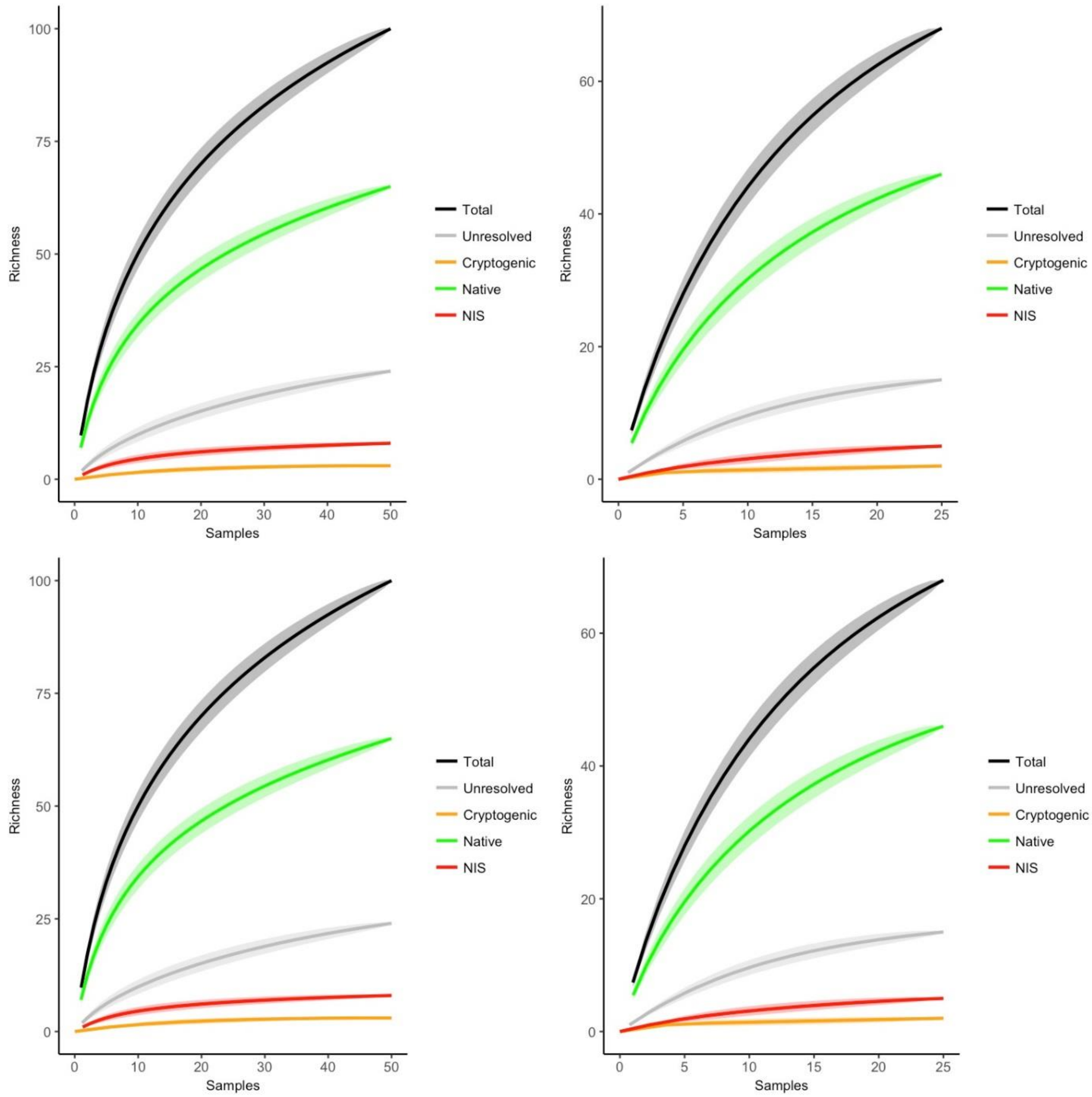



**Figure 3.4. Species accumulation curves by invasion status for Humboldt Bay, 2015, across all depths (top left), intertidal (top right), shallow subtidal (bottom left), and deep depths (bottom right).** Status is designated based on literature and SERC NEMESIS database. NIS asymptote across all depths agrees with species richness estimators (see Table 3.1). Shading around each line represents 1SD.

**Table 3.1. Species richness estimators by invasion status for Humboldt Bay in 2015 and San Francisco Bay in 2014, 2015, and 2016.**

| Bay | Year | Status | Species | Chao | Chao SE | Jack1 | Jack1 SE | Jack2 | Boot | Boot SE | n |
|---|---|---|---|---|---|---|---|---|---|---|---|
| HB | 2015 | Cryptogenic | 8 | 8.49 | 1.31 | 8.99 | 0.99 | 9 | 8.52 | 0.62 | 100 |
| HB | 2015 | Native | 87 | 121.38 | 18.83 | 111.75 | 5.69 | 127.52 | 97.86 | 3.07 | 100 |
| HB | 2015 | NIS | 15 | 15.16 | 0.53 | 15.99 | 0.99 | 14.06 | 15.93 | 0.85 | 100 |
| HB | 2015 | Total | 137 | 169.49 | 13.84 | 174.62 | 8.18 | 190.52 | 154.7 | 4.83 | 100 |
| HB | 2015 | Unresolved | 36 | 42.66 | 5.26 | 46.89 | 3.57 | 48.94 | 41.39 | 2.14 | 100 |
| SF | 2014 | Cryptogenic | 8 | 8 | 0.46 | 8.98 | 0.98 | 9.94 | 8.46 | 0.56 | 50 |
| SF | 2014 | Native | 41 | 60.75 | 17.07 | 51.77 | 4.72 | 59.5 | 45.58 | 2.4 | 50 |
| SF | 2014 | NIS | 24 | 24.98 | 1.84 | 25.96 | 1.38 | 26 | 25.01 | 0.93 | 50 |
| SF | 2014 | Total | 76 | 91.74 | 10.82 | 90.69 | 5.11 | 98.5 | 82.75 | 2.84 | 50 |
| SF | 2014 | Unresolved | 12 | 12.24 | 0.72 | 12.98 | 0.98 | 12.06 | 12.71 | 0.72 | 50 |
| SF | 2015 | Cryptogenic | 8 | 8 | 0 | 8 | 0 | 7.06 | 8.18 | 0.4 | 50 |
| SF | 2015 | Native | 32 | 42.45 | 10.08 | 39.84 | 3.41 | 44.7 | 35.35 | 1.84 | 50 |
| SF | 2015 | NIS | 26 | 28.2 | 3.33 | 28.94 | 1.7 | 29.94 | 27.44 | 1.02 | 50 |
| SF | 2015 | Total | 66 | 77.83 | 8.65 | 78.74 | 4.29 | 84.64 | 71.83 | 2.43 | 50 |
| SF | 2015 | Unresolved | 9 | 10.96 | 3.67 | 10.96 | 1.39 | 11.94 | 9.87 | 0.76 | 50 |
| SF | 2016 | Cryptogenic | 8 | 8 | 0 | 8 | 0 | 5.18 | 8.42 | 0.65 | 50 |
| SF | 2016 | Native | 32 | 35.06 | 3.59 | 36.9 | 2.19 | 37.94 | 34.44 | 1.35 | 50 |
| SF | 2016 | NIS | 26 | 26 | 0 | 26 | 0 | 22.24 | 26.58 | 0.77 | 50 |
| SF | 2016 | Total | 75 | 79.08 | 3.48 | 84.8 | 3.1 | 83.12 | 80.44 | 2.47 | 50 |
| SF | 2016 | Unresolved | 18 | 30.25 | 16.8 | 22.9 | 2.19 | 26.76 | 20 | 1.13 | 50 |

### ***Percent Contribution of NIS to Total Species Richness in San Francisco and Humboldt Bays.***

San Francisco Bay had a much higher average proportion of NIS making up total species richness relative to Humboldt Bay (Figures 3.5 to 3.8). NIS contributed up to 36.5% of total observed species richness in San Francisco Bay (Figures 3.5 to 3.7), but just 10% of total observed species richness in Humboldt Bay (Figure 3.8). The difference between the two Bays is due to opposite patterns of native and NIS richness: Humboldt had a high number of native species and few NIS, whereas San Francisco Bay had fewer native species and more NIS.

Across depths in Humboldt Bay, NIS made up a relatively small percentage of overall species richness. In general, NIS were slightly more prevalent at shallower depths than deeper in Humboldt Bay, with intertidal sites having the greatest proportion of NIS (Figure 3.8). NIS were absent entirely from the shallow and deep sites at one location (US Coast Guard). Unresolved taxa made up a fairly constant proportion of overall species richness across sites and depths.

The percent contribution of NIS to overall richness was relatively constant among sites in San Francisco Bay in 2014 and 2016. In 2015, NIS made up a disproportionately larger percentage of overall richness, with greater variation among sites, a change that may have been related to a marine heat wave that occurred that year (Cavole *et al.* 2016).

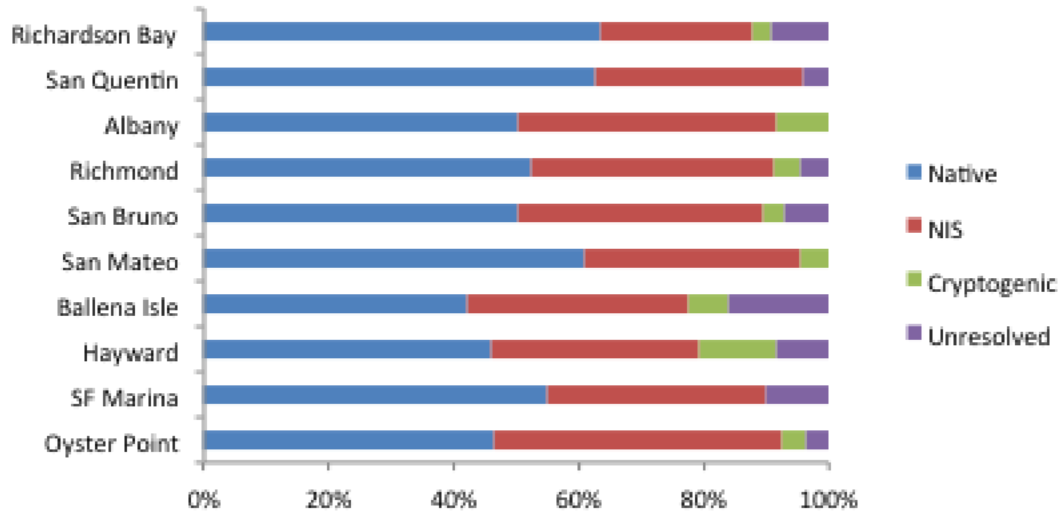



**Figure 3.5. San Francisco Bay, 2014.** Total species richness contribution percentages for native (blue), NIS (red), cryptogenic (green) and unresolved (purple) species per site and depth.

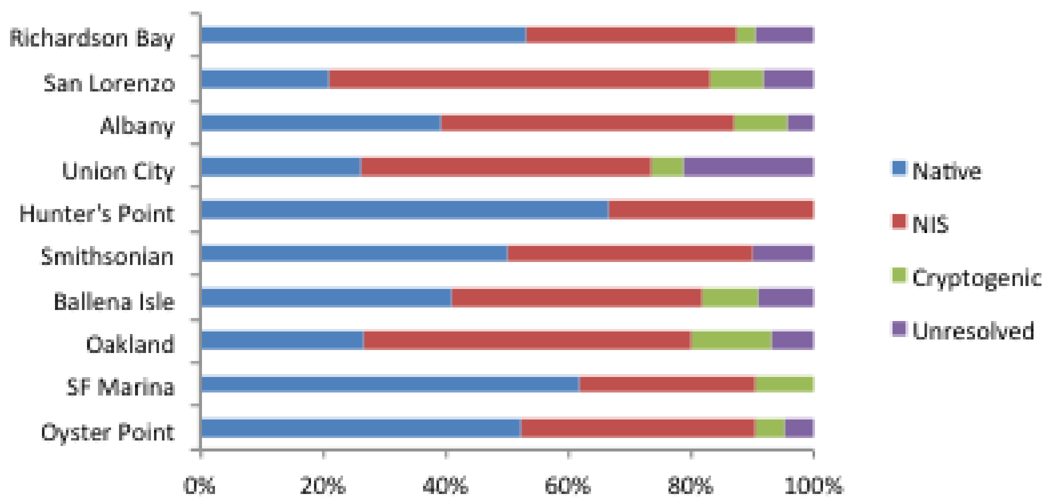



**Figure 3.6. San Francisco Bay, 2015.** Total species richness contribution percentages for native (blue), NIS (red), cryptogenic (green) and unresolved (purple) species for low salinity (bottom) and high salinity (top) sites.

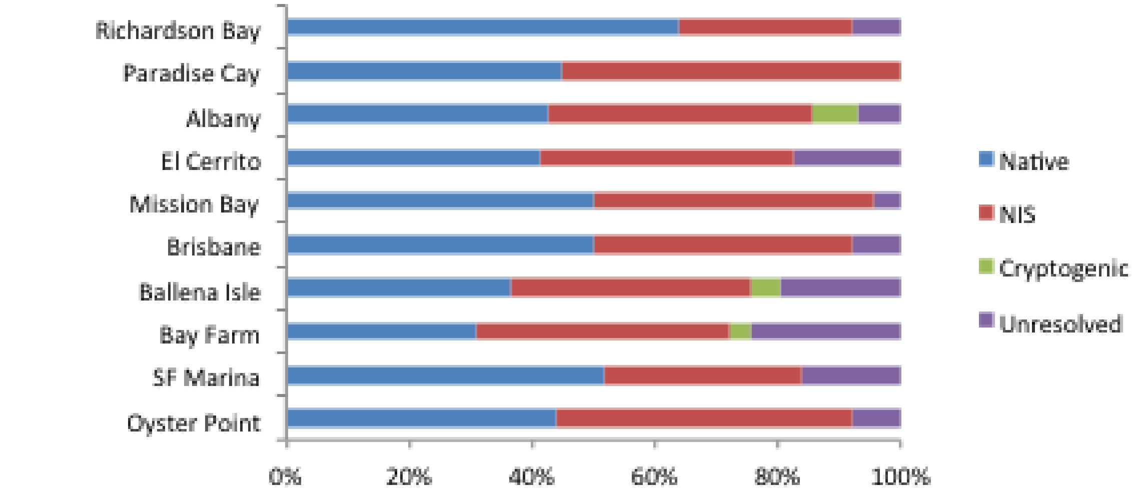



**Figure 3.7. San Francisco Bay, 2016.** Total species richness contribution percentages for native (blue), NIS (red), cryptogenic (green) and unresolved (purple) species per site.


**Figure 3.8. Humboldt Bay, 2015** Total species richness contribution percentages for native (blue), NIS (red), cryptogenic (green) and unresolved (purple) species per site.

**<u>Relative Abundance of NIS per Site in San Francisco and Humboldt Bays</u>.** Overall, NIS made up a large percentage of the individuals found in San Francisco Bay, but not Humboldt Bay. In San Francisco Bay, NIS made up a much larger percentage of individuals in our grab samples than native species, reaching a maximum abundance of 93% of all individuals (Figures 3.9 to 3.12).

There was significant variation among sites and years in San Francisco Bay in the relative abundance of NIS, which ranged from 29% to 93% (Figures 3.9 to 3.11).

Although NIS made up a relatively small proportion of all individuals sampled in Humboldt Bay, we found higher NIS abundance at sites closer to the back portion of the Bay. In contrast, NIS abundance was very low at sites closer to the mouth of the Bay (Figure 3.12). We also found that NIS abundance in Humboldt Bay was greatest at intertidal sites and declined with depth, making up the smallest percentage of all organisms at deep locations (Figure 3.12).

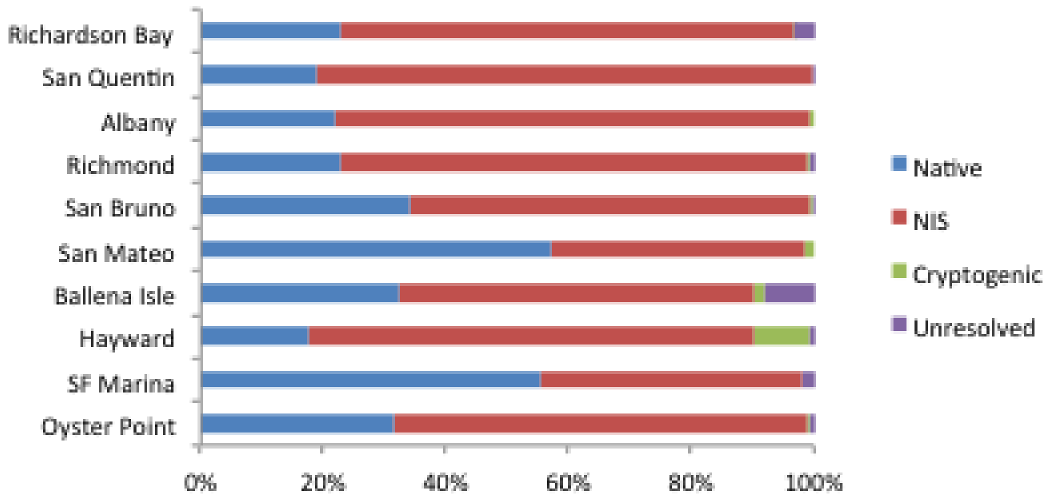



**Figure 3.9. San Francisco Bay, 2014.** Total abundance contribution percentages for native (blue), NIS (red), cryptogenic (green) and unresolved (purple) species per site and depth.

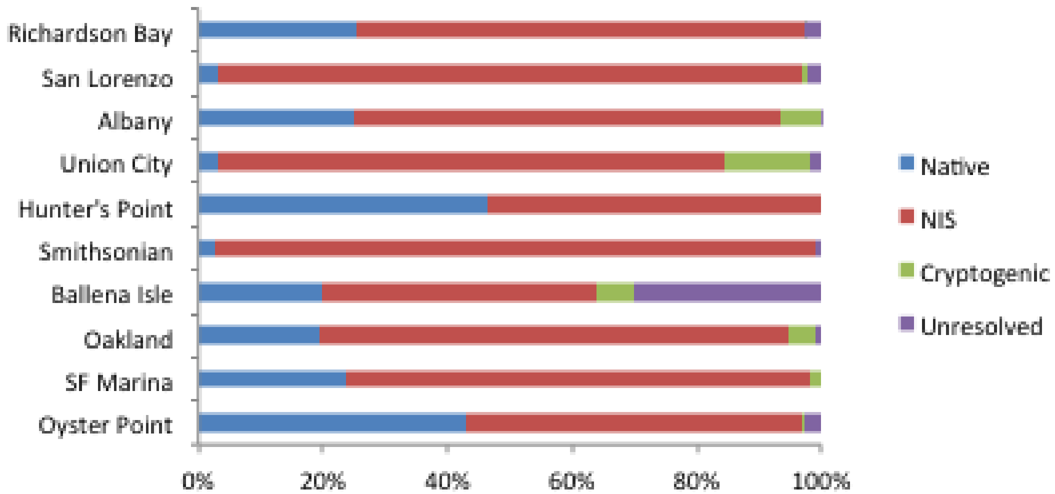



**Figure 3.10. San Francisco Bay, 2015.** Total abundance contribution percentages for native (blue), NIS (red), cryptogenic (green) and unresolved (purple) species for low salinity (bottom) and high saliniy (top) sites .

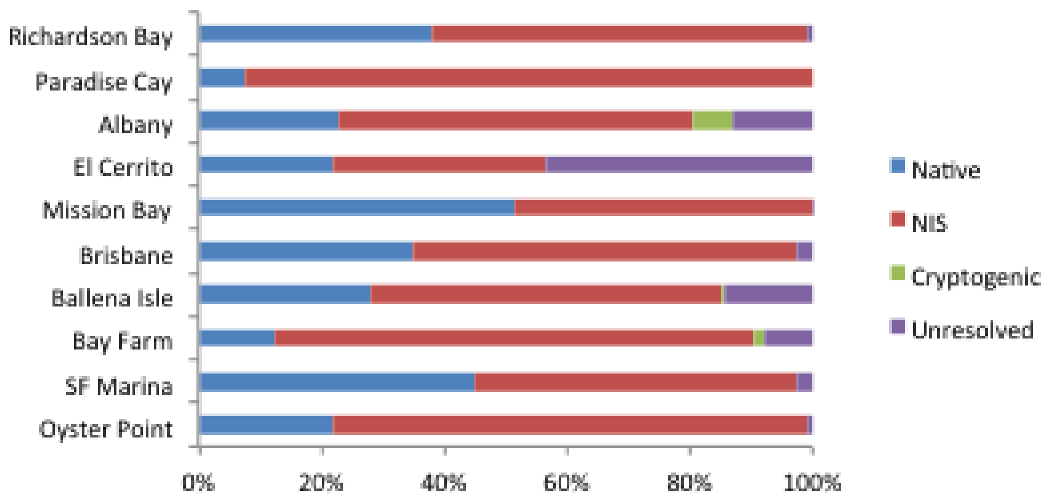



**Figure 3.11. San Francisco Bay, 2016.** Total abundance contribution percentages for native (blue), NIS (red), cryptogenic (green) and unresolved (purple) species per site.

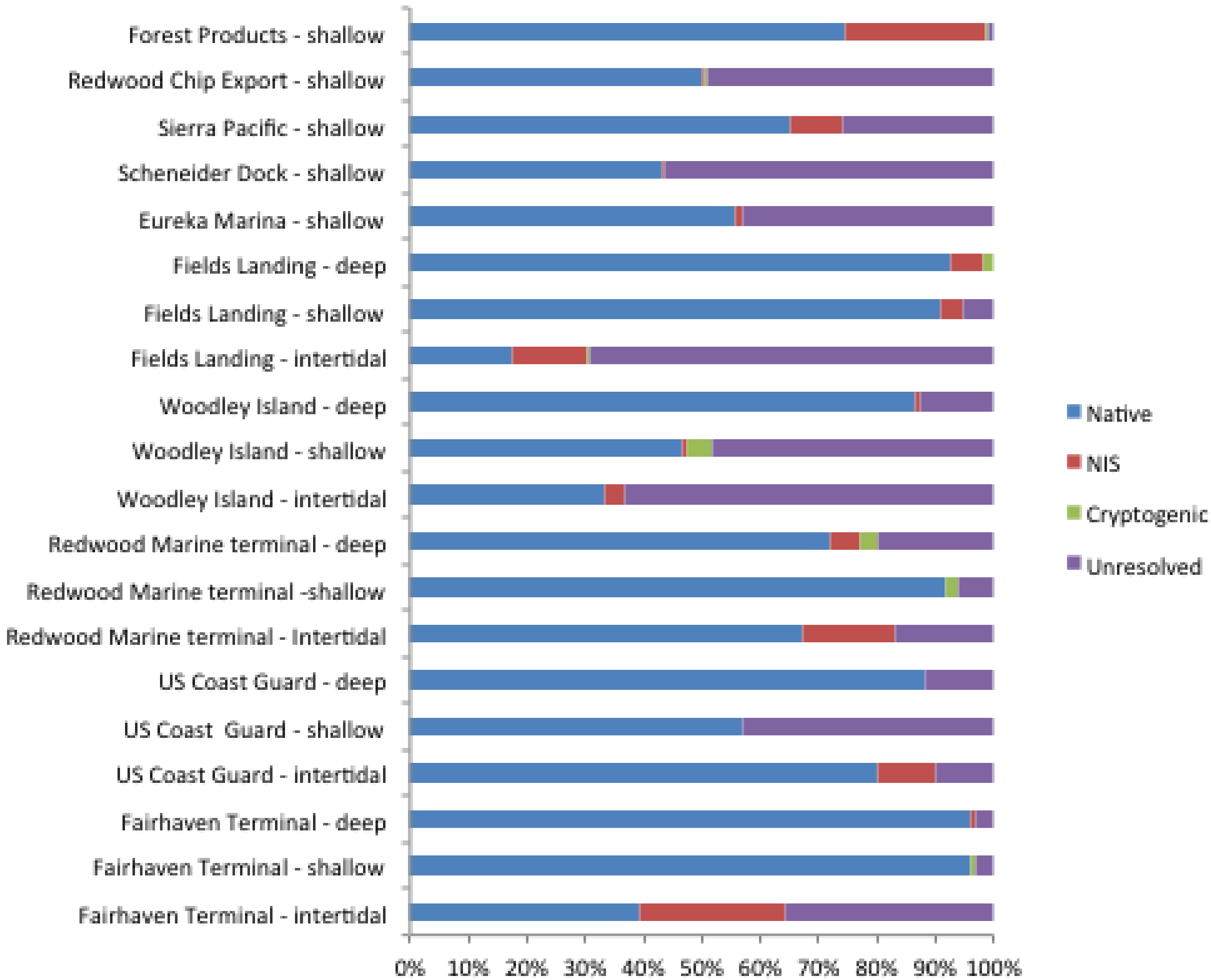



**Figure 3.12. Humboldt Bay, 2015** Total abundance contribution percentages for native (blue), NIS (red), cryptogenic (green) and unresolved (purple) species per site.

## *C. Newly Detected NIS across Bays and Years for the Soft Sediment Community*

A total of 2 taxa were detected that appear to be new records for Humboldt Bay in 2015, using morphological taxonomy in the present study, and no new species were detected in the San Francisco Bay surveys (shallow subtidal zone surveyed in three years, 2014–2016). Importantly, no taxa new to California were detected morphologically in soft sediment habitats across these bays during the present study.

We found the Asian cephalaspidean gastropods *Philine auriformis* and *P. orientalis* in Humboldt Bay in grab samples from 2 and 3 out of 10 sites, respectively. Each species occurred in low abundance. *P. auriformis* was previously recorded in Coos Bay (1998). *P. orientalis* was previously found in Bodega Bay in 1998, and in San Francisco and Tomales Bays in 2004.

We consider these records to be tentative new records for Humboldt Bay, pending further confirmation, with caution engendered by *Philine*'s tendency to fluctuate greatly in population size, and its occurrence in deeper waters subtidally and offshore. In that context, it seems likely that neither record represents a significant range expansion along the coast.

The relative lack of new records is surprising given the spatial and temporal scale of these sampling efforts, including three years in San Francisco Bay, and detailed morphological analyses. The results suggest that the rate of invasion or detection may be quite variable over time, or perhaps that a shift in invasion rates has occurred since previous analyses of invasion detection encompassing soft sediment were performed in the late 1990s. Repeated sampling over time in each Bay will help determine whether this is a lasting or ephemeral pattern.

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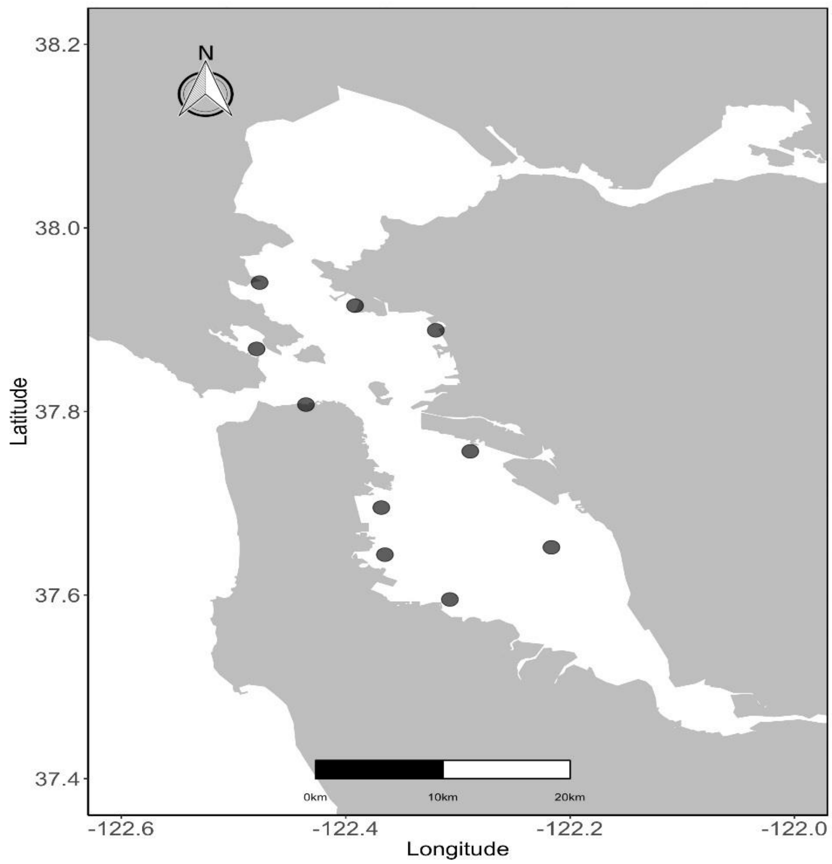
**Appendix 3.1: Survey Locations by Estuary and Year**

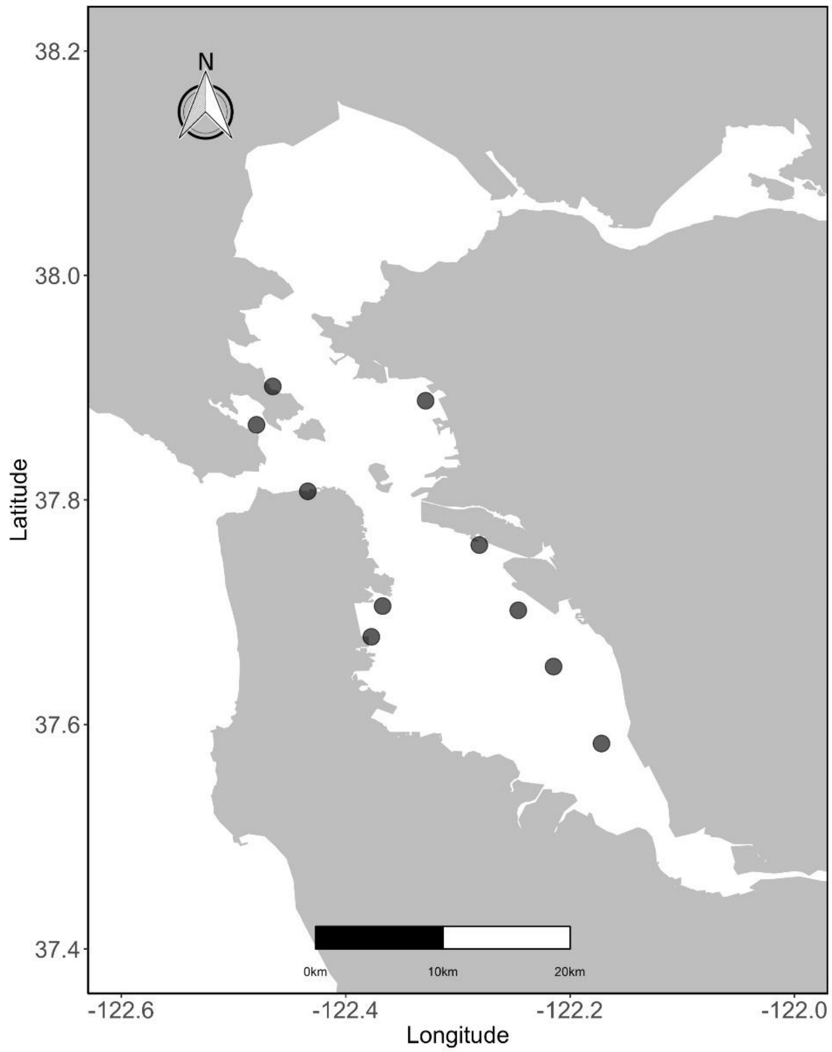
The maps and tables below indicate locations and dates for soft sediment surveys for each estuary and year.

***San Francisco Bay 2014***



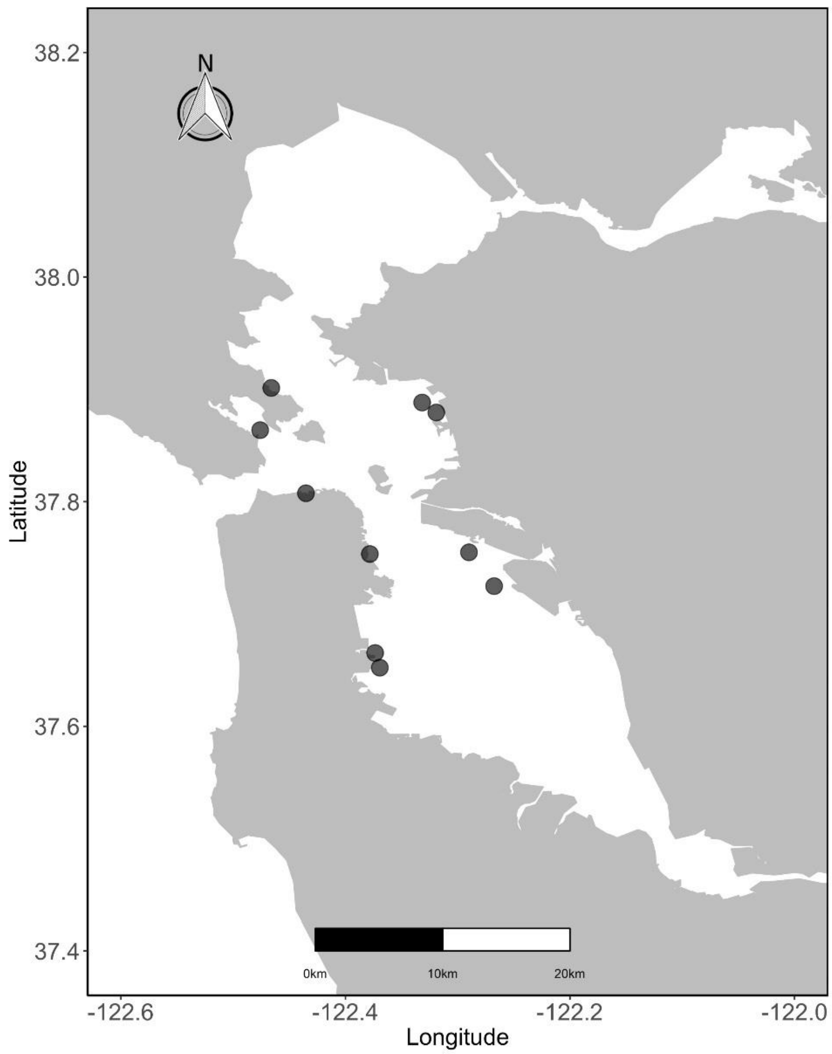

| Site | Latitude | Longitude | Depth (m) | Salinity (‰) | Temperature ($^{o}$C) |
|---|---|---|---|---|---|
| **San Mateo** | 37°35.715'N | 122°18.431'W | 2.3 | 31.10 | 19.13 |
| **San Bruno** | 37°38.642'N | 122°21.906'W | 1.9 | 31.29 | 18.80 |
| **Albany** | 37°53.304'N | 122°19.187'W | 2.0 | 29.93 | 19.14 |
| **Hayward** | 37°39.122'N | 122°13.003'W | 1.8 | 30.85 | 19.94 |
| **San Quentin** | 37°56.424'N | 122°28.608'W | 2.0 | 29.18 | 18.47 |
| **Ballena Isle** | 37°45.395'N | 122°17.342'W | 2.3 | 31.07 | 20.72 |
| **Richmond** | 37°54.913'N | 122°23.503'W | 1.8 | 29.83 | 20.87 |
| **Oyster Point** | 37°41.718'N | 122°22.098'W | 2.0 | 31.29 | 17.77 |
| **San Francisco Marina** | 37°48.450'N | 122°26.130'W | 1.4 | 32.23 | 16.72 |
| **Richardson Bay** | 37°52.090'N | 122°28.770'W | 1.8 | 32.06 | 19.48 |

***San Francisco Bay 2015***



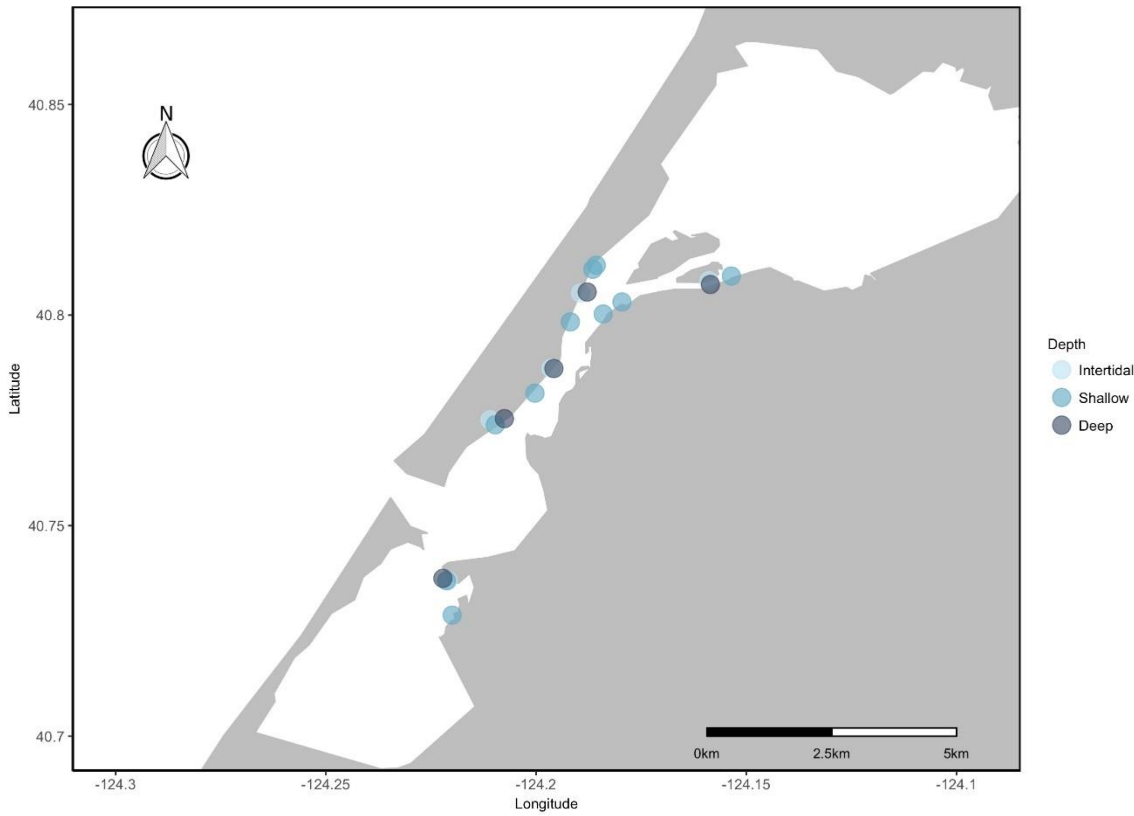

| Site | Latitude | Longitude | Depth (m) | Salinity (‰) | Temperature ($^{o}$C) |
|---|---|---|---|---|---|
| **Union City** | 37°34.982'N | 122°10.325'W | 1.9 | 30.11 | 21.22 |
| **San Lorenzo** | 37°39.093'N | 122°12.886'W | 2.1 | 30.37 | 21.78 |
| **Albany** | 37°53.303'N | 122°19.729'W | 2.6 | 28.92 | 20.13 |
| **Hunter's Point** | 37°42.327'N | 122°22.030'W | 3.3 | 30.99 | 19.19 |
| **Oakland** | 37°42.100'N | 122°14.773'W | 2.0 | 30.31 | 18.19 |
| **Ballena Isle** | 37°45.589'N | 122°16.859'W | 2.3 | 30.69 | 20.01 |
| **Smithsonian** | 37°54.065'N | 122°27.903'W | 2.3 | 29.36 | 19.22 |
| **Oyster Point** | 37°40.681'N | 122°22.634'W | 3.5 | 30.86 | 18.40 |
| **San Francisco Marina** | 37°48.462'N | 122°26.032'W | 1.7 | 32.06 | 15.74 |
| **Richardson Bay** | 37°52.014'N | 122°28.774'W | 2.0 | 31.57 | 17.59 |

***San Francisco Bay 2016***




| Site | Latitude | Longitude | Depth (m) | Salinity (‰) | Temperature ($^oC$) |
|---|---|---|---|---|---|
| **Brisbane** | 37.6522°N | 122.3694°W | 2.1 | 28.06 | 17.45 |
| **Bay Farm** | 37.7248°N | 122.2676°W | 2.1 | 24.58 | 18.64 |
| **Albany** | 37.8794°N | 122.3191°W | 2.8 | 27.68 | 17.36 |
| **Mission Bay** | 37.7534°N | 122.3783°W | 2.0 | 28.52 | 16.74 |
| **El Cerrito** | 37.8883°N | 122.3317°W | 2.2 | 27.68 | 17.36 |
| **Ballena Isle** | 37.7549°N | 122.2900°W | 2.0 | 25.00 | 18.46 |
| **Paradise Cay** | 37.9013°N | 122.4661°W | 1.9 | 21.90 | 18.62 |
| **Oyster Point** | 37.6653°N | 122.3736°W | 2.3 | 28.06 | 17.62 |
| **San Francisco Marina** | 37.8075°N | 122.4352°W | 2.0 | 29.18 | 16.00 |
| **Richardson Bay** | 37.8637°N | 122.4760°W | 2.4 | 29.28 | 15.86 |

***Humboldt Bay 2015***




| Depth | Site | Latitude | Longitude | Depth (m) | Salinity (‰) | Temperature ($^{o}$C) |
|---|---|---|---|---|---|---|
| Intertidal | **Woodley Island** | 40.80816°N | 124.15886°W | 0.0 | 33.97 | 18.47 |
| | **Redwood Marine Terminal** | 40.80524°N | 124.18944°W | 0.0 | 34.06 | 17.10 |
| | **Fairhaven Terminal** | 40.78738°N | 124.19643°W | 0.0 | 33.52 | 16.54 |
| | **US Coast Guard** | 40.77512°N | 124.21095°W | 0.0 | 33.88 | 16.62 |
| | **Fields Landing** | 40.73701°N | 124.22095°W | 0.0 | 33.60 | 15.38 |
| Shallow | **Eureka Marina** | 40.80313°N | 124.17957°W | 2.2 | 34.17 | 18.70 |
| | **Schneider Dock** | 40.80027°N | 124.18404°W | 2.0 | 33.66 | 16.56 |
| | **Sierra Pacific** | 40.81184°N | 124.18567°W | 2.1 | 33.66 | 15.86 |
| | **Woodley Island** | 40.80928°N | 124.15356°W | 2.0 | 34.28 | 20.52 |
| | **Redwood Marine Terminal** | 40.81088°N | 124.18650°W | 2.0 | 34.38 | 19.24 |
| | **Redwood Chip Export** | 40.79839°N | 124.19184°W | 2.0 | 33.76 | 17.24 |
| | **Fairhaven Terminal** | 40.78147°N | 124.20026°W | 2.0 | 34.18 | 17.32 |
| | **US Coast Guard** | 40.77396°N | 124.20970°W | 2.0 | 34.36 | 17.62 |
| | **Fields Landing** | 40.73694°N | 124.22128°W | 2.0 | 33.98 | 15.64 |
| | **Forest Products** | 40.72877°N | 124.21996°W | 2.0 | 33.78 | 15.30 |
| Deep | **Woodley Island** | 40.80726°N | 124.15854°W | 4.8 | 34.60 | 20.76 |
| | **Redwood Marine Terminal** | 40.80548°N | 124.18783°W | 5.0 | 34.54 | 19.50 |
| | **Fairhaven Terminal** | 40.78732°N | 124.19575°W | 5.0 | 34.16 | 17.90 |
| | **US Coast Guard** | 40.77542°N | 124.20753°W | 5.0 | 34.42 | 17.90 |
| | **Fields Landing** | 40.73750°N | 124.22215°W | 5.0 | 34.00 | 16.84 |

## Appendix 3.2. Taxa Identified Morphologically by Estuary and Year

**San Francisco Bay 2014, 2015, 2016:** Number of grabs (out of five replicates per site) in which each taxon was found, along with invasion status assigned based on literature and SERC's NEMESIS database.

| | SPECIES STATUS | Albany | | | Ballena Isle | | | Bay Farm | Brisbane | El Cerrito | Hayward | Hunter's Point | Mission Bay | Oakland | Oyster Point | | | Paradise Cay | Richardson Bay | | | Richmond | San Bruno | San Francisco Marina | | | San Lorenzo | San Mateo | San Quentin | Smithsonian | Union City |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 | 2016 | 2016 | 2016 | 2014 | 2015 | 2016 | 2015 | 2014 | 2015 | 2016 | 2016 | 2014 | 2015 | 2016 | 2014 | 2014 | 2014 | 2015 | 2016 | 2015 | 2014 | 2014 | 2015 | 2015 |
| **ANNELIDA** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Capitellidae** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Capitellidae | U | | | | 1 | | | | | | | | | | | | | | | | | | | 3 | | | | | | | |
| *Heteromastus filiformis complex* | I | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Heteromastus sp.* | C | | | | | 3 | | | | | | | | 1 | | | | | | 1 | | | | | 1 | | | | | | |
| *Mediomastus sp.* | C | | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | |
| **Cirratulidae** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Aphelochaeta monilaris* | N | | | | | | | | | | | | | | | | | | | | | | | 4 | | | | | | | |
| *Cirriformia moorei* | N | 4 | 4 | 5 | 4 | 4 | 4 | 2 | 5 | 4 | 5 | 4 | 5 | 4 | 5 | 5 | 5 | 4 | 2 | 1 | 1 | 1 | 5 | 1 | | 2 | 3 | 3 | 1 | 2 | 2 |
| *Cirriformia sp.* | N | | | | | | | | | | | | | | | | | | | | | | | | | 2 | | | | | |
| *Cirriformia spirabrancha* | N | | | 1 | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | |
| **Dorvilleidae** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Schistomeringos annulata* | N | | 3 | | 1 | 5 | | 1 | 1 | | | 1 | | 3 | | 1 | | 4 | 2 | 1 | | 1 | | | 1 | 1 | 3 | | | 1 | |
| *Schistomeringos sp.* | N | | | 3 | 4 | | 5 | | | 3 | 1 | | 3 | | | | 4 | | 1 | | 2 | | | 1 | | | | 3 | | | |
| **Eunicidae** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Marphysa sp. C Harris* | C | | | | 1 | | | 2 | | | 4 | | | 4 | | | | | | | | | | | | | 5 | 2 | | | 5 |
| **Glyceridae** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Glycera americana* | N | | | | | | 1 | | | 1 | | | 1 | | | | | 4 | | 1 | 1 | | | | 1 | 1 | | | 1 | 3 | 1 |
| *Glycera cf. oxycephala* | U | | | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | |
| **Gonianidae** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Glycinde picta* | N | 5 | 4 | 4 | 3 | | 5 | 3 | 1 | 4 | 1 | 2 | 3 | | | 1 | 5 | 3 | 5 | 4 | 3 | 5 | | 5 | 4 | 5 | 5 | | 3 | 4 | 1 |
| *Glycinde sp.* | U | | | | 1 | | | | | | 1 | | | | | | | | | | | | 1 | | | | | | | | |
| **Lumbrinereidae** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Scoletoma tetraura complex* | N | 1 | | 2 | 1 | 3 | 3 | 2 | 5 | | 1 | 4 | 5 | | 4 | 5 | 5 | | | 1 | 2 | | 5 | | 3 | 4 | | 1 | 2 | | |
| **Maldanidae** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Sabaco elongatus* | I | 5 | 5 | 5 | 3 | 3 | 2 | 1 | 5 | 5 | 2 | 4 | 1 | | 5 | 5 | 4 | 5 | 4 | 2 | 1 | 5 | 5 | | | | 1 | 1 | 4 | | 2 |
| **Nepthydae** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Nephtys caecoides* | N | 1 | 3 | 2 | | | | 1 | | | | | | | | | | | | 2 | 3 | 1 | | | 2 | 3 | | | | | |
| *Nephtys ferruginea* | N | | | | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | |
| **Nereididae** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Onuphis iridescens* | N | | | | | | | | | | | | | | | | | | 1 | | | | | | | | | | 2 | | |
| *Platynereis bicanaliculata* | N | | | | | | | | | | | | | | | | | 2 | 2 | 2 | | | | | | | | | 2 | | |
| **Opheliidae** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Armandia brevis* | N | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | | |
| **Orbiniidae** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Leitoscoloplos pugettensis* | N | 5 | 5 | 5 | 3 | 2 | 5 | 1 | 1 | 5 | 3 | | 5 | | | 2 | 5 | 4 | 2 | 3 | 5 | 4 | 1 | 4 | 4 | 5 | 3 | 3 | 3 | 5 | |
| **Phyllodocidae** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Eumida bifoliata* | N | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | | |
| *Phyllodoce longipes* | C | | | | | | | | | | | | | | | | | | 2 | | | | 1 | | | | | | | | |
| **Polynoidae** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Harmothoe imbricata complex* | N | 3 | 5 | 4 | 5 | 4 | 5 | 3 | 5 | 5 | 5 | 3 | 3 | 5 | 1 | 5 | 5 | 5 | 5 | 2 | 2 | 4 | 3 | 3 | | 2 | 5 | 3 | 5 | 2 | 2 |
| *Hesperonoe adventor* | N | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | |
| *Hesperonoe sp.* | N | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | |
| *Malmgreniella sp. SF1* | U | | | | | | | | | | | | | | | | | | | | 1 | | | | | 1 | | | | | |
| **Sabellidae** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Euchone limnicola* | N | 4 | | | | | 1 | | 3 | | | 4 | 5 | | | 3 | 3 | 2 | 4 | 5 | 4 | | 2 | | 1 | 2 | | | 5 | 2 | |
| **Syllidae** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Megasyllis nipponica* | I | 2 | 1 | 3 | | | 3 | | | | | | | | 1 | | 5 | | 1 | 1 | | 1 | 1 | 2 | 4 | 2 | | | 4 | 2 | |
| **Terebelleidae** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Amaeana occidentalis* | N | | | | | | | | | | | | | | | | | | 3 | 2 | 5 | | | 2 | 5 | 3 | | | 1 | | |
| *Amaeana sp. A Harris* | I | 1 | | | 1 | | | | | | | 4 | 4 | | 4 | 3 | | | | | | | 4 | 2 | | 2 | | | 2 | 5 | |
| *Neoamphitrite sp. A Harris* | N | 1 | 2 | 4 | | 3 | | | | | 1 | | | | | 1 | | | | | | 1 | | | | | 1 | | | | |
| *Polycirrus californicus complex* | N | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | |
| *Polycirrus sp.* | U | | | | 5 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Polycirrus sp. SF2* | U | | | | | | 3 | 2 | | | | | | | | | | | | | | | | | | | | | | | |
| **ARTHROPODA** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Amphipoda** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Americhelidium pectinatum* | N | | | 3 | | | 1 | | | 2 | | | 1 | | | | 3 | | | | 1 | | | | | | | | | | |
| *Ampelisca abdita* | I | 1 | 3 | | | | 4 | 1 | 5 | 5 | | 3 | 5 | | 2 | 5 | 5 | 4 | 5 | 5 | 5 | 5 | 1 | 1 | | | 2 | | 5 | 5 | 2 |
| *Ampithoe lacertosa* | N | | | 1 | | | | | | 1 | | | | | | | | 2 | 1 | | | | | | 1 | | | | | | |
| *Ampithoe valida* | I | | | | | | | | | | | | | | | | | 2 | | | | | | | | | | | | | |
| Cumacean | U | | | | | | | | | | | | 1 | | | | | | | | | | | | | 3 | | | | | |
| *Grandidierella japonica* | I | 1 | | 4 | | | | | 4 | 5 | | | 2 | | | | 5 | 5 | | 1 | | 3 | | | 2 | 4 | 1 | | 1 | 1 | 1 |
| *Liljeborgia geminata complex* | C | | | | | | | | | | | | | | | | | | | | | | | | 2 | | | | | | |
| *Listriella cf. goleta* | N | | | | | | | | | | | | | | | | | | | | | | | 3 | | | | | | | |
| *Monocorophium acherusicum* | I | | 1 | | | | 5 | 3 | | | | | | | | | 1 | | 4 | 2 | | 2 | | | | | 5 | | | | 4 |
| Oedicerotidae | U | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | |
| *Paradexamine sp.* | U | | | 4 | | | | | | 1 | | | | | | | | | | | | | | | | | | | | | |
| *Photis brevipes* | N | | | | | | | | | | | | | | | | | | 5 | 4 | 1 | 1 | | | | | | | 1 | | |
| *Sinocorophium alienense* | I | | | 2 | | 1 | | | 3 | 1 | | | 2 | | | | 1 | 1 | | | 1 | | | | | 3 | 1 | | | | |
| *Sinocorophium heteroceratum* | I | 4 | 5 | 4 | 3 | 3 | | | 5 | 5 | | 4 | 5 | | 5 | 5 | 5 | 2 | 5 | 4 | 5 | 5 | 5 | 5 | 5 | 5 | | 1 | 4 | 5 | 3 |
| **Caprellidae** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Caprella californica* | N | | | | | | | | | | | | | | | | | | 5 | 2 | | | | | | | | | | | |
| *Caprella mutica* | I | | | 1 | | | | | | 1 | | | | | | | | | | | | | | | | | | | | | |
| *Caprella scaura* | I | 1 | 1 | 5 | | | | | | 5 | | | | | | | | 1 | 3 | | | | | | | | | | 1 | | |

| | SPECIES STATUS | Albany | | | Ballena Isle | | | Bay Farm | Brisbane | El Cerrito | Hayward | Hunter's Point | Mission Bay | Oakland | Oyster Point | | | Paradise Cay | Richardson Bay | | | Richmond | San Bruno | San Francisco Marina | | | San Lorenzo | San Mateo | San Quentin | Smithsonian | Union City |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2014 | 2015 | 2016 | 2014 | 2015 | 2016 | 2016 | 2016 | 2016 | 2014 | 2015 | 2016 | 2015 | 2014 | 2015 | 2016 | 2016 | 2014 | 2015 | 2016 | 2014 | 2014 | 2014 | 2015 | 2016 | 2015 | 2014 | 2014 | 2015 | 2015 |
| **Decapoda** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Cancer productus* | N | | | 1 | | | | | | 1 | | | | | | | 1 | | | | 1 | 1 | | | | | | | | | |
| *Cancer sp.* | U | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | | | | |
| *Crangon nigricauda* | N | 1 | | | 1 | | 1 | | 1 | | 1 | 3 | | | 2 | | | | 2 | 1 | 1 | | 3 | | | | | | | 4 | |
| *Glebocarcinus oregonensis* | N | | 2 | | | 2 | 1 | | | | | 1 | | | 1 | | | | 1 | 3 | | | | | | | | 1 | 3 | 3 | |
| *Hemigrapsus oregonensis* | N | 2 | | | 3 | 1 | | | 2 | 1 | 2 | 1 | | | 1 | | 1 | | 5 | 1 | | 4 | 4 | | | | | 3 | 1 | 1 | |
| *Heptacarpus stimpsoni* | N | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | |
| *Lophopanopeus bellus* | N | | | | | | 2 | | | | | | | | | | | | | | | | | | | | | | | | |
| *Metacarcinus magister* | N | | | | | | | | | | | 2 | | | | | | | | | | | | | | 1 | | | | | |
| *Palaemon macrodactylus* | I | | | | 1 | | | | | | 1 | | | | 2 | | | | | | | | | | | | | | | 2 | |
| *Pinnixa franciscana* | N | | | | | | | | | | | 1 | | | 1 | 3 | | | | | | | | 1 | 1 | | | | | | |
| *Pyromaia tuberculata* | N | | | | | 1 | | | | 1 | | 2 | | 1 | 1 | 2 | | | | | | 1 | 2 | | | | | 2 | | | |
| *Scleroplax granulata* | N | | | | 1 | | | | | | | | | | | | | | | | | | 2 | | | | | | | | |
| *Upogebia pugettensis* | N | | | | | | | | 1 | | | | | | | | | | | | | | 1 | | 1 | | | 1 | | | |
| **Isopoda** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Cirolanidae | U | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | | |
| *Idotea resecata* | N | | | | | | | | | | | | | | | | | | 2 | | | | | | | | | | | | |
| *Paranthura japonica* | I | | 1 | 3 | | | 4 | 2 | | 4 | | | | | | | 4 | 1 | 3 | | | 3 | 1 | | | | 3 | | | | |
| **Pycnogonida** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Ammothea hilgendorfi* | C | 1 | 3 | 4 | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Tanaidacea** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Leptochelia sp.* | U | | 1 | | | | 1 | | | 5 | | | | | | | | | 5 | 3 | | | | | | | | | | | |
| **BRYOZOA** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Bryozoa** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Anguinella palmata* | I | | | | | | | | | | | | | 1 | 1 | | | | | | | | | | | | | | | | |
| *Aspidelectra melolontha* | I | | | | | | 1 | 1 | | | | | | | | | | | | | | | | | | | 2 | | | | |
| Calloporidae | U | | | | | 1 | | | | | 2 | | | | | | | | | | | | | | | | | | | | 1 |
| *Celeporella hyalina* | C | | | | | | 2 | | | | | | | | | | | | | | | | | | | | | | | | |
| *Conopeum sp.* | U | | | | | | 5 | 1 | | | | | | | | | | | | | | | | | | | | | | | |
| *Cryptosula pallasiana* | I | | | | | | 1 | 1 | | | 2 | | | | | | | | | | | | | | | | 4 | | | | 1 |
| *Electra sp.* | U | | | | | | 4 | | | | | | | | | | | | | | | | | | | | | | | | |
| *Electra venturaensis* | N | | | | | | 3 | | 2 | | | | | | | | | | | | | | | | | | | | | | |
| *Hincksina sp.* | U | | | | | | | 1 | | | | | | | | | | | | | | | | | | | | | | | 1 |
| *Schizoporella errata* | I | | | | | | 2 | 1 | | | | | | 2 | | | | | | | | | | | | | 4 | | | | 4 |
| *Smittoidea prolifica* | I | | | | | | 3 | 2 | 1 | | | | | 1 | | | | | | | | | | | | | | | | | 2 |
| **CNIDARIA** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Anthozoa** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Actinaria | U | | | | | 4 | 5 | 3 | 4 | 5 | | | | 2 | | 4 | 3 | | | 2 | | | | | | | 3 | | | | 1 |
| *Stylatula elongata* | N | | 1 | | | | | | | | | 3 | 5 | | 1 | | | | | 1 | 2 | 1 | | 1 | 2 | 1 | | | | | |
| *Zaolutus actius* | N | 3 | | | 5 | | | | | | 3 | | | | 1 | | | | 5 | | | 5 | 4 | | | | | 3 | 3 | | |
| **Ctenophora** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Ctenophora | U | | | 3 | | | 5 | 1 | 2 | 4 | | | | | | | 4 | | | | | | | | | 1 | | | | | |
| **Hydrozoa** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Hydrozoa | U | | | | 1 | | | | | | | | | | 3 | | | | | | | | | | | | | | | | |
| **ECHINODERMATA** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Asterozoa** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Amphipholis squamata* | C | | | | 3 | | 2 | | | | 1 | | | | 2 | | | | | | | | | | | | | | | | |
| *Amphipodia cf. urtica* | U | | | | | | 1 | | | | | | | | | | | | | | 3 | | | | | 2 | | | | | |
| Amphiuridae | U | | | | | | | 1 | | | | | | | | | | | 1 | 1 | | | | 1 | | | 5 | | | 1 | 1 |
| **MOLLUSCA** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Bivalvia** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Cryptomya californica* | N | 2 | | | 2 | 1 | 5 | 1 | 5 | 1 | 1 | | 2 | | 1 | 4 | 3 | | | | 3 | | 2 | | | | | 3 | | | 1 |
| *Leukoma staminea* | N | | | | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | |
| *Lyonsia californica* | N | 2 | 1 | 2 | 3 | | | 1 | 2 | | | | | | 1 | | | | | | | | 2 | | | | | 1 | | | |
| *Macoma inquinata* | N | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | |
| *Macoma petalum* | I | | | | | | | | | | | | | | 2 | | | | | | | | | | | | | | | | |
| *Musculista senhousia* | I | | 2 | 4 | 4 | 4 | 5 | 1 | 4 | 1 | 4 | 2 | 1 | 3 | | 5 | 4 | | | 2 | | | 3 | | | | 1 | 3 | | | |
| *Ostrea lurida* | N | | | | | | | | | | 2 | | | | | | | | | | | | 1 | | | | | 2 | | | |
| *Tagelus subteres* | N | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | | |
| *Theora lubrica* | I | 1 | 3 | 5 | | 1 | 3 | | 3 | 4 | | 4 | 3 | | 5 | 1 | 5 | 4 | | 2 | 5 | | 1 | 1 | 2 | 4 | 1 | | | 3 | |
| *Venerupis philippinarum* | I | | | | 4 | 3 | 5 | 3 | 5 | 1 | 5 | 1 | 1 | 5 | 2 | 4 | 3 | 1 | | 3 | 1 | 1 | 2 | 3 | 3 | 3 | 5 | 2 | | 2 | 5 |
| **Gastropoda** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Crepidula convexa* | I | | | | 4 | 4 | 4 | 2 | | | 4 | | | 3 | | | | | | | | | | | | | 4 | 3 | | | |
| *Crepidula plana* | I | | | | 2 | 1 | 3 | 1 | 1 | | 3 | | | 2 | | | | | | 1 | | | 1 | | | | 3 | 2 | | | |
| *Philine orientalis* | I | 2 | 1 | 2 | 1 | 2 | 4 | | 2 | 2 | 3 | 4 | 3 | | 2 | 1 | 4 | 4 | 1 | 2 | 2 | 2 | 1 | 1 | 2 | 4 | 1 | 2 | 4 | | |
| *Phyllaplysia taylori* | N | | | | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | |
| **NEMERTEA** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Nemertea** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Nemertea | U | | | | 2 | | | | | | | | | | | | | | 2 | | | 3 | | | | | | | 2 | | |
| **UROCHORDATA** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Tunicata** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Molgula manhattensis* | I | 1 | 3 | 4 | 5 | | 2 | | | | | | | 1 | 1 | | | | | | | | | | | | | 1 | | | |

**Humboldt Bay 2015:** Number of grabs (out of five replicates per site and depth) in which each taxon was found, along with invasion status assigned based on literature and SERC's NEMESIS database.

| | SPECIES STATUS | Eureka Marina | Fairhaven Terminal | | | Fields Landing | | | Forest Products | Redwood Chip Export | Redwood Marina | | | Scheneider Dock | Sierra Pacific | US Coast Guard | | | Woodley Island | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Shallow | Deep | Intertidal | Shallow | Deep | Intertidal | Shallow | Shallow | Shallow | Deep | Intertidal | Shallow | Shallow | Shallow | Deep | Intertidal | Shallow | Deep | Intertidal | Shallow |
| **ANNELIDA** | | | | | | | | | | | | | | | | | | | | | |
| **Arenicolidae** | | | | | | | | | | | | | | | | | | | | | |
| Arenicolidae | U | 1 | | | | | | | | | | | | | | | | | | | |
| **Capitellidae** | | | | | | | | | | | | | | | | | | | | | |
| *Heteromastus filobranchus* | N | 3 | | | | 3 | | 4 | 2 | 5 | | 1 | | 5 | 1 | 1 | | | | | |
| *Heteromastus cf filobranchus* | N | 1 | | | | | | | | | | | | | | | | | | | |
| *Heteromastus sp.* | N | | 1 | 2 | 1 | | | | | | | | | | | 3 | | 5 | | 1 | |
| **Cirratulidae** | | | | | | | | | | | | | | | | | | | | | |
| *Aphelochaeta cf. glandaria* | U | | | | | | | | | 1 | | | | | | | | | | | |
| Cirratulidae | U | | | | | | | | 1 | | | | | | | | | | | | |
| *Cirratulus sp.* | U | | | | | | 1 | 1 | | | 2 | | | | 2 | | | | | | |
| *Cirriformia sp.* | N | | | | | | | | | | | | | | | | | 1 | 4 | | 2 |
| *Polycirrus sp.* | U | | | | | | | | | | | 1 | | | | | | | | | |
| **Dorvilleidae** | | | | | | | | | | | | | | | | | | | | | |
| *Dorvillea longicoris* | N | | | | | | | | | | | 1 | | | | | | | | | |
| *Dorvillea sp.* | U | 1 | | | | | | | | | 3 | 1 | | | 3 | | | | | | |
| **Glyceridae** | | | | | | | | | | | | | | | | | | | | | |
| *Glycera americana* | N | | 1 | | 1 | | | | | | | | | | 1 | | | | | | |
| *Glycera tenuis* | N | | 1 | | 3 | | | | | | | | | | | 5 | | 3 | | | |
| **Gonianidae** | | | | | | | | | | | | | | | | | | | | | |
| *Glycinde picta* | N | 4 | | | 1 | 1 | 3 | 4 | 2 | 5 | | 4 | 5 | 3 | 2 | 1 | | 1 | 1 | 1 | 3 |
| **Lumbrinereidae** | | | | | | | | | | | | | | | | | | | | | |
| *Drilonereis sp.* | U | | | | | | | | | | 2 | | 4 | | | | | | 2 | | |
| *Lumbrinereis californiensis* | N | | 1 | | | | | | | | | | | | | | | | | | |
| *Scoletoma luti* | N | | | | | | 1 | | | 2 | | | | 1 | | 1 | | | | | |
| *Scoletoma sp.* | U | | | | | | | | | | 2 | | | | | | | | | | |
| **Nepthydae** | | | | | | | | | | | | | | | | | | | | | |
| *Nephtys ferruginea* | N | | | | | | | | | | | | | 1 | | | | | | | |
| *Nepthys caecoides* | N | | 2 | | 1 | 2 | 3 | 2 | 4 | 4 | 1 | 3 | 3 | | 1 | 3 | | 4 | 2 | | 4 |
| **Nereididae** | | | | | | | | | | | | | | | | | | | | | |
| *Nereis sp.* | U | | | | | | | | | | | | 2 | | | | | | | | |
| *Nereis vexillosa* | N | | | | 1 | | | | | | 1 | | | | | | | | | | |
| *Platynereis bicanaliculata* | N | 1 | | 1 | | | | 2 | 4 | 2 | 1 | 3 | | | 2 | | | | 1 | | |
| Syllidae | U | | | | | | | | | | 1 | | | | | | | | | | |
| **Orbiniidae** | | | | | | | | | | | | | | | | | | | | | |
| *Leitoscoloplos pugettensis* | N | | 1 | | 4 | 5 | 1 | 5 | 5 | 3 | 5 | 4 | 4 | 4 | 5 | 1 | | 2 | 4 | | 2 |
| **Oweniidae** | | | | | | | | | | | | | | | | | | | | | |
| *Owenia collaris* | N | | | | | | | | 3 | | | | | | | | | | | | |
| **Pectinariidae** | | | | | | | | | | | | | | | | | | | | | |
| *Pectinaria californiensis* | N | | | | | | | | | | 1 | | 1 | | | | | | | | |
| **Phyllodocidae** | | | | | | | | | | | | | | | | | | | | | |
| *Eteone cf. balboensis* | N | | | | | | | | | | | | | | | | | | | 1 | |
| *Eteone spilotus* | N | | | | | | | | | | | | | | | | | | | 2 | |
| *Eumida longicornuta* | N | | | | | | | 2 | | | | | 1 | | | | | | | | |
| *Phyllodoce hartmanae* | N | 3 | | | 1 | | 1 | | | | | | 2 | 2 | | | | | | | |
| **Pilargidae** | | | | | | | | | | | | | | | | | | | | | |
| *Pilargis berkeleyi* | N | | | | | | | | | | | | | | 2 | | | | | | |
| *Pilargis maculata* | N | | | | | | | | | | | | 1 | | | | | | | | |
| **Polynoidae** | | | | | | | | | | | | | | | | | | | | | |
| *Halosydna brevisetosa* | N | | | | | | | | | | | | | | | | | 1 | | | |
| *Harmothoe imbricata complex* | N | | | | | | | | | | 1 | | | | | | | | | | |
| *Hesperone laevis* | N | 1 | | | | | | | | | | | | | | | | | | | |
| *Malmgreniella bansei* | N | 2 | | | | | | | | 1 | | | | 2 | | | | | 1 | | |
| *Malmgreniella macginitiei* | N | | | | | | | | | | | | | 1 | | | | | | | |
| **Sabellidae** | | | | | | | | | | | | | | | | | | | | | |
| *Euchone limnicola* | N | | | | | | | | | | 1 | | 2 | | | | | | | | |

| | SPECIES STATUS | Eureka Marina | Fairhaven Terminal | | | Fields Landing | | | Forest Products | Redwood Chip Export | Redwood Marina | | | Scheneider Dock | Sierra Pacific | US Coast Guard | | | Woodley Island | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Shallow | Deep | Intertidal | Shallow | Deep | Intertidal | Shallow | Shallow | Shallow | Deep | Intertidal | Shallow | Shallow | Shallow | Deep | Intertidal | Shallow | Deep | Intertidal | Shallow |
| **Spionidae** | | | | | | | | | | | | | | | | | | | | | |
| *Boccardia proboscidea* | N | | | | | | | | | | | 3 | | | | | | | | 4 | |
| *Dipolydora caulleryi* | C | | | | | | | | 1 | 2 | | | | | | | | | | | 2 |
| *Paraprionospio alata* | C | 1 | | | | | | | | | | | | | | | | | | | |
| *Pygospio californica* | C | | | | | | | | | | | | | | | | 1 | | | | |
| *Scolelepis squamata complex* | C | | | | | | | | | | | | 2 | | | | | | | | |
| **Terebelledae** | | | | | | | | | | | | | | | | | | | | | |
| *Amaeana occidentalis* | N | 2 | 1 | | | | | | 2 | 4 | | 1 | 3 | 4 | 3 | | | | 2 | | |
| *Polycirrus sp.* | U | | | | | | | | | | 3 | | | | | | | 1 | 1 | | 2 |
| **Trochochaetidae** | | | | | | | | | | | | | | | | | | | | | |
| *Trochochaeta franciscanum* | N | | | | | | | | | | | | 1 | | | | | | | | |
| **ARTHROPODA** | | | | | | | | | | | | | | | | | | | | | |
| **Amphipoda** | | | | | | | | | | | | | | | | | | | | | |
| *Allorchestes angusta* | N | | | | | | 1 | | | | | | | 1 | | | | | | 1 | |
| *Americhelidium shoemakeri* | N | | | | | | | | | | | | | | | 2 | | | | | |
| *Ampithoe lacertosa* | N | | | | | 2 | 1 | | 1 | | | 1 | | | 1 | | | | | | |
| *Ampithoe valida* | I | | | | | | | | | | | 3 | | | | | | | | 2 | |
| *Aogammarus pugettensis* | N | | | | | | | | | | | 1 | | | | | | | | | |
| *Eohaustorius washingtonianus* | N | | | 1 | | | | | | | | | | | | | | | | | |
| *Grandidierella japonica* | I | | | | | | 5 | 1 | 4 | | 1 | 4 | | 1 | 5 | | | | 1 | 1 | 1 |
| *Maera similis* | N | | | | | | | | | | 1 | | | | | | | | | | |
| *Megamoera subtener* | N | | | | | 1 | | | | 1 | 4 | | | | | | | | | | |
| *Monocorophium acherusicum* | I | | | | | | | | 1 | | | 1 | | | | | | | | | |
| *Monocorophium insidiosum* | I | | | | | | 1 | | 4 | | 1 | | | | 1 | | | | | | 1 |
| *Paracorophium lucasi* | I | 2 | | | | 2 | 4 | 3 | 3 | | 3 | 3 | | | 4 | | | | | | |
| *Pontogeneia rostrata* | N | | | | | | 1 | | 3 | | | | | | | | | | | | |
| *Protomedeia prudens* | N | 1 | | | 2 | 1 | 2 | 3 | | | 1 | | 1 | | | | 1 | | | | |
| *Rhepoxynius sp.* | U | | | | | | 1 | 2 | | | | | | | | | | | | | |
| **Caprellidae** | | | | | | | | | | | | | | | | | | | | | |
| *Caprella californica* | N | | | | 1 | 2 | 5 | 4 | 4 | 1 | 1 | 1 | | | 5 | | | | 1 | | 1 |
| *Caprella cf. alaskana* | I | | | | | | | | | | | | | | 1 | | | | | | |
| *Caprella septentrionalis* | N | | | | | | | | | 1 | | | | | | | | | | | |
| *Caprella sp. B* | U | | 1 | | | 3 | | | | | | | | | | | 1 | | | | |
| **Cirripedia** | | | | | | | | | | | | | | | | | | | | | |
| *Balanus crenatus* | N | | | | | | 1 | | | | 2 | | 2 | | 2 | | | 3 | | | 1 |
| **Cumacea** | | | | | | | | | | | | | | | | | | | | | |
| *Lamprops augustinensis* | N | | | | | | | | | | | | | | | 2 | | 1 | | | |
| **Decapoda** | | | | | | | | | | | | | | | | | | | | | |
| *Cancer productus* | N | | | | | | 1 | | | 2 | 1 | 3 | | | | | | | | | |
| *Cancer sp.* | U | | | | | | | | | | | | | | | | | 1 | | | |
| *Crangon nigricauda* | N | 3 | | | | 2 | 1 | 2 | | 1 | | | | 2 | 1 | | | 1 | 1 | | |
| *Emerita analoga* | N | | | | | | | | | | | | | | | | 1 | | | | |
| *Hemigrapsus oregonensis* | N | 1 | | | | | | | 2 | | | 3 | | | 2 | | | | 1 | | 1 |
| *Heptacarpus stimpsoni* | N | | | | | | | | | | 1 | | | | 1 | | | | | | |
| Hippolytidae | U | | | | | | | | 1 | 1 | | | | | | | | | | | |
| *Lophopanopeus bellus* | N | | | | | | | | | | 2 | | | | | | | | | | |
| *Metacarcinus magister* | N | | | | | 2 | | | | | | | | | | | | 1 | | | |
| *Neotrypaea californiensis* | N | | | 1 | | | | | | | | | | | | | | | | | |
| *Neotrypaea sp.* | U | | | | | | | | | | | 1 | 1 | | | | | | | | |
| *Pagurus sp.* | U | | 1 | | | | 1 | | | | | | | | 1 | | | | | | |
| *Pinnixa shmitti* | N | 3 | 1 | | | | | | | | 1 | | 1 | | 3 | | | | | | |
| Pinnotheridae | U | | | 1 | | | | | | | | | | | | | | | | | |
| *Pugettia gracilis* | N | | | | | | 1 | | 1 | | | | | | | | | | | | |
| *Romaleon antennarium* | N | | | | | 1 | 1 | 1 | 3 | 1 | | | 1 | | 2 | 2 | | | | | 1 |
| *Scleroplax granulata* | N | | | | | | | | | | 1 | | 1 | | 1 | 1 | | | | | 1 |
| **Isopoda** | | | | | | | | | | | | | | | | | | | | | |

| | SPECIES STATUS | Eureka Marina | Fairhaven Terminal | | | Fields Landing | | | Forest Products | Redwood Chip Export | Redwood Marina | | | Scheneider Dock | Sierra Pacific | US Coast Guard | | | Woodley Island | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Shallow | Deep | Intertidal | Shallow | Deep | Intertidal | Shallow | Shallow | Shallow | Deep | Intertidal | Shallow | Shallow | Shallow | Deep | Intertidal | Shallow | Deep | Intertidal | Shallow |
| **Isopoda** | | | | | | | | | | | | | | | | | | | | | |
| *Exirolana linguifrons* | N | | | | | | | | | | | | | | | | 3 | | | | |
| *Idotea rufescens* | N | | | | | | | | 3 | | | 2 | | | | | | | | | |
| *Paracerceis cordata* | N | | | | | | | | | 1 | | | | | 1 | | | | | | |
| **Tanaidacea** | | | | | | | | | | | | | | | | | | | | | |
| *Leptochelia sp.* | U | | | | | | 3 | | | | | | | | 1 | | | | | 1 | |
| **BRYOZOA** | | | | | | | | | | | | | | | | | | | | | |
| **Bryozoa** | | | | | | | | | | | | | | | | | | | | | |
| *Celleporella hyalina* | C | | | | | 2 | | | | | 4 | | | | | | | | | | |
| *Electra sp.* | U | | | | | | 1 | | | | 3 | | | | | | | | | | |
| *Microporella californica* | N | | | | | 2 | | | | | 4 | | | | | | | | | | |
| *Parasmittina collifera* | N | | | | | | | | | | 1 | | | | | | | | | | |
| *Parasmittina sp.* | U | | | | | | | | | | 2 | | | | | | | | | | |
| *Tegella sp.* | U | | | | | | | | | | 1 | | | | | | | | | | |
| *Watersipora subtorquata* | I | 3 | | | | | | | | 1 | | | | | | | | | | | |
| **CNIDARIA** | | | | | | | | | | | | | | | | | | | | | |
| **Anthozoa** | | | | | | | | | | | | | | | | | | | | | |
| Anthozoa | U | | | | | | | | | 1 | 1 | | | | | | | | | | |
| **CTENOPHORA** | | | | | | | | | | | | | | | | | | | | | |
| **Ctenophora** | | | | | | | | | | | | | | | | | | | | | |
| Ctenophora | U | | | 1 | | | | | | | | | | | | | | | | | |
| **ECHINODERMATA** | | | | | | | | | | | | | | | | | | | | | |
| **Asterozoa** | | | | | | | | | | | | | | | | | | | | | |
| *Amphipholis squamata* | C | | | | | | | | | | 1 | | | | | | | | | | |
| *Amphipoda cf. occidentalis* | U | | | | | | | 1 | | 1 | | | | | | | | | | | |
| *Amphipodia digitata* | N | 1 | | | | | | | | | | | | 2 | | | | | | | |
| *Amphipodia occidentalis* | C | | | | 1 | | 2 | | | | | | 1 | | | | | | | | |
| *Ophiothrix spiculata* | N | 1 | | | | | | | | | | | | | | | | | | | |
| **Echinozoa** | | | | | | | | | | | | | | | | | | | | | |
| *Dendraster excentricus* | N | | | | | | | | | | | | | | | | | | 1 | | |
| *Paracaudina chilensis* | I | | | 3 | | | | | | | | | | | | | | | | | |
| **MOLLUSCA** | | | | | | | | | | | | | | | | | | | | | |
| **Bivalvia** | | | | | | | | | | | | | | | | | | | | | |
| *Clinocardium nutalli* | N | | | | | | 1 | 1 | | | 1 | | | | 2 | 2 | | 2 | 2 | | |
| *Cryptomia californica* | N | | | | | | | | | 1 | 3 | | | | | | 1 | | | | |
| *Leukoma staminea* | N | | | | | | 1 | 2 | 2 | | | | | | | | | | | 2 | |
| *Lyonsia californica* | N | 1 | | | | | 1 | | | 1 | | | 3 | 1 | 2 | | | | 1 | | 2 |
| *Macoma nasuta* | N | 5 | 3 | 2 | 4 | 5 | 4 | 5 | 5 | 5 | 3 | 5 | 5 | 4 | 5 | 2 | | 2 | 3 | 3 | 3 |
| *Macrotoma sp.* | U | | | | | | 3 | 3 | 4 | 2 | 1 | | 2 | 4 | 1 | | | 3 | 1 | | 2 |
| *Musculista senhousia* | I | | 1 | | | | | | | | 1 | | | | | | 1 | | | | |
| *Mytilus trossulus* | N | | | | | | | | 1 | | | | | | | | | | | | |
| *Saxidomus nuttalli* | N | | | | | | | 3 | | | | | | | | | 1 | | | | 1 |
| *Saxidomus sp.* | U | | | | | | | | 1 | | | | | | | | | | | | |
| *Solen sicarius* | N | 1 | | | | | | | | | | | 3 | 1 | | | | | 1 | | 1 |
| *Tellina bodegensis* | N | | | | | | | | | 2 | | | | 2 | 1 | | | | 2 | | |
| *Venerupis philippinarum* | I | | | | | 1 | 1 | | | | | | | | | | 1 | | | | |
| **Gastropoda** | | | | | | | | | | | | | | | | | | | | | |
| *Alia carinata* | N | | | | 1 | | | | 4 | 2 | | 3 | | 1 | 3 | | 1 | 1 | | | |
| *Cylinchna attonsa* | N | 1 | | | | | | | | | | | | | | | 1 | | | | |
| *Dirona picta* | N | | | | | | | | | 2 | | | 1 | 1 | | | 1 | | | | |
| *Lacuna marmorata* | N | | | | | | | | | | | 1 | | | | | 1 | | | | |
| *Nassarius mendicus* | N | 3 | 2 | | | | 1 | 2 | | 2 | 3 | | 2 | 1 | 3 | | 1 | 2 | 1 | | |
| *Olivella biplicata* | N | | 3 | | | | 1 | | | | | | | | | 1 | 1 | 1 | | | |
| *Olivella pycna* | N | 1 | 3 | | | | 1 | 1 | 1 | | | | | 4 | 1 | | 1 | 1 | | | |
| *Philine auriformis* | I | 1 | | | | | | | | | | | | 1 | | | 1 | | | | |
| *Philine orientalis* | N | 1 | | | | | | | | 1 | | | | | 1 | | 1 | | | | |

| | SPECIES STATUS | Eureka Marina | Fairhaven Terminal | | | Fields Landing | | | Forest Products | Redwood Chip Export | Redwood Marina | | | Scheneider Dock | Sierra Pacific | US Coast Guard | | | Woodley Island | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Shallow | Deep | Intertidal | Shallow | Deep | Intertidal | Shallow | Shallow | Shallow | Deep | Intertidal | Shallow | Shallow | Shallow | Deep | Intertidal | Shallow | Deep | Intertidal | Shallow |
| *Phyllaplysia taylori* | N | | | | | | | | 1 | 1 | | 2 | | | | | 1 | | | | |
| *Rictaxis punctocaelatus* | N | 5 | | | | | | 1 | 1 | 2 | | | 1 | | 1 | | 1 | 1 | 2 | | |
| *Turbonilla sp.* | U | | | | 1 | | | | | | | | | 1 | | | 1 | | | | |
| **Nudibranchia** | | | | | | | | | | | | | | | | | | | | | |
| Nudibranchia | U | | | | | | | 1 | | | | 1 | 1 | | | | 1 | | | | |
| **Octopodidae** | | | | | | | | | | | | | | | | | | | | | |
| Octopodidae | N | | | | | | | | 1 | | | | | | | | 1 | | | | |
| **NEMERTEA** | | | | | | | | | | | | | | | | | | | | | |
| **Nemertea** | | | | | | | | | | | | | | | | | | | | | |
| Nemertea | U | 1 | | 1 | | | | | 2 | 2 | | | | 1 | 2 | | 1 | | | | |
| **PHORONIDA** | | | | | | | | | | | | | | | | | | | | | |
| **Phoronida** | | | | | | | | | | | | | | | | | | | | | |
| Phoronida | U | 4 | | | | | 4 | | | 4 | | 3 | | 4 | 1 | | 1 | | 1 | 1 | 1 |
| **PORIFERA** | | | | | | | | | | | | | | | | | | | | | |
| **Porifera** | | | | | | | | | | | | | | | | | | | | | |
| Porifera | U | | | | | | | | | | 2 | | | | | | 1 | | 1 | | |

# Chapter 4: Macro-Zooplankton Communities

**Introduction**

To detect the presence of non-native invertebrate taxa within macro-zooplankton assemblages, we sampled four estuaries including Humboldt Bay, Marina del Rey, Port Hueneme, and San Francisco Bay. For the first three estuaries, we sampled 10 sites per estuary in one year (2015), using both pump sampling and plankton net tows at each site (see below). For San Francisco Bay, we sampled 30-32 sites in each of three years (2014-2016), using plankton net tows. The specific locations and dates are indicated in Appendix 4.1.

For pump samples, a modified trash pump (North Star S106120 model; Honda GX160 gas motor) coupled to a plankton net assembly (0.75m diameter net; 80µm mesh size) was used to collect and filter zooplankton at 1m depth over 10 minutes, totaling 5$m^3$ water volume filtered per sample. Five replicate pump samples were collected across 3-5 random locations within each site (Table 4.1). Samples were preserved in either 95% ethanol or 10% formalin in preparation for taxonomic identification of zooplankton species through genetic or morphological techniques, respectively. At each randomly-selected location within a site where pump sampling took place, latitude and longitude were recorded using a handheld GPS unit, and water temperature, dissolved oxygen, and salinity were measured at 1m depth.

For the three bays with pump sampling, we also collected two replicate vertical net tows in open water adjacent to each pump site (Table 4.1). A weighted plankton net (0.50m diameter; 80µm mesh size; 5-10lb weight) was deployed to 5m depth and pulled vertically up through the water column to collect the sample. The first tow sample was preserved in 95% ethanol and the second tow sample was preserved in 10% formalin in preparation for taxonomic identification of zooplankton species through genetic or morphological techniques, respectively. Latitude and longitude were recorded for the deployment location of the two replicate tows using a handheld GPS unit. Additionally, water temperature, dissolved oxygen, and salinity were measured at 1m and 5m depths.

For San Francisco Bay, we sampled 30-32 sites in each of the three years using vertical net tow as described above. For each site, two samples were collected for genetic analyses, including a vertical tow from each 5m and 10m depth. An identical pair for samples was collected for morphological samples from each station, along with an additional sample (5m depth) for voucher specimens. All samples were preserved as described above for each sample type.

**Table 4.1. Summary of zooplankton samples collected in California (2014-2015).** Samples were collected for both genetic and morphological analysis from four different estuaries, using pump and vertical net tow methods. Shown are the number of sampled in each bay and year per method, and the number of these samples allocated for each genetic and morphological analyses.

| Bay | Year | Month | Method | Total Sites | Total Samples | Metagenetics | Morphology |
|---|---|---|---|---|---|---|---|
| San Francisco | 2014 | June | Tow | 30 | 180 | 60 | 120 |
| San Francisco | 2015 | June | Tow | 32 | 192 | 64 | 128 |
| Humboldt | 2015 | June | Pump | 10 | 50 | 30 | 20 |
| | | | Tow | 10 | 20 | 10 | 10 |
| Marina Del Rey | 2015 | July | Pump | 10 | 50 | 30 | 20 |
| | | | Tow | 10 | 20 | 10 | 10 |
| Port Hueneme | 2015 | July | Pump | 10 | 50 | 30 | 20 |
| | | | Tow | 10 | 20 | 10 | 10 |
| San Francisco | 2016 | July | Tow | 32 | 192 | 64 | 128 |

Thus, across the four estuaries, we collected a total of 774 zooplankton samples for analysis (Table 4.1). Once collected, plankton samples were shipped to SERC to be curated and organized, then shipped to collaborating laboratories for morphological and genetic analyses as follows:

- **Morphological Analyses.** In general, for each of the pump sample sites, two replicates were sent for morphological analyses to Jeff Cordell, University of Washington. This included a formalin-preserved sample for identification of macro-zooplankton species present, and an ethanol-preserved sample for collection of identified voucher specimens of each taxon for DNA barcoding by MLML. For the net tow samples, the formalin-preserved samples were also sent to Jeff Cordell for identification of macro-zooplankton species present.

- **Genetic Analyses.** The remaining ethanol preserved samples (including pump samples and net tow samples) per site were sent directly to MLML for whole community analysis using next generation sequencing (see Chapter 5).

### Results

The morphological analyses of zooplankton revealed only NIS that were previously detected in California. NIS detected in morphological analyses were restricted primarily to the copepods (Table 4.2), which were already known to be present in the respective bays, based upon previous studies by our research group and others. While other NIS are likely present (see Chapter 6), most of these are meroplankton, and species-level identifications are often not possible for these larval forms, which lack diagnostic morphological characteristics.

**Table 4.2: List of zooplankton taxa detected by morphological analysis per bay.** NIS detected are indicated by an asterisk (*) in each column, and species names are also highlighted in grey.

| Taxon | 2014-2016 San Francisco Bay | 2015 Humboldt Bay | 2015 Marina del Rey | 2015 Port Hueneme |
|---|---|---|---|---|
| **ANNELIDA** | | | | |
| **Clitellata** | | | | |
| **Oligochaeta** | | | | |
| Oligochaeta | 8 | 0 | 0 | 0 |
| **Polychaeta** | | | | |
| Oweniidae | 0 | 7 | 0 | 0 |
| Polychaeta | 10 | 20 | 13 | 15 |
| *Polygordius* sp. | 0 | 1 | 0 | 0 |
| Syllidae | 3 | 0 | 1 | 0 |
| **BRYOZOA** | | | | |
| Bryozoa | 0 | 2 | 10 | 16 |
| **CHAETOGNATHA** | | | | |
| Chaetognatha | 1 | 20 | 11 | 5 |
| **CHELICERATA** | | | | |
| **Arachnida** | | | | |
| Acarina | 2 | 0 | 0 | 0 |
| **CHORDATA** | | | | |
| **Actinopterygii** | | | | |
| Teleostei | 4 | 17 | 14 | 20 |
| **Tunicata** | | | | |
| **Appendicularia** | | | | |
| *Fritillaria* sp. | 0 | 3 | 0 | 0 |
| *Oikopleura dioica* | 4 | 14 | 10 | 16 |

| Taxon | | | 2014-2016 San Francisco Bay | 2015 Humboldt Bay | 2015 Marina del Rey | 2015 Port Hueneme |
|---|---|---|---|---|---|---|
| | **Ascidiacea** | | | | | |
| | | Ascidiacea | 7 | 1 | 8 | 19 |
| | | *Botryllus/Botrylloides* spp. | 7 | 3 | 6 | 7 |
| | **Doliolida** | | | | | |
| | | Doliolida | 0 | 2 | 1 | 0 |
| **CILIOPHORA** | | | | | | |
| | **Tintinnida** | | | | | |
| | | Tintinnida | 3 | 10 | 10 | 13 |
| **CNIDARIA** | | | | | | |
| | **Hydrozoa** | | | | | |
| | | *Aglantha digitale* | 0 | 0 | 3 | 0 |
| | | Hydrozoa | 3 | 10 | 10 | 5 |
| | | *Obelia* sp. | 0 | 3 | 0 | 3 |
| | | Siphonophora | 0 | 3 | 1 | 0 |
| **CRUSTACEA** | | | | | | |
| | **Amphipoda** | | | | | |
| | | Caprellidae | 2 | 2 | 0 | 4 |
| | | Corophiidae | 3 | 2 | 0 | 1 |
| | | Gammaridea | 5 | 10 | 2 | 7 |
| | | Hyperiidea | 0 | 1 | 0 | 0 |

| Taxon | 2014-2016 San Francisco Bay | 2015 Humboldt Bay | 2015 Marina del Rey | 2015 Port Hueneme |
|---|---|---|---|---|
| **Branchiopoda** | | | | |
| **Cladocera** | | | | |
| *Bosmina* sp. (FW) | 2 | 0 | 0 | 0 |
| *Ceriodaphnia* sp. (FW) | 2 | 0 | 0 | 0 |
| Chydoridae (FW) | 1 | 0 | 0 | 0 |
| *Daphnia* spp. (FW) | 1 | 0 | 0 | 0 |
| *Diaphanosoma* sp. (FW) | 2 | 0 | 0 | 0 |
| *Evadne nordmanni* | 0 | 18 | 0 | 0 |
| *Evadne spinifera* | 0 | 0 | 6 | 0 |
| *Holopedium gibberum* (FW) | 1 | 0 | 0 | 0 |
| *Penilia avirostris* | 0 | 0 | 10 | 0 |
| *Pleopsis polyphemoides* | 0 | 0 | 1 | 1 |
| *Pleuroxus* sp. (FW) | 1 | 0 | 0 | 0 |
| *Podon leuckarti* | 0 | 16 | 0 | 0 |
| *Pseudevadne tergestina* | 0 | 0 | 11 | 2 |
| *Sida crystallina* (FW) | 2 | 0 | 0 | 0 |
| *Simocephalus* sp. (FW) | 2 | 0 | 0 | 0 |
| **Cirripedia** | | | | |
| Cirripedia | 9 | 20 | 12 | 19 |

| Taxon | 2014-2016 San Francisco Bay | 2015 Humboldt Bay | 2015 Marina del Rey | 2015 Port Hueneme |
|---|---|---|---|---|
| **Copepoda** | | | | |
| **Calanoida** | | | | |
| *Acartia (Acartiura) hudsonica* | 4 | 12 | 0 | 16 |
| *Acartia (Acartiura)* sp. | 1 | 3 | 0 | 0 |
| *Acartia californiensis* | 9 | 8 | 9 | 7 |
| *Acartia danae* | 0 | 0 | 0 | 8 |
| *Acartia* spp. | 5 | 20 | 17 | 20 |
| *Acartia tonsa* | 4 | 9 | 12 | 15 |
| *Acartiella sinensis** | 2* | 0 | 0 | 0 |
| Calanoida | 2 | 4 | 2 | 1 |
| *Calanus pacificus* | 0 | 4 | 0 | 0 |
| *Calanus* sp. | 0 | 5 | 2 | 2 |
| *Calocalanus* sp. | 0 | 0 | 0 | 1 |
| *Calocalanus styliremis* | 0 | 0 | 0 | 1 |
| *Calocalanus tenuis* | 0 | 0 | 0 | 1 |
| *Centropages abdominalis* | 0 | 4 | 0 | 0 |
| *Centropages bradyi* | 0 | 0 | 1 | 0 |
| *Centropages* spp. | 0 | 5 | 0 | 0 |
| *Clausocalanus furcatus* | 0 | 0 | 9 | 1 |
| *Clausocalanus* sp. | 0 | 0 | 9 | 14 |
| *Ctenocalanus vanus* | 0 | 1 | 0 | 0 |
| Eucalanidae | 0 | 2 | 0 | 0 |
| *Eurytemora americana* | 0 | 10 | 0 | 0 |

| Taxon | 2014-2016 San Francisco Bay | 2015 Humboldt Bay | 2015 Marina del Rey | 2015 Port Hueneme |
|---|---|---|---|---|
| *Eurytemora pacifica* | 0 | 0 | 0 | 3 |
| *Eurytemora* sp. | 0 | 14 | 0 | 4 |
| *Lucicutia gemina* | 0 | 1 | 0 | 0 |
| *Mecynocera clausi* | 0 | 0 | 0 | 1 |
| *Metridia* sp. | 0 | 1 | 0 | 0 |
| *Microcalanus* sp. | 0 | 1 | 0 | 0 |
| *Osphranticum labronectum* (FW) | 1 | 0 | 0 | 0 |
| *Paracalanus indicus* | 0 | 0 | 0 | 1 |
| *Paracalanus quasimodo* | 1 | 0 | 0 | 0 |
| *Paracalanus* sp. | 6 | 11 | 14 | 20 |
| Pontellidae | 0 | 3 | 5 | 2 |
| *Pontellopsis* sp. | 0 | 0 | 1 | 0 |
| *Pseudocalanus mimus* | 1 | 8 | 0 | 0 |
| *Pseudocalanus* sp. | 1 | 13 | 0 | 0 |
| *Pseudodiaptomus euryhalinus* | 0 | 0 | 0 | 0 |
| *Pseudodiaptomus forbesi** | 4* | 0 | 0 | 0 |
| *Pseudodiaptomus marinus** | 2* | 1* | 0 | 0 |
| *Pseudodiaptomus euryhalinus* | 0 | 0 | 0 | 1 |
| *Pseudodiaptomus* sp. | 10 | 2 | 10 | 8 |
| *Sinocalanus doerrii* (FW) | 1 | 0 | 0 | 0 |
| *Skistodiaptomus pallidus* (FW) | 1 | 0 | 0 | 0 |

| Taxon | | 2014-2016 San Francisco Bay | 2015 Humboldt Bay | 2015 Marina del Rey | 2015 Port Hueneme |
|---|---|---|---|---|---|
| | *Stephos pacificus** | 1* | 0 | 0 | 0 |
| | *Stephos* sp. | 1 | 0 | 0 | 0 |
| | *Tortanus discaudatus* | 1 | 1 | 0 | 0 |
| | *Tortanus* sp. | 6 | 7 | 0 | 1 |
| **Caligoida** | | | | | |
| | Caligoida | 4 | 5 | 0 | 3 |
| **Canuelloida** | | | | | |
| | *Coullana canadensis* | 2 | 0 | 0 | 0 |
| | *Longipedia* sp. | 0 | 8 | 1 | 2 |
| **Clausidiidae** | | | | | |
| | Clausidiidae | 8 | 15 | 0 | 2 |
| **Cyclopoida** | | | | | |
| | *Acanthocyclops* sp. (FW) | 1 | 0 | 0 | 0 |
| | cf. *Tropocyclops* sp. (FW) | 1 | 0 | 0 | 0 |
| | *Corycaeus amazonicus* | 0 | 0 | 3 | 1 |
| | *Corycaeus anglicus* | 0 | 9 | 3 | 9 |
| | *Corycaeus* cf. *erythraeus* | 0 | 0 | 0 | 1 |
| | *Corycaeus* cf. *latus* | 0 | 0 | 3 | 1 |
| | *Corycaeus* sp. | 0 | 11 | 10 | 9 |
| | Cyclopidae (FW) | 8 | 1 | 1 | 3 |
| | Cyclopoida (Parasitic) | 1 | 0 | 0 | 0 |
| | *Diacyclops thomasi* (FW) | 1 | 0 | 0 | 0 |
| | *Dioithona oculata* | 0 | 2 | 17 | 20 |

| Taxon | | 2014-2016 San Francisco Bay | 2015 Humboldt Bay | 2015 Marina del Rey | 2015 Port Hueneme |
|---|---|---|---|---|---|
| | *Eucyclops* sp. | 2 | 0 | 0 | 0 |
| | *Farranula curta* | 0 | 0 | 0 | 2 |
| | *Limnoithona sinensis* (FW)* | 1* | 0 | 0 | 0 |
| | *Limnoithona tetraspina** | 4* | 0 | 0 | 0 |
| | *Macrocyclops albidus* (FW) | 1 | 0 | 0 | 0 |
| | *Mesocyclops* sp. (FW) | 1 | 0 | 0 | 0 |
| | *Oithona atlantica* | 0 | 3 | 3 | 2 |
| | *Oithona davisae** | 10* | 3* | 17* | 7* |
| | *Oithona nana* | 0 | 0 | 1 | 0 |
| | *Oithona plumifera* | 0 | 0 | 0 | 2 |
| | *Oithona similis* | 2 | 18 | 10 | 20 |
| | *Oithona* sp. | 0 | 0 | 0 | 1 |
| | *Oncaea* sp. | 0 | 10 | 1 | 5 |
| | *Paroithona* sp. | 0 | 1 | 0 | 0 |
| | Thaumatopsyllidae | 0 | 0 | 0 | 1 |
| **Harpacticoida** | | | | | |
| | Ectinosomatidae | 0 | 1 | 0 | 0 |
| | *Emerita analoga* | 0 | 0 | 4 | 0 |
| | *Euterpina acutifrons* | 10 | 12 | 18 | 14 |
| | Harpacticoida | 10 | 15 | 3 | 7 |
| | *Harpacticus* sp. | 0 | 5 | 0 | 10 |
| | *Microsetella norvegica* | 1 | 4 | 1 | 5 |
| | *Microsetella rosea* | 0 | 3 | 0 | 1 |
| | *Microsetella* sp. | 0 | 0 | 1 | 0 |

| Taxon | 2014-2016 San Francisco Bay | 2015 Humboldt Bay | 2015 Marina del Rey | 2015 Port Hueneme |
|---|---|---|---|---|
| *Neotachidius triangularis* | 1 | 0 | 0 | 0 |
| *Porcellidium* sp. | 0 | 3 | 0 | 2 |
| *Pseudobradya* sp. | 3 | 5 | 0 | 0 |
| Tachidiidae | 5 | 4 | 0 | 0 |
| *Tisbe* spp. | 4 | 1 | 0 | 1 |
| *Zaus* sp. | 0 | 2 | 0 | 0 |
| **Monstrilloida** | | | | |
| Monstrilloida | 0 | 0 | 0 | 1 |
| **Poecilostomatoida** | | | | |
| Ergasilidae | 1 | 0 | 0 | 0 |
| Poecilostomatoida | 6 | 8 | 2 | 6 |
| Copepoda | 14 | 20 | 20 | 20 |
| Copepoda (Parasitic) | 0 | 2 | 2 | 1 |
| **Cumacea** | | | | |
| Cumacea | 0 | 2 | 0 | 2 |
| **Decapoda** | | | | |
| **Brachyura** | | | | |
| Cancridae | 1 | 4 | 0 | 0 |
| *Fabia subquadrata* | 0 | 3 | 0 | 0 |
| Grapsidae | 4 | 0 | 4 | 3 |
| *Lophopanopeus* sp. | 1 | 0 | 0 | 0 |
| Pinnotheridae | 2 | 16 | 0 | 0 |
| *Rhithropanopeus harrisii** | 1* | 0 | 0 | 0 |
| Xanthidae | 0 | 2 | 0 | 0 |

| Taxon | | 2014-2016 San Francisco Bay | 2015 Humboldt Bay | 2015 Marina del Rey | 2015 Port Hueneme |
|---|---|---|---|---|---|
| **Callianassidae** | | | | | |
| | *Neotrypaea* sp. | 1 | 1 | 0 | 0 |
| **Caridea** | | | | | |
| | Caridea | 4 | 11 | 3 | 1 |
| | Hippolytidae | 0 | 1 | 0 | 0 |
| | Pandalidae | 0 | 0 | 0 | 1 |
| **Crangonoidea** | | | | | |
| | Crangonidae | 1 | 3 | 1 | 0 |
| **Paguridae** | | | | | |
| | Paguridae | 0 | 2 | 0 | 0 |
| | Penaeidae | 0 | 0 | 8 | 0 |
| **Porcellanidae** | | | | | |
| | Porcellanidae | 1 | 0 | 0 | 0 |
| **Euphausiacea** | | | | | |
| | Euphausiacea | 0 | 1 | 4 | 0 |
| | *Thysanoessa* sp. | 0 | 0 | 0 | 0 |
| **Facetotecta** | | | | | |
| | Facetotecta | 0 | 1 | 0 | 0 |
| **Isopoda** | | | | | |
| | Cirolanidae | 0 | 1 | 0 | 1 |
| | Isopoda | 6 | 5 | 2 | 1 |
| | Munnidae | 1 | 0 | 0 | 0 |
| | Sphaeromatidae | 2 | 0 | 0 | 0 |
| **Mysidacea** | | | | | |
| | Mysidacea | 1 | 0 | 0 | 1 |

| Taxon | | 2014-2016 San Francisco Bay | 2015 Humboldt Bay | 2015 Marina del Rey | 2015 Port Hueneme |
|---|---|---|---|---|---|
| **Mysidae** | | | | | |
| | *Alienacanthomysis macropsis* | 0 | 1 | 0 | 0 |
| **Ostracoda** | | | | | |
| | Ostracoda | 7 | 4 | 1 | 3 |
| **Tanaidacea** | | | | | |
| | Tanaidacea | 3 | 1 | 0 | 2 |
| **CTENOPHORA** | | | | | |
| | Ctenophora | 0 | 4 | 0 | 0 |
| | *Pleurobrachia* sp. | 0 | 4 | 0 | 0 |
| **DINOFLAGELLATA** | | | | | |
| | *Noctiluca* sp. | 0 | 18 | 0 | 0 |
| **ECHINODERMATA** | | | | | |
| | Echinodermata | 0 | 6 | 5 | 10 |
| **FORAMINIFERA** | | | | | |
| | Foraminifera | 0 | 0 | 0 | 1 |
| **INSECTA** | | | | | |
| | Chironomidae | 1 | 0 | 0 | 0 |
| **MOLLUSCA** | | | | | |
| **Bivalvia** | | | | | |
| | Bivalvia | 9 | 18 | 11 | 10 |
| **Gastropoda** | | | | | |
| | Gastropoda | 3 | 18 | 11 | 18 |
| | *Littorina* sp. | 0 | 3 | 0 | 2 |
| | Pteropoda | 0 | 0 | 9 | 1 |

| Taxon | 2014-2016 San Francisco Bay | 2015 Humboldt Bay | 2015 Marina del Rey | 2015 Port Hueneme |
|---|---|---|---|---|
| **NEMATODA** | | | | |
| Nematoda | 8 | 18 | 0 | 3 |
| Nemertea | 0 | 1 | 2 | 0 |
| **PHORONIDA** | | | | |
| Phoronida | 1 | 13 | 0 | 0 |
| **PLATYHELMINTHES** | | | | |
| Turbellaria | 9 | 11 | 14 | 10 |
| **ROTIFERA** | | | | |
| Rotifera | 6 | 16 | 1 | 19 |
| **UNIDENTIFIED** | | | | |
| Unidentified | 5 | 6 | 8 | 13 |

## Appendix 4.1: Survey Locations by Bay and Year

The tables below indicate locations and dates for macro-zooplankton surveys for each bay and year. A separate table is shown for each bay and year, indicating the sampling date, method, location, and number of replicate samples (for total, metagenetic analysis, and morphological analysis).

### ***San Francisco Bay 2014***

| Bay | Year | Month | Method | Site | Landmark | Latitude | Longitude | Total Replicates | Metagenetics | Morphology |
|---|---|---|---|---|---|---|---|---|---|---|
| San Francisco | 2014 | June | Tow | SFHS-01 | North of Dumbarton Bridge | 37.5111 | -122.1295 | 6 | 2 | 4 |
| San Francisco | 2014 | June | Tow | SFHS-02 | Dumbarton Bridge | 37.5349 | -122.1710 | 6 | 2 | 4 |
| San Francisco | 2014 | June | Tow | SFHS-03 | Between Dumbarton and San Mateo Bridges | 37.5519 | -122.1955 | 6 | 2 | 4 |
| San Francisco | 2014 | June | Tow | SFHS-04 | Between Dumbarton and San Mateo Bridges | 37.5720 | -122.2322 | 6 | 2 | 4 |
| San Francisco | 2014 | June | Tow | SFHS-05 | San Mateo Bridge | 37.5805 | -122.2518 | 6 | 2 | 4 |
| San Francisco | 2014 | June | Tow | SFHS-06 | San Mateo Bridge | 37.5866 | -122.2608 | 6 | 2 | 4 |
| San Francisco | 2014 | June | Tow | SFHS-07 | North of San Mateo Bridge | 37.6039 | -122.2842 | 6 | 2 | 4 |
| San Francisco | 2014 | June | Tow | SFHS-08 | Burlingame | 37.6296 | -122.3168 | 6 | 2 | 4 |
| San Francisco | 2014 | June | Tow | SFHS-09 | San Francisco International Airport | 37.6574 | -122.3141 | 6 | 2 | 4 |
| San Francisco | 2014 | June | Tow | SFHS-10 | South San Francisco | 37.6861 | -122.3184 | 6 | 2 | 4 |
| San Francisco | 2014 | June | Tow | SFHS-11 | South San Francisco | 37.7085 | -122.3596 | 6 | 2 | 4 |
| San Francisco | 2014 | June | Tow | SFHS-12 | Richmond Marina | 37.7355 | -122.3603 | 6 | 2 | 4 |
| San Francisco | 2014 | June | Tow | SFHS-13 | Across from Alameda | 37.7656 | -122.3775 | 6 | 2 | 4 |
| San Francisco | 2014 | June | Tow | SFHS-14 | Bay Bridge | 37.7999 | -122.3912 | 6 | 2 | 4 |
| San Francisco | 2014 | June | Tow | SFHS-15 | Fisherman's Wharf | 37.8126 | -122.4027 | 6 | 2 | 4 |
| San Francisco | 2014 | June | Tow | SFHS-16 | Golden Gate | 37.8098 | -122.4477 | 6 | 2 | 4 |
| San Francisco | 2014 | June | Tow | SFHS-17 | Treasure Island | 37.8326 | -122.3836 | 6 | 2 | 4 |
| San Francisco | 2014 | June | Tow | SFHS-18 | Angel Island | 37.8556 | -122.4178 | 6 | 2 | 4 |
| San Francisco | 2014 | June | Tow | SFHS-19 | Between Tiburon and Angel Island | 37.8717 | -122.4465 | 6 | 2 | 4 |
| San Francisco | 2014 | June | Tow | SFHS-20 | Tiburon | 37.8830 | -122.4340 | 6 | 2 | 4 |
| San Francisco | 2014 | June | Tow | SFHS-21 | San Quentin Prison | 37.9187 | -122.4582 | 6 | 2 | 4 |
| San Francisco | 2014 | June | Tow | SFHS-22 | Richmond | 37.9304 | -122.4379 | 6 | 2 | 4 |
| San Francisco | 2014 | June | Tow | SFHS-23 | Southern San Pablo Bay | 37.9638 | -122.4379 | 6 | 2 | 4 |
| San Francisco | 2014 | June | Tow | SFHS-24 | Bay Bridge | | | | | |
| San Francisco | 2014 | June | Tow | SFHS-25 | San Pablo | | | | | |
| San Francisco | 2014 | June | Tow | SFHS-26 | San Pablo | 38.0316 | -122.3693 | 6 | 2 | 4 |
| San Francisco | 2014 | June | Tow | SFHS-27 | Northeast San Pablo Bay | 38.0495 | -122.3315 | 6 | 2 | 4 |
| San Francisco | 2014 | June | Tow | SFHS-28 | Carquinez Strait, Highway 80 bridge | 38.0634 | -122.2227 | 6 | 2 | 4 |
| San Francisco | 2014 | June | Tow | SFHS-29 | Carquinez Strait, Benecia | 38.0453 | -122.1767 | 6 | 2 | 4 |
| San Francisco | 2014 | June | Tow | SFHS-30 | Carquinez Strait, Highway 680 bridge | 38.0364 | -122.1279 | 6 | 2 | 4 |
| San Francisco | 2014 | June | Tow | SFHS-31 | Suisun Bay, Cacheco Creek | 38.0524 | -122.0943 | 6 | 2 | 4 |
| San Francisco | 2014 | June | Tow | SFHS-32 | Suisun Bay, Roe Island | 38.0761 | -122.0291 | 6 | 2 | 4 |

## *San Francisco Bay 2015*

| Bay | Year | Month | Method | Site | Landmark | Latitude | Longitude | Total Replicates | Metagenetics | Morphology |
|---|---|---|---|---|---|---|---|---|---|---|
| San Francisco | 2015 | June | Tow | SFHS-01 | North of Dumbarton Bridge | 37.5160 | -122.1304 | 6 | 2 | 4 |
| San Francisco | 2015 | June | Tow | SFHS-02 | Dumbarton Bridge | 37.5321 | -122.1650 | 6 | 2 | 4 |
| San Francisco | 2015 | June | Tow | SFHS-03 | Between Dumbarton and San Mateo Bridges | 37.5515 | -122.1948 | 6 | 2 | 4 |
| San Francisco | 2015 | June | Tow | SFHS-04 | Between Dumbarton and San Mateo Bridges | 37.5717 | -122.2142 | 6 | 2 | 4 |
| San Francisco | 2015 | June | Tow | SFHS-05 | San Mateo Bridge | 37.5852 | -122.2423 | 6 | 2 | 4 |
| San Francisco | 2015 | June | Tow | SFHS-06 | San Mateo Bridge | 37.5970 | -122.2604 | 6 | 2 | 4 |
| San Francisco | 2015 | June | Tow | SFHS-07 | North of San Mateo Bridge | 37.6070 | -122.2730 | 6 | 2 | 4 |
| San Francisco | 2015 | June | Tow | SFHS-08 | Burlingame | 37.6232 | -122.2901 | 6 | 2 | 4 |
| San Francisco | 2015 | June | Tow | SFHS-09 | San Francisco International Airport | 37.6594 | -122.3221 | 6 | 2 | 4 |
| San Francisco | 2015 | June | Tow | SFHS-10 | South San Francisco | 37.6853 | -122.3258 | 6 | 2 | 4 |
| San Francisco | 2015 | June | Tow | SFHS-11 | South San Francisco | 37.7174 | -122.3477 | 6 | 2 | 4 |
| San Francisco | 2015 | June | Tow | SFHS-12 | Richmond Marina | 37.7326 | -122.3595 | 6 | 2 | 4 |
| San Francisco | 2015 | June | Tow | SFHS-13 | Across from Alameda | 37.7634 | -122.3768 | 6 | 2 | 4 |
| San Francisco | 2015 | June | Tow | SFHS-14 | Bay Bridge | 37.7977 | -122.3915 | 6 | 2 | 4 |
| San Francisco | 2015 | June | Tow | SFHS-15 | Fisherman's Wharf | 37.8131 | -122.3994 | 6 | 2 | 4 |
| San Francisco | 2015 | June | Tow | SFHS-16 | Golden Gate | 37.8091 | -122.4468 | 6 | 2 | 4 |
| San Francisco | 2015 | June | Tow | SFHS-17 | Treasure Island | 37.8321 | -122.3887 | 6 | 2 | 4 |
| San Francisco | 2015 | June | Tow | SFHS-18 | Angel Island | 37.8474 | -122.4042 | 6 | 2 | 4 |
| San Francisco | 2015 | June | Tow | SFHS-19 | Between Tiburon and Angel Island | 37.8669 | -122.4476 | 6 | 2 | 4 |
| San Francisco | 2015 | June | Tow | SFHS-20 | Tiburon | 37.8770 | -122.4273 | 6 | 2 | 4 |
| San Francisco | 2015 | June | Tow | SFHS-21 | San Quentin Prison | 37.9087 | -122.4577 | 6 | 2 | 4 |
| San Francisco | 2015 | June | Tow | SFHS-22 | Richmond | 37.9304 | -122.4367 | 6 | 2 | 4 |
| San Francisco | 2015 | June | Tow | SFHS-23 | Southern San Pablo Bay | 37.9633 | -122.4368 | 6 | 2 | 4 |
| San Francisco | 2015 | June | Tow | SFHS-24 | Bay Bridge | 38.0093 | -122.4207 | 6 | 2 | 4 |
| San Francisco | 2015 | June | Tow | SFHS-25 | San Pablo | 38.0203 | -122.4064 | 6 | 2 | 4 |
| San Francisco | 2015 | June | Tow | SFHS-26 | San Pablo | 38.0396 | -122.3661 | 6 | 2 | 4 |
| San Francisco | 2015 | June | Tow | SFHS-27 | Northeast San Pablo Bay | 38.0548 | -122.3171 | 6 | 2 | 4 |
| San Francisco | 2015 | June | Tow | SFHS-28 | Carquinez Strait, Highway 80 bridge | 38.0610 | -122.2216 | 6 | 2 | 4 |
| San Francisco | 2015 | June | Tow | SFHS-29 | Carquinez Strait, Benecia | 38.0419 | -122.1668 | 6 | 2 | 4 |
| San Francisco | 2015 | June | Tow | SFHS-30 | Carquinez Strait, Highway 680 bridge | 38.0368 | -122.1281 | 6 | 2 | 4 |
| San Francisco | 2015 | June | Tow | SFHS-31 | Suisun Bay, Cacheco Creek | 38.0484 | -122.0967 | 6 | 2 | 4 |
| San Francisco | 2015 | June | Tow | SFHS-32 | Suisun Bay, Roe Island | 38.0653 | -122.0527 | 6 | 2 | 4 |

## *Humboldt Bay 2015*

| Bay | Year | Month | Method | Site | Landmark | Latitude | Longitude | Total Replicates | Metagenetics | Morphology |
|---|---|---|---|---|---|---|---|---|---|---|
| Humboldt | 2015 | July | Pump | HB-P01 | Woodley Island Marina | 40.8075 | -124.1631 | 5 | 3 | 2 |
| Humboldt | 2015 | July | Pump | HB-P02 | Schneider Dock | 40.7973 | -124.1866 | 5 | 3 | 2 |
| Humboldt | 2015 | July | Pump | HB-P03 | Eureka Public Marina | 40.8034 | -124.1780 | 5 | 3 | 2 |
| Humboldt | 2015 | July | Pump | HB-P04 | Redwood Marine Terminal Berth A | 40.8165 | -124.1814 | 5 | 3 | 2 |
| Humboldt | 2015 | July | Pump | HB-P05 | Redwood Marine Terminal Berth B | 40.8037 | -124.1883 | 5 | 3 | 2 |
| Humboldt | 2015 | July | Pump | HB-P06 | CA Redwood Chip Export | 40.7981 | -124.1906 | 5 | 3 | 2 |
| Humboldt | 2015 | July | Pump | HB-P07 | Fairhaven Terminal | 40.7885 | -124.1947 | 5 | 3 | 2 |
| Humboldt | 2015 | July | Pump | HB-P08 | US Coast Guard | 40.7679 | -124.2157 | 5 | 3 | 2 |
| Humboldt | 2015 | July | Pump | HB-P09 | E2 Landing Marina | 40.7383 | -124.2226 | 5 | 3 | 2 |
| Humboldt | 2015 | July | Pump | HB-P10 | HB Forest Products Terminal | 40.7325 | -124.2191 | 5 | 3 | 2 |
| Humboldt | 2015 | July | Tow | HB-T01 | Woodley Island Marina | 40.7338 | -124.2199 | 2 | 1 | 1 |
| Humboldt | 2015 | July | Tow | HB-T02 | Schneider Dock | 40.7366 | -124.2216 | 2 | 1 | 1 |
| Humboldt | 2015 | July | Tow | HB-T03 | Eureka Public Marina | 40.7684 | -124.2148 | 2 | 1 | 1 |
| Humboldt | 2015 | July | Tow | HB-T04 | Redwood Marine Terminal Berth A | 40.7912 | -124.1914 | 2 | 1 | 1 |
| Humboldt | 2015 | July | Tow | HB-T05 | Redwood Marine Terminal Berth B | 40.7999 | -124.1892 | 2 | 1 | 1 |
| Humboldt | 2015 | July | Tow | HB-T06 | CA Redwood Chip Export | 40.8038 | -124.1787 | 2 | 1 | 1 |
| Humboldt | 2015 | July | Tow | HB-T07 | Fairhaven Terminal | 40.7972 | -124.1874 | 2 | 1 | 1 |
| Humboldt | 2015 | July | Tow | HB-T08 | US Coast Guard | 40.8022 | -124.1886 | 2 | 1 | 1 |
| Humboldt | 2015 | July | Tow | HB-T09 | E2 Landing Marina | 40.8168 | -124.1802 | 2 | 1 | 1 |
| Humboldt | 2015 | July | Tow | HB-T10 | HB Forest Products Terminal | 40.8066 | -124.1640 | 2 | 1 | 1 |

## ***Marina del Rey 2015***

| Bay | Year | Month | Method | Site | Landmark | Latitude | Longitude | Total Replicates | Metagenetics | Morphology |
|---|---|---|---|---|---|---|---|---|---|---|
| Marina Del Rey | 2015 | July | Pump | MDR-P01 | Waves MDR Apartments A | 33.9729 | -118.4495 | 5 | 3 | 2 |
| Marina Del Rey | 2015 | July | Pump | MDR-P02 | Waves MDR Apartments B | 33.9744 | -118.4512 | 5 | 3 | 2 |
| Marina Del Rey | 2015 | July | Pump | MDR-P03 | Neptune Marina | 33.9752 | -118.4568 | 5 | 3 | 2 |
| Marina Del Rey | 2015 | July | Pump | MDR-P04 | ESPRIT MDR Apartments | 33.9762 | -118.4495 | 5 | 3 | 2 |
| Marina Del Rey | 2015 | July | Pump | MDR-P05 | Dolphin Marina | 33.9787 | -118.4495 | 5 | 3 | 2 |
| Marina Del Rey | 2015 | July | Pump | MDR-P06 | Holiday Marina | 33.9801 | -118.4537 | 5 | 3 | 2 |
| Marina Del Rey | 2015 | July | Pump | MDR-P07 | Del Rey Yacht Club A | 33.9806 | -118.4514 | 5 | 3 | 2 |
| Marina Del Rey | 2015 | July | Pump | MDR-P08 | Del Rey Yacht Club B | 33.9827 | -118.4527 | 5 | 3 | 2 |
| Marina Del Rey | 2015 | July | Pump | MDR-P09 | Catalina Yacht Anchorage | 33.9824 | -118.4439 | 5 | 3 | 2 |
| Marina Del Rey | 2015 | July | Pump | MDR-P10 | Anchorage 47 | 33.9793 | -118.4438 | 5 | 3 | 2 |
| Marina Del Rey | 2015 | July | Tow | MDR-T01 | Coastal north of bay mouth | 33.9690 | -118.4690 | 2 | 1 | 1 |
| Marina Del Rey | 2015 | July | Tow | MDR-T02 | Coastal north of bay mouth | 33.9683 | -118.4737 | 2 | 1 | 1 |
| Marina Del Rey | 2015 | July | Tow | MDR-T03 | Coastal north of bay mouth | 33.9661 | -118.4730 | 2 | 1 | 1 |
| Marina Del Rey | 2015 | July | Tow | MDR-T04 | Coastal north of bay mouth | 33.9713 | -118.4709 | 2 | 1 | 1 |
| Marina Del Rey | 2015 | July | Tow | MDR-T05 | Coastal north of bay mouth | 33.9686 | -118.4716 | 2 | 1 | 1 |
| Marina Del Rey | 2015 | July | Tow | MDR-T06 | Coastal south of bay mouth | 33.9532 | -118.4569 | 2 | 1 | 1 |
| Marina Del Rey | 2015 | July | Tow | MDR-T07 | Coastal south of bay mouth | 33.9506 | -118.4552 | 2 | 1 | 1 |
| Marina Del Rey | 2015 | July | Tow | MDR-T08 | Coastal south of bay mouth | 33.9480 | -118.4593 | 2 | 1 | 1 |
| Marina Del Rey | 2015 | July | Tow | MDR-T09 | Coastal south of bay mouth | 33.9511 | -118.4617 | 2 | 1 | 1 |
| Marina Del Rey | 2015 | July | Tow | MDR-T10 | Coastal south of bay mouth | 33.9504 | -118.4584 | 2 | 1 | 1 |

## ***Port Hueneme 2015***

| Bay | Year | Month | Method | Site | Landmark | Latitude | Longitude | Total Replicates | Metagenetics | Morphology |
|---|---|---|---|---|---|---|---|---|---|---|
| Port Hueneme | 2015 | July | Pump | PH-P01 | Berth 1 | 34.1473 | -119.2093 | 5 | 3 | 2 |
| Port Hueneme | 2015 | July | Pump | PH-P02 | Berth 4 | 34.1488 | -119.2054 | 5 | 3 | 2 |
| Port Hueneme | 2015 | July | Pump | PH-P03 | Channel piles | 34.1464 | -119.2105 | 5 | 3 | 2 |
| Port Hueneme | 2015 | July | Pump | PH-P04 | Berth 5 | 34.1488 | -119.2026 | 5 | 3 | 2 |
| Port Hueneme | 2015 | July | Pump | PH-P05 | Port ops building | 34.1463 | -119.2117 | 5 | 3 | 2 |
| Port Hueneme | 2015 | July | Pump | PH-P06 | Port mouth south jetty | 34.1443 | -119.2115 | 5 | 3 | 2 |
| Port Hueneme | 2015 | July | Pump | PH-P07 | Desalination station | 34.1477 | -119.2108 | 5 | 3 | 2 |
| Port Hueneme | 2015 | July | Pump | PH-P08 | Wharf 3 | 34.1498 | -119.2062 | 5 | 3 | 2 |
| Port Hueneme | 2015 | July | Pump | PH-P09 | Navy boat ramps | 34.1533 | -119.2099 | 5 | 3 | 2 |
| Port Hueneme | 2015 | July | Pump | PH-P10 | Wharfinger floating dock | 34.1482 | -119.2020 | 5 | 3 | 2 |
| Port Hueneme | 2015 | July | Tow | PH-T01 | Berth 1 | 34.1485 | -119.2021 | 2 | 1 | 1 |
| Port Hueneme | 2015 | July | Tow | PH-T02 | Berth 4 | 34.1481 | -119.2046 | 2 | 1 | 1 |
| Port Hueneme | 2015 | July | Tow | PH-T03 | Channel piles | 34.1483 | -119.2063 | 2 | 1 | 1 |
| Port Hueneme | 2015 | July | Tow | PH-T04 | Berth 5 | 34.1522 | -119.2090 | 2 | 1 | 1 |
| Port Hueneme | 2015 | July | Tow | PH-T05 | Port ops building | 34.1530 | -119.2101 | 2 | 1 | 1 |
| Port Hueneme | 2015 | July | Tow | PH-T06 | Port mouth south jetty | 34.1499 | -119.2084 | 2 | 1 | 1 |
| Port Hueneme | 2015 | July | Tow | PH-T07 | Desalination station | 34.1486 | -119.2093 | 2 | 1 | 1 |
| Port Hueneme | 2015 | July | Tow | PH-T08 | Wharf 3 | 34.1468 | -119.2106 | 2 | 1 | 1 |
| Port Hueneme | 2015 | July | Tow | PH-T09 | Navy boat ramps | 34.1452 | -119.2114 | 2 | 1 | 1 |
| Port Hueneme | 2015 | July | Tow | PH-T10 | Wharfinger floating dock | 34.1433 | -119.2141 | 2 | 1 | 1 |

## ***San Francisco Bay 2016***

| Bay | Year | Month | Method | Site | Landmark | Latitude | Longitude | Total Replicates | Metagenetics | Morphology |
|---|---|---|---|---|---|---|---|---|---|---|
| San Francisco | 2016 | July | Tow | SFHS-01 | North of Dumbarton Bridge | 37.5089 | -122.1219 | 6 | 2 | 4 |
| San Francisco | 2016 | July | Tow | SFHS-02 | Dumbarton Bridge | 37.5169 | -122.1501 | 6 | 2 | 4 |
| San Francisco | 2016 | July | Tow | SFHS-03 | Between Dumbarton and San Mateo Bridges | 37.5508 | -122.1881 | 6 | 2 | 4 |
| San Francisco | 2016 | July | Tow | SFHS-04 | Between Dumbarton and San Mateo Bridges | 37.5704 | -122.2237 | 6 | 2 | 4 |
| San Francisco | 2016 | July | Tow | SFHS-05 | San Mateo Bridge | 37.5823 | -122.2488 | 6 | 2 | 4 |
| San Francisco | 2016 | July | Tow | SFHS-06 | San Mateo Bridge | 37.5899 | -122.2572 | 6 | 2 | 4 |
| San Francisco | 2016 | July | Tow | SFHS-07 | North of San Mateo Bridge | 37.6072 | -122.2806 | 6 | 2 | 4 |
| San Francisco | 2016 | July | Tow | SFHS-08 | Burlingame | 37.6366 | -122.3095 | 6 | 2 | 4 |
| San Francisco | 2016 | July | Tow | SFHS-09 | San Francisco International Airport | 37.6641 | -122.3241 | 6 | 2 | 4 |
| San Francisco | 2016 | July | Tow | SFHS-10 | South San Francisco | 37.6831 | -122.3291 | 6 | 2 | 4 |
| San Francisco | 2016 | July | Tow | SFHS-11 | South San Francisco | 37.7035 | -122.3438 | 6 | 2 | 4 |
| San Francisco | 2016 | July | Tow | SFHS-12 | Richmond Marina | 37.7257 | -122.3530 | 6 | 2 | 4 |
| San Francisco | 2016 | July | Tow | SFHS-13 | Across from Alameda | 37.7628 | -122.3711 | 6 | 2 | 4 |
| San Francisco | 2016 | July | Tow | SFHS-14 | Bay Bridge | 37.7938 | -122.3863 | 6 | 2 | 4 |
| San Francisco | 2016 | July | Tow | SFHS-15 | Fisherman's Wharf | 37.8127 | -122.4012 | 6 | 2 | 4 |
| San Francisco | 2016 | July | Tow | SFHS-16 | Golden Gate | 37.8094 | -122.4464 | 6 | 2 | 4 |
| San Francisco | 2016 | July | Tow | SFHS-17 | Treasure Island | 37.8334 | -122.3810 | 6 | 2 | 4 |
| San Francisco | 2016 | July | Tow | SFHS-18 | Angel Island | 37.8516 | -122.4136 | 6 | 2 | 4 |
| San Francisco | 2016 | July | Tow | SFHS-19 | Between Tiburon and Angel Island | 37.8665 | -122.4468 | 6 | 2 | 4 |
| San Francisco | 2016 | July | Tow | SFHS-20 | Tiburon | 37.8842 | -122.4362 | 6 | 2 | 4 |
| San Francisco | 2016 | July | Tow | SFHS-21 | San Quentin Prison | 37.9154 | -122.4701 | 6 | 2 | 4 |
| San Francisco | 2016 | July | Tow | SFHS-22 | Richmond | 37.9300 | -122.4336 | 6 | 2 | 4 |
| San Francisco | 2016 | July | Tow | SFHS-23 | Southern San Pablo Bay | 37.9627 | -122.4410 | 6 | 2 | 4 |
| San Francisco | 2016 | July | Tow | SFHS-24 | Bay Bridge | 38.0020 | -122.4346 | 6 | 2 | 4 |
| San Francisco | 2016 | July | Tow | SFHS-25 | San Pablo | 38.0201 | -122.3996 | 6 | 2 | 4 |
| San Francisco | 2016 | July | Tow | SFHS-26 | San Pablo | 38.0215 | -122.3678 | 6 | 2 | 4 |
| San Francisco | 2016 | July | Tow | SFHS-27 | Northeast San Pablo Bay | 38.0548 | -122.3114 | 6 | 2 | 4 |
| San Francisco | 2016 | July | Tow | SFHS-28 | Carquinez Strait, Highway 80 bridge | 38.0603 | -122.2242 | 6 | 2 | 4 |
| San Francisco | 2016 | July | Tow | SFHS-29 | Carquinez Strait, Benecia | 38.0407 | -122.1693 | 6 | 2 | 4 |
| San Francisco | 2016 | July | Tow | SFHS-30 | Carquinez Strait, Highway 680 bridge | 38.0403 | -122.1274 | 6 | 2 | 4 |
| San Francisco | 2016 | July | Tow | SFHS-31 | Suisun Bay, Cacheco Creek | 38.0475 | -122.1000 | 6 | 2 | 4 |
| San Francisco | 2016 | July | Tow | SFHS-32 | Suisun Bay, Roe Island | 38.0635 | -122.0624 | 6 | 2 | 4 |

# Section II: Genetic Detection and Analysis of NIS by DNA Sequencing of Voucher Specimens and Plankton.

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# Chapter 5: High Throughput Sequencing of Fouling and Infaunal Organisms from California Bays

## Introduction

This chapter reports the results of DNA sequencing of specimens (also referred to as "vouchers," although physical specimens were not always kept). Genetic identification of specimens used the concept of DNA barcoding, the use of species-specific DNA sequence to aid or confirm identification of specimens. For most animal subjects, DNA barcoding uses a fragment of the Cytochrome c oxidase subunit I (COI) mitochondrial gene. Additional loci, such as the 28S rRNA gene (equivalently, large subunit, or LSU, rRNA) can supplement or substitute for COI when interspecific variation in COI is low. In this study, vouchers were examined by expert taxonomists or parataxonomists (*i.e.*, those trained in species identification), and DNA sequencing served to evaluate accuracy and consistency of identification, as well as to further expand a library of DNA sequences for NIS. The combined morphological and molecular approaches have produced a set of identifications for which we can have very high confidence in correct identification, and provided information on which taxa are prone to misidentification. Conversely, the joint application of morphology and genetics has pointed to some weaknesses in the molecular approach, namely the sensitivity of the technique to exogenous DNA.

Joint morphological and genetic analysis of voucher specimens is not without drawbacks, in particular additive costs of sample collection and sorting, morphological identification, and sequencing. For these reasons, a purely genetic approach (omitting morphological identification) or a metagenetic analysis (equivalently "metabarcoding," omitting sorting) could be applied to settling plates or other environmental samples in some situations. The extremely high abundance of planktonic organisms makes individual analysis prohibitive and metagenetics particularly attractive (Chapter 6). For settling plates, we addressed the cost and labor issue of genetic analysis through adoption of novel high-throughput sequencing methods.

High throughput voucher sequencing is the use of next-generation sequencing (NGS) technology to obtain, in parallel, genetic sequences from many DNA fragments. Applying this method to tissue vouchers allowed us to address specific goals from the project, such as the identification of individual epifaunal and infaunal specimens, comparisons of molecular and morphological results, and the expansion of the DNA barcode database in a faster and more cost-effective way than with traditional Sanger sequencing.

At the time of this report, traditional Sanger DNA sequencing (also called dideoxynucleotide chain termination sequencing) provides longer read lengths and lower sequencing error rate than NGS methods. When the number of samples is not prohibitive, Sanger sequencing produces higher quality and longer sequence data. However, the use of NGS allowed us to more quickly process many thousands of samples. The resulting gigabytes of NGS data can also be used to identify sequences underrepresented in the database to be re-sequenced with the traditional Sanger method. In this study, species that we knew *a priori* were underrepresented in the reference database were also sequenced with Sanger as a first course of action and added to the database for the later analysis of the NGS voucher data.

**High Throughput Voucher Sequencing Molecular Methods**

***Glossary of Terms***

A glossary of technical terms used in description of molecular methods and data analysis is given at the end of this report.

***Materials received for analysis.***

Marine invertebrate tissue samples from specimens presumed to be purely from one individual organism were collected from PVC settlement plates by SERC personnel and stored in 90% ethanol at room temperature until they could be further processed. MLML periodically received shipments of specimens from SERC sorted to vials and assigned unique identifying codes.

***DNA Isolation***

DNA isolation was accomplished using either Qiagen DNeasy columns for unique tissues destined for Sanger Sequencing or Fisher MagJET Genomic DNA kits for tissues directed toward high throughput next generation sequencing. Briefly, a subsample of tissue, up to approximately the size of a grain of rice (around 25 mg), was rinsed of ethanol with distilled water (or removed directly from DMSO-based storage buffer (DNE) without rinsing), moved to a lysis solution in a 96-well block (or individual tubes for the DNeasy kit), and processed according to each manufacturers' instructions. In cases where provided tissue was smaller than the recommended size, we nonetheless carried the tissue through the extraction and downstream processes. Genomic DNA was suspended in nuclease-free water. Two wells (A01 and D05) were left empty of tissue as blanks to check for cross-contamination between wells. Genomic DNA was stored and cataloged in 96-well plate format (henceforth, genomic DNA plates).

***PCR Amplification***

The COI gene was amplified by polymerase chain reaction as described in Geller *et al.* (2013), using jgLCO1490 and jgHCO2198 primers for Sanger sequencing and substituting mlCOIintF (Leray *et al.* 2013) for jgLCO1490 in NGS sequencing. The LSU gene amplification process was similar but used primers specific for that gene. From a genomic DNA plate, well D05 (void of tissue, containing only water) was carried through to detect potential cross-well contamination by genomic DNA, while well A01 was used as the PCR no-template control, substituting 1 µL of nuclease-free water for template. Reactions were checked for PCR success on an agarose gel stained with ethidium bromide. Each primer pair contained extra nucleotides that coded for position on the 96-well PCR plate. Products for conventional sequencing were amplified with unmodified primers and sent to Elim Biopharmaceuticals (Hayward, CA) for sequencing.

***Plate-indexing***

Sequencing on the Ion Torrent PGM instrument required PCR templates to be pooled prior to additional preparation for sequencing. In order to later separate resulting sequences for each PCR product, PCR amplification products from the initial round of COI or 28S amplification (already containing well index tags) were re-amplified with primers containing extra nucleotides that signify the source PCR plate. PCR success was assessed with an agarose gel stained with ethidium bromide. Plates with a high proportion (>50%) of successfully amplified wells were then pooled into a single tube and purified using Agencourt AMPure beads according to the manufacturer's protocol. Plates with lower success were further optimized until a majority of templates were amplified.

***Ion Torrent Library Preparation***

The purified pool of PCR products was quantified and end-repaired using the Ion Fragment Library kit according to the manufacturer's protocol, except that half volumes were used in the end-repair reaction to save reagent costs. End-repair products were purified using Ampure beads.

Purified and end-repaired products were ligated with an IonXpress barcode adapter, unique to each plate, (*i.e.*, a plate index) and purified with Ampure beads. The resulting pool of fragmented, adapter-ligated PCR products was then size selected for a 400 bp (base-pair) library (490 bp target) using a Pippin prep instrument. The size selected sample was again purified with Ampure beads and PCR-amplified. Amplified libraries were purified with Ampure, and quality-checked on an Agilent Bioanalyzer 2100. The optimal template dilution for sequencing was determined with a TaqMan qPCR kit. Template was loaded onto an Ion 318 Chip V2 and sequenced with the Ion Torrent PGM using the Ion PGM Hi-Q View kit. All Ion Torrent reagent kits were purchased from Life Technologies.

***Sequence Analysis***

Voucher sequencing files were downloaded from the Torrent server as fastq files. Sequences were demultiplexed, quality filtered, and assembled into contiguous sequences (contigs). Contigs were searched using BLAST (Basic Local Alignment Search Tool) against two databases; our in-house database of reference sequences (MLML-refs) and COArbitrator (described below). The BLAST results were sorted and filtered to find the most likely genetic identification. These steps are more fully described in the following paragraphs.

***Demultiplexing, Filtering, and Assembling of Ion Torrent Sequence Reads***

An initial round of demultiplexing and filtering was done by the Ion Torrent within the default settings and sequences below the Phred quality score of Q20[1] were removed. The remaining sequences were separated by IonXpress barcodes (used to indicate plate of origin, see molecular methods section). QIIME version 1 was used to demultiplex (separate) reads for each well of the plate, and additional quality filtering steps were performed using custom scripts[2] to allow for parallel processing. Briefly, the

[1] Q20 indicates a 99% base call accuracy. For more information see: https://en.wikipedia.org/wiki/Phred_quality_score

[2] Custom scripts can be found here: https://github.com/DidemnumVex/IonTorrentVoucher/blob/master/IonZipSplitv3.2.py

custom script (IonZipSplitv3.2) unzips and renames the sequence files and those files are passed through:

1. *convert_fastaqual_fastq.py* to separate nucleotide sequence from quality scores into two different files (fasta and qual). These are input files for *split_libraries.py*
2. *split_libraries.py*[3] with a minimum sequence length of 75, a quality score window of 50, minimum quality score (Q20), and *-disable_primers* set to 'True'. Primers were left in place to provide an anchor of conserved sequence for the assembler.
3. *convert_fastaqual_fastq.py* to merge the nucleotide and quality files into a single file (fastq).
4. The program MIRA was then used to assemble the sequences.

After voucher reads were assembled, they were combined into a single fasta file, which was then passed to Geneious v10 (Biomatters, Christchurch, New Zealand) for primer trimming. Because of the size of the file, it took Geneious several days to find and remove primers from these sequences.

***BLAST Search Against MLML and COArbitrator Nucleotide Sequences***

The assembled sequences were then searched using BLAST (Basic Local Alignment Search Tool) against two separate databases. The first database (COArbitrator) was curated by Philip Heller and contains COI nucleotide sequences after confirmation of COI amino acid motifs from the Conserved Domain Database (NCBI). This is to ensure that there are open reading frames in the sequences and that they can be translated correctly. The protein sequences themselves were not used for taxonomic assignment because of loss of genetic information in variable codon positions. The second database (MLML) was generated from in-house sequencing of voucher material identified by SERC associates. Sequences were searched with the blastn (BLAST nucleotide) default settings, with the exception that matches with an e-value below 0.01 were ignored. Sequences were searched in parallel using the python multiprocessing module, allowing 56 search threads to run simultaneously. This drastically reduced the time to run the assembled sequences through BLAST. The same search process was performed on the assembled sequences against the MLML reference database. Results were saved as separate xml files for later processing and filtering.

***BLAST Result Filtering***

Probable BLAST matches were chosen as follows:

All records returned by BLAST ("hits") below 94.5% pairwise similarities were ignored: this threshold assumes genetic similarity of 94.5% or less rejects a conspecific relationship between a reference and a novel sequence. (95% is a typical threshold value for species assignment; we adjusted this slightly to account for higher sequencing error rate by Ion Torrent, compared to Sanger sequencing). Assemblies were grouped by Vial ID and given the following concordance ranks (where the lowest value is the

[3] http://qiime.org/scripts/split_libraries.html

strongest concordance between genetic and morphological taxonomic assignment) as follows for each Vial ID group:

1. Genus and species of reference and assigned morphospecies match, there was a long alignment, and the morphospecies was not a common contaminant
2. Genus match, long alignment, morphospecies not common contaminant
3. Genus match, long alignment, morphospecies is common contaminant
4. Genus and species match, long alignment, morphospecies is common contaminant
5. Family match, long alignment
6. Order match, long alignment
7. Class match, long alignment
8. Phylum match, long alignment
9. Genus and species match, short alignment, morphospecies not a common contaminant
10. Genus match, short alignment, morphospecies not common contaminant
11. Genus match, short alignment, morphospecies is common contaminant
12. Genus and species match, short alignment, morphospecies is common contaminant
13. Family match, short alignment
14. Order match, short alignment
15. Class match, short alignment

where "morphospecies" is the taxonomic assignment based on morphology, "short alignments" are alignments less than 280 bp and "long alignments" are longer than 280 bp. In practice, alignment length is a function of query sequence length, since references were all >280 bp, and database adequacy (vouchers will have shorter regions of alignment to more distantly related species). "Common contaminants" are species with sequences that were frequently found in wells with presumptive morphospecies that could not be mistaken for the other; phylum level mismatches were used as a proxy for such unmistakable mismatches. Results were then sorted ascending by the match rank, descending by database (MLML or Coarbitrator), and descending by percent pairwise identity, and the top hit was chosen. If no match could be assigned by these criteria, "No BLAST Hit" was assigned for that VialID. Morphological and molecular assignments that disagreed at the phylum level were included in the "No BLAST Hit" category.

The above ranking system favors long alignments over shorter alignments. Shorter alignments arise from short contigs. It is possible that, among assemblies from a vial, an incorrect long contig could be prioritized over a correct short contig. Generally, though, extraneous contigs are filtered out by other criteria (*e.g.*, they are common contaminants or phylum-level mismatches to morphospecies identifications).

## Results and Discussion

### ***Genetic Assignments***

Of 21,109 vials processed, 56% of vials (11,826) were assigned a genetic identification. [Note: identification does not have an associated statistical probability but is based on the BLAST result ranking system (previous section) and the available reference databases]. Vials that could not be identified are discussed below. The resulting concordance between morphological versus genetic identification varied greatly by taxon (Table 5.1). For instance, within the Bryozoa, 80% were correctly identified to the species level, and 89% to the genus or species levels. Similarly, chordates were correctly identified to species 68% of the time and to the genus level for an additional 15% of vials. However, within the sponges, the correct species was never assigned and in 55% of the cases, the phylum was the lowest rank attempted by the morphologist. Cnidarians were similarly difficult to identify morphologically, with 26% identified to the class level only, though this is not surprising since hydroids and small anthozoans are reputedly difficult to identify in the field.

Overall, concordance of species-level assignments appeared relatively low, at best 80% for bryozoans and less for many frequently occurring taxa such as annelids and crustaceans. However, it should be noted that our analysis of concordance didn't differentiate between the *refinement* of a coarse identification (*e.g.,* morphological ID = *Mytilus* sp. and genetic ID = *Mytilus trossulus*) versus a *reassignment* (*e.g.*, morphological ID = *Mytilus galloprovincialis* and genetic ID = *Mytilus trossulus*). Both were considered *nonconcordant*. For present purposes, our definition of concordance was strict, requiring an exact match (but allowing for synonymy, when known). However, when *both* the genetic and morphological identifications were resolved only to the same higher taxon (*e.g.*, a genus such as *Mytilus* sp.), results were considered concordant at that level (in this case, the genus level).

Many morphological assignments were made only to the genus or higher levels. Table 5.1 shows the percent of vouchers where morphological and genetic assignment mismatched at the genus (and other higher levels). For generic assignments, there was much stronger agreement between genetics and morphology. For example, while 60.5% of arthropod vouchers agreed at the species level, 88.5% agreed at the genus level (species matches plus genus-only matches). This suggests that morphological assignments are relatively reliable at the genus level. However, this may not be adequate for NIS studies, as many genera have both native and introduced species.

Table 5.2 shows all genetic species assignments for all sampled bays. The set of vouchers that were sequenced was not a random sample of organisms on settling plates, therefore the abundance of specimens for each genetically identified species is not a reflection of relative population sizes. This table, however, may supplement geographic analyses based on morphological identification.

While not tallied, refinement (or coarsening) of identification is shown in Figures 5.1 through 5.12, which are matrices ("heat maps') in which genetic and morphological identification are paired in a square array with cells colored by frequency of results. In this document, matrices are static figures and have been plotted for all (Figure 5.1 and 5.12) or individual phyla (Figs. 5.2 to 5.11). Dynamic (zoomable) matrices can be provided in html format.

***Concordance of Morphological and Genetic Identification for Specimens with Species-level Morphological Assignment.***

Vouchers that were fully resolved by morphology to binomials are the set of specimens for which taxonomists and parataxonomist had highest confidence in identification. Concordance rate for all specimens, regardless of level of resolution, may unreasonably underestimate taxonomists' accuracy by including vouchers where there was implicit uncertainty. That is, by declining to provide a fully resolved name, a taxonomist was declaring uncertainty. DNA sequences may identify such specimens, but the unresolved name is not necessarily an error, but rather an inefficiency or ineffectiveness. While the ability to genetically identify a voucher that could not be morphologically identified is important to biotic surveys, we separately assessed concordance between genetic and morphological identifications for only fully resolved vouchers (Table 5.3). For vouchers given binomial names, there was an overall concordance of 82%. Some of the taxa with highest rates of misidentification (assuming the genetic ID to be correct) were the polychaetes *Capitella teleta* and *Eulalia levicor*, the barnacle *Megabalanus rosa*, the bryozoan *Bugula longirostrata*, and the chordate *Ascidia virginea.*

There were many species for which no specimens given binomial names could be verified. Examples are the ascidian *Botrylloides pizoni* and the hydrozoan *Bougainvillia muscus*. This, however, does not mean that none of these species were genetically identified among all specimens. Rather, they may have been identified from specimens not fully resolved by morphological identification, for example the polychaete *Eulalia levicor*, the amphipod *Ampelisca abdita*, or the barnacle *Megabalanus rosa*.

For many taxa, apparent misidentification was found but involved few specimens for each genetic reassignment. For example, eight specimens of the polychaete *Schistomeringos longicornis* were identified by both morphology and genetics, while another 19 were genetically identified as 12 other species. Many of these morphological-genetic mismatches were clearly due to implausible genetic assignments (discussed below), such as a morphological nudibranch that was genetically identified as a mussel. Thus, the total 18% overall discordance rate for fully resolved morphological assignments combines both true morphological misidentification and genetic misassignment. Our concern should focus on abundant, systematic misidentifications of the sort mentioned in the previous paragraph.

Finally, apparent discordance could be a result of unrecognized synonymy or errors of identification within Genbank. While some level of database curation has taken place within Coarbitrator, it is nearly impossible to manually verify that every sequence in Genbank was properly identified, thus it is important to investigate a reference's provenance before drawing conclusions based on genetic identification.

The results given here paint a picture of taxonomists' strengths and weaknesses and suggest that they might spend less time on certain taxonomic groups and more on others. It is evident that Porifera, Platyhelminthes, Nemertea, and Cnidaria present particular problems for morphological identification.

Identification of Porifera and Cnidaria rely on microscopical characters (spicules and nematocysts) that are inconvenient for field taxonomy, and tiny Platyhelminthes and Nemertea are relatively devoid of useful macroscopic characters. For these 'difficult' taxa, it is also imperative that references from reputable and verified sources be used for genetic identifications.

***Failed Genetic Identification***

Of 21,109 vials processed, 9,283 failed to yield results (Table 5.4) due to a combination of factors, including a) failure to make an assembly (2,993 vials), b) failure to find a BLAST hit (6,269 vials), c) human or bacterial contamination (2 vials) or d) because the resulting alignment was too short to confirm a blast hit (19 vials). The failed assemblies are actually fewer than we expected because of our use of pooled 96 well plates without manually removing weak PCR products. Because we did not choose only the strongest PCR products for sequencing, low quality PCR products were passed through to the sequencing stage. Ordinarily, we would not have attempted to use traditional Sanger sequencing on such PCR products. Some of these weak PCR products yielded usable sequence, but many did not. Sequencing failure rate was only 14%, attrition typical of other high-volume sequencing projects.

While only two vials were found to have failed due to bacterial or human DNA contamination, these only represent vials where there was also no plausible match was found within the assembled contigs. There were more assemblies that were evidently human or bacterial sequences (far more bacterial than human), but those vials also produced plausible assemblies. This was similarly true for short alignments. Short alignments were only taken into consideration when there was no plausible long alignment that matched. However, if there was no match and the resulting alignment was short, it was categorized to have failed due to alignment length. Lack of a BLAST match to any known reference was the largest category of failure. There are a few possible reasons for this result:

1. An absence of reference sequences exceeding the 94.5% similarity threshold. This threshold is meant to limit matches to conspecifics, and so will exclude closely related organisms even if there was a 'hit' at *e.g.,* 93%. This may also be affected by sequencing error for a haplotype already near that identity threshold (*i.e.*, error to a conspecific sequence 95% similar to a reference could push it below our threshold). These sequences have been retained and may later be identified as our database expands.
2. True 'No Hit' results. For a portion of the 'No Hit' category, BLAST returned 'No HIT' according to the default minimum criteria for match (*i.e.*, e-value was greater than 10). These may represent nonsense sequences or sequences for which there is not even a distant relative within the database. Given that our sequences could include bacterial COI sequences, it is plausible that there were many unknown bacterial sequences within the assemblies.
3. The only hits were implausible. If the only hit for an assembly was from phylum different than expected, the sorting algorithm categorized the result as "No-Hit". While these were the minority of the 'No Hit' category, exact numbers are not currently available. These result from poor quality sequences, chimeric sequences, or laboratory or symbiont contamination.

**Contamination**

Figure 5.12 shows genetic versus morphological identifications without filtering "extra" sequences from vouchers, low quality sequences, or implausible taxa (that is, belonging to a different phylum than expected). In this figure, the diagonal pattern indicates concordance, while the diffuse cloud of points reflects unexpected genetic assignments. Strong horizontal and vertical arrays of points represent patterns of likely contamination, either by symbiotic organisms (epibionts, gut contents) or physical transfer of genetic material (*i.e*., SERC or MLML lab contamination). The word "contamination" is here used in a broad sense of any deviation from a single sequence from a voucher, be that for natural or artifactual causes. Sources of contamination are not yet understood. Examination of extraction no-tissue controls and PCR no-template controls showed a very low rate of laboratory contamination: of 259 plates extracted, 11 showed a positive signal in the no-tissue-added well. Only 3 of 259 PCR plates showed a positive signal in the no-template-added well. (PCR plates showing a positive signal were re-run to achieve no contamination). We conducted a series of experiments to determine if well-to-well movement of DNA occured during extractions on mock extraction plates by filling wells that surrounded a tissue-free well (lysis buffer only) with tissue extractions. We found that empty wells could be contaminated during the heated, shaking steps of extraction when foil sealing film or press-on tube caps were used, but was eliminated when plates with wells using screw-on caps with o-rings were used. We therefore switched to plates using screw-on caps. Despite this change to the extraction procedure, an analysis of the number of sequences detected in a well over time showed only a small reduction (Figure 5.13). In summary, tissue and PCR contamination was rare, and we took effort to further minimize tissue contamination during extraction, yet we continued to observe multiple sequences from most vials.

Interestingly, the highest number of phyla/well was seen for specimens that came from bulk voucher vials (multiple specimens per vial). This suggests that, even though specimens were later sorted into separate extraction wells, being stored with other specimens resulted in DNA contamination. A previous study showed that ethanol from bulk collection jars could yield DNA (Hajibabaei *et al*. 2012), thus it is plausible that tissues were contaminated prior to extraction.

We examined the identity of extra DNA sequences in wells (Table 5.5) and found many that were among the most common organisms on settling plates (bryozoans and ascidians, for example). Encrusting organisms might be the most likely to be attached to other organisms when sampled. Other extra sequences were from were common epibionts or commensals such as caprellid amphipods. scaleworms and syllids (*Halosydna* and *Megasyllis*) that could be clinging to targeted organisms. However, preliminary experiments suggested that environmental DNA is leaked into settling plate soak water during plate retrieval and processing. Some of the organisms in Table 5.5 would shed blood (molluscs, annelids, bryozoans, chordates and arthropods) or superficial cells (sponges and cnidarians) into the soak water if injured during processing. In short, there appear to be multiple routes for DNA to move from one specimen, vial, or well to another.

Lastly, certain taxa were more likely to be contaminated by bacterial sequences (data not shown). These included sponges, tunicates, and bryozoans. Sponge-associated bacteria are subjects of extensive research and bacteria are known to compose a great deal of biomass within the tissues of certain Porifera species (Vacelet and Donadey 1977, Hentschel *et al*. 2006). Similarly, a bryozoan–associated bacteria called '*Endobugula'* (Lim and Haygood 2004) was detected among the assemblies. Tunicates, with their mode of ultrafilter feeding, are enriched with ingested bacterial cells. For example, when we compared a *Ciona*-derived COI sequence from this project to Genbank, we discovered that there was a bacterial sequence within Genbank mislabeled as *Ciona intestinalis*. This may also indicate a *Ciona*-specific bacterial species, but more work would need to be done to know the host specificity.

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**Appendix 5.1**

**Table 5.1. Concordance between morphological and genetic identifications by taxon rank.** Vial count represents number of genetic versus morphological matches at the species (complete binomial) level or mismatches for the specific given rank. Percent of phylum total is the species match or higher taxon mismatch divided by the total for that phylum, as a percentage. Long alignments are alignments longer than 280 bp. Short alignments are shown separately to examine whether if concordance is affected by the length of the region of overlap between query (vial) and subject (reference).

| | | **Vial Count** | | | **Percent of phylum total** | | |
|---|---|---|---|---|---|---|---|
| | | Long Alignment | Short Alignment | All | Long Alignment | Short Alignment | All |
| Annelida | Species Match | 442 | 159 | 601 | 31.19% | 36.81% | 32.50% |
| | Species Mismatch | 211 | 94 | 305 | 14.89% | 21.76% | 16.50% |
| | Genus Mismatch | 343 | 42 | 385 | 24.21% | 9.72% | 20.82% |
| | Family Mismatch | 185 | 35 | 220 | 13.06% | 8.10% | 11.90% |
| | Order Mismatch | 230 | 102 | 332 | 16.23% | 23.61% | 17.96% |
| | Class Mismatch | 6 | 0 | 6 | 0.42% | 0.00% | 0.32% |
| Arthropoda | Species Match | 797 | 91 | 888 | 66.14% | 34.73% | 60.53% |
| | Species Mismatch | 303 | 106 | 409 | 25.15% | 40.46% | 27.88% |
| | Genus Mismatch | 37 | 19 | 56 | 3.07% | 7.25% | 3.82% |
| | Family Mismatch | 42 | 20 | 62 | 3.49% | 7.63% | 4.23% |
| | Order Mismatch | 23 | 26 | 49 | 1.91% | 9.92% | 3.34% |
| | Class Mismatch | 3 | 0 | 3 | 0.25% | 0.00% | 0.20% |
| Bryozoa | Species Match | 2046 | 347 | 2393 | 80.05% | 67.91% | 78.02% |
| | Species Mismatch | 254 | 89 | 343 | 9.94% | 17.42% | 11.18% |
| | Genus Mismatch | 15 | 1 | 16 | 0.59% | 0.20% | 0.52% |
| | Family Mismatch | 113 | 52 | 165 | 4.42% | 10.18% | 5.38% |
| | Order Mismatch | 53 | 22 | 75 | 2.07% | 4.31% | 2.45% |
| | Class Mismatch | 75 | 0 | 75 | 2.93% | 0.00% | 2.45% |
| Chordata | Species Match | 1908 | 442 | 2350 | 68.46% | 54.57% | 65.33% |
| | Species Mismatch | 429 | 175 | 604 | 15.39% | 21.60% | 16.79% |
| | Genus Mismatch | 151 | 41 | 192 | 5.42% | 5.06% | 5.34% |

| | | Vial Count | | | Percent of phylum total | | |
|---|---|---|---|---|---|---|---|
| | | Long Alignment | Short Alignment | All | Long Alignment | Short Alignment | All |
| | Family Mismatch | 75 | 33 | 108 | 2.69% | 4.07% | 3.00% |
| | Order Mismatch | 224 | 119 | 343 | 8.04% | 14.69% | 9.54% |
| Cnidaria | Species Match | 35 | 5 | 40 | 8.18% | 5.62% | 7.74% |
| | Species Mismatch | 188 | 37 | 225 | 43.93% | 41.57% | 43.52% |
| | Genus Mismatch | 35 | 10 | 45 | 8.18% | 11.24% | 8.70% |
| | Family Mismatch | 49 | 3 | 52 | 11.45% | 3.37% | 10.06% |
| | Order Mismatch | 114 | 34 | 148 | 26.64% | 38.20% | 28.63% |
| | Class Mismatch | 7 | 0 | 7 | 1.64% | 0.00% | 1.35% |
| Echinodermata | Order Mismatch | 0 | 8 | 8 | | 100.00% | 100.00% |
| Entoprocta | Species Match | 0 | 1 | 1 | 0.00% | 100.00% | 33.33% |
| | Class Mismatch | 2 | 0 | 2 | 100.00% | 0.00% | 66.67% |
| Mollusca | Species Match | 314 | 49 | 363 | 39.10% | 42.98% | 39.59% |
| | Species Mismatch | 281 | 37 | 318 | 34.99% | 32.46% | 34.68% |
| | Genus Mismatch | 126 | 14 | 140 | 15.69% | 12.28% | 15.27% |
| | Family Mismatch | 30 | 8 | 38 | 3.74% | 7.02% | 4.14% |
| | Order Mismatch | 41 | 6 | 47 | 5.11% | 5.26% | 5.13% |
| | Class Mismatch | 11 | 0 | 11 | 1.37% | 0.00% | 1.20% |
| Nemertea | Species Mismatch | 32 | 0 | 32 | 59.26% | | 59.26% |
| | Order Mismatch | 1 | 0 | 1 | 1.85% | | 1.85% |
| | Class Mismatch | 21 | 0 | 21 | 38.89% | | 38.89% |
| Platyhelminthes | Species Mismatch | 3 | 1 | 4 | 5.00% | 50.00% | 6.45% |
| | Family Mismatch | 2 | 1 | 3 | 3.33% | 50.00% | 4.84% |
| | Class Mismatch | 55 | 0 | 55 | 91.67% | 0.00% | 88.71% |
| Porifera | Species Mismatch | 70 | 11 | 81 | 27.24% | 40.74% | 28.52% |
| | Family Mismatch | 7 | 8 | 15 | 2.72% | 29.63% | 5.28% |
| | Order Mismatch | 38 | 8 | 46 | 14.79% | 29.63% | 16.20% |

| | | Vial Count | | | Percent of phylum total | | |
|---|---|---|---|---|---|---|---|
| | | Long Alignment | Short Alignment | All | Long Alignment | Short Alignment | All |
| | Class Mismatch | 142 | 0 | 142 | 55.25% | 0.00% | 50.00% |
| All | | 9569 | 2257 | 11826 | | | |

**Table 5.2. Genetic Identification of vouchers by bay**. BD = Bodega, HB = Humboldt, MDR = Marina Del Rey, MI = Mission, MO = Morro, MB = Monterey Bay, PH = Port Hueneme, SD = San Diego, SF = San Francisco. Unk=Unknown and indicates we don't have location information for those samples. Numbers refer to the number of tissue vials with a genetic identification (row) from a bay location (column). Bays highlighted in yellow were the focus of Part II of the initial phase.

| | | | **VialID** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Bay** | **BD** | **HB** | **MDR** | **MI** | **MO** | **Unk** | **MB** | **PH** | **SD** | **SF** | Total |
| **Genus (or lowest rank)** | **species** | **Phylum** | 1061 | 954 | 313 | 987 | 1203 | 60 | 39 | 278 | 958 | 5973 | 11826 |
| *Polysiphonia* | *schneideri* | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| *Alitta* | *succinea* | Annelida | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 30 | 30 |
| *Amphiduros* | *pacificus* | | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 2 |
| *Asabellides* | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| *Barantolla* | *americana* | | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| *Bergstroemia* | *nigromaculata* | | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| *Capitella* | *capitata* | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 11 | 11 |
| | *teleta* | | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 17 | 20 |
| *Chone* | *magna* | | 7 | 0 | 0 | 1 | 11 | 0 | 0 | 0 | 0 | 0 | 19 |
| *Cirratulus* | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| | *cirratus* | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 |
| *Ctenodrilus* | *serratus* | | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 10 |
| *Eulalia* | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| | *levicor* | | 0 | 0 | 0 | 0 | 17 | 0 | 0 | 0 | 0 | 0 | 17 |
| *Eupolymnia* | *heterobranchia* | | 29 | 0 | 0 | 0 | 9 | 0 | 0 | 1 | 0 | 0 | 39 |
| *Ficopomatus* | *enigmaticus* | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 16 | 16 |
| *Halosydna* | *brevisetosa* | | 0 | 8 | 0 | 0 | 14 | 0 | 0 | 0 | 0 | 0 | 22 |
| *Harmothoe* | *imbricata* | | 36 | 11 | 0 | 10 | 3 | 2 | 0 | 0 | 0 | 221 | 283 |
| *Hydroides* | *elegans* | | 0 | 0 | 27 | 9 | 0 | 0 | 0 | 0 | 1 | 0 | 37 |
| *Leitoscoloplos* | *pugettensis* | | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 |
| *Lumbrineris* | *perkinsi* | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 0 | 7 |
| *Marphysa* | *sanguine* | | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 10 |
| *Megalomma* | *splendida* | | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| *Megasyllis* | *nipponica* | | 9 | 0 | 2 | 11 | 0 | 1 | 0 | 8 | 11 | 248 | 290 |
| *Myrianida* | *convoluta* | | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | *pachycera* | | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| | *pentadentata* | | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 5 | 4 | 12 |

| | | | VialID | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Bay | BD | HB | MDR | MI | MO | Unk | MB | PH | SD | SF | Total |
| **Genus (or lowest rank)** | **species** | **Phylum** | 1061 | 954 | 313 | 987 | 1203 | 60 | 39 | 278 | 958 | 5973 | 11826 |
| *Myxicola* | | | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 |
| *Nainereis* | | | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| *Naineris* | *dendritica* | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 4 |
| *Neanthes* | *acuminata* | | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 13 | 16 |
| *Nereis* | *vexillosa* | | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 11 |
| *Ophryotrocha* | *labronica* | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 11 | 12 |
| *Oxydromus* | *pugettensis* | | 13 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 1 | 16 |
| *Parasabella* | | | 0 | 0 | 8 | 2 | 0 | 0 | 0 | 0 | 13 | 3 | 26 |
| *Phyllodoce* | *medipapillae* | | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| *Platynereis* | | | 91 | 58 | 0 | 2 | 50 | 0 | 0 | 3 | 7 | 86 | 297 |
| | *bicaniculata* | | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 |
| *Polycirrus* | | | 4 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 5 |
| *Polydora* | *cornuta* | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 4 |
| *Protodorvillea* | *gracilis* | | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 3 | 4 |
| *Schistomeringos* | *longicornis* | | 4 | 6 | 0 | 4 | 0 | 1 | 0 | 0 | 0 | 47 | 62 |
| *Schizobranchia* | *insignis* | | 0 | 1 | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 7 |
| *Serpula* | *columbiana* | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| *Streblosoma* | *uncinatus* | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 5 |
| *Streblospio* | *benedicti* | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| *Syllis* | *alternata* | | 10 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 2 | 0 | 15 |
| | *elongata* | | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 3 |
| family_Capitellidae | | | 2 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 7 | 1 | 14 |
| family_Chrysopetalidae | | | 0 | 32 | 0 | 0 | 43 | 0 | 0 | 0 | 3 | 10 | 88 |
| family_Nereidae | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| family_Nereididae | | | 11 | 0 | 0 | 0 | 6 | 1 | 0 | 0 | 0 | 17 | 35 |
| family_Opheliidae | | | 11 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 1 | 7 | 23 |
| family_Syllidae | | | 2 | 0 | 0 | 0 | 18 | 0 | 0 | 0 | 1 | 5 | 26 |
| family_Terebellidae | | | 0 | 9 | 0 | 5 | 2 | 0 | 0 | 3 | 24 | 280 | 323 |
| *Amathia* | | Arthropoda | 1 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 15 | 22 |
| *Americorophium* | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 10 |
| *Ampelisca* | *abdita* | | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 6 |

| | | | VialID | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Bay | BD | HB | MDR | MI | MO | Unk | MB | PH | SD | SF | Total |
| **Genus (or lowest rank)** | **species** | **Phylum** | 1061 | 954 | 313 | 987 | 1203 | 60 | 39 | 278 | 958 | 5973 | 11826 |
| *Amphibalanus* | *amphitrite* | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 11 | 13 |
| | *improvisus* | | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 75 | 76 |
| *Ampithoe* | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 63 | 63 |
| | *lacertosa* | | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 12 |
| | *sectiman* | | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | *valida* | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 3 |
| *Aoroides* | | | 6 | 0 | 0 | 1 | 2 | 0 | 0 | 3 | 2 | 38 | 52 |
| | *columbiae* | | 11 | 0 | 0 | 0 | 29 | 0 | 0 | 0 | 0 | 0 | 40 |
| *Aruga* | *holmesi* | | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 7 |
| *Balanus* | *crenatus* | | 32 | 61 | 0 | 0 | 38 | 0 | 0 | 0 | 0 | 70 | 201 |
| | *glandula* | | 2 | 29 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 33 |
| | *trigonus* | | 0 | 0 | 0 | 1 | 6 | 0 | 0 | 13 | 1 | 0 | 21 |
| *Cancer* | *antennarius* | | 2 | 4 | 0 | 0 | 1 | 0 | 0 | 0 | 4 | 0 | 11 |
| *Caprella* | | | 0 | 0 | 0 | 0 | 8 | 0 | 0 | 0 | 2 | 0 | 10 |
| | *californica* | | 8 | 0 | 0 | 0 | 17 | 0 | 0 | 6 | 4 | 7 | 42 |
| | *equilibra* | | 2 | 0 | 0 | 0 | 4 | 0 | 0 | 5 | 0 | 2 | 13 |
| | *mutica* | | 5 | 2 | 0 | 0 | 31 | 0 | 0 | 3 | 2 | 60 | 103 |
| | *scaura* | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| | *simia* | | 0 | 0 | 0 | 0 | 34 | 0 | 0 | 6 | 7 | 52 | 99 |
| *Deutella* | *californica* | | 1 | 4 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 10 |
| *Ericthonius* | | | 3 | 0 | 0 | 0 | 11 | 0 | 0 | 1 | 2 | 4 | 21 |
| *Gammaropsis* | *shoemakeri* | | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 1 | 6 | 0 | 12 |
| | *thompsoni* | | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 3 |
| *Gammarus* | *daiberi* | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 6 |
| *Gnorimosphaeroma* | *oregonensis* | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 12 | 12 |
| *Grandidierella* | *japonica* | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 12 | 12 |
| *Hemigrapsus* | *oregonensis* | | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 10 |
| *Hyalella* | *azteca* | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| *Ianiropsis* | *serricaudis* | | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 24 |
| *Jassa* | *marmorata* | | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | *slatteryi* | | 10 | 1 | 0 | 0 | 21 | 1 | 0 | 7 | 2 | 7 | 49 |

| | | | VialID | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Bay | BD | HB | MDR | MI | MO | Unk | MB | PH | SD | SF | Total |
| **Genus (or lowest rank)** | **species** | **Phylum** | 1061 | 954 | 313 | 987 | 1203 | 60 | 39 | 278 | 958 | 5973 | 11826 |
| | *staudei* | | 1 | 5 | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 12 |
| *Leptochelia* | | | 5 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 3 | 9 |
| *Leucothoe* | *alata* | | 2 | 0 | 3 | 0 | 0 | 1 | 0 | 0 | 2 | 83 | 91 |
| *Liljeborgia* | | | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 7 | 8 |
| *Megabalanus* | *rosa* | | 0 | 3 | 0 | 1 | 3 | 0 | 0 | 10 | 5 | 0 | 22 |
| *Melitida* | *rylovae* | | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 7 |
| *Metacarcinus* | *magister* | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| *Monocorophium* | | | 5 | 0 | 0 | 0 | 0 | 1 | 0 | 3 | 2 | 12 | 23 |
| | *acherusicum* | | 9 | 5 | 0 | 0 | 44 | 0 | 0 | 1 | 1 | 17 | 77 |
| | *insidiosum* | | 1 | 3 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 5 | 11 |
| | *uenoi* | | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 |
| *Munna* | *japonica* | | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 6 |
| *Nebalia* | | | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 |
| *Pachycheles* | | | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| *Pachygrapsus* | *crassipes* | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| *Paracerceis* | *cordata* | | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 16 |
| | *sculpta* | | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 5 | 2 | 12 |
| *Paradexamine* | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 12 | 15 |
| *Paranthura* | | | 9 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 48 | 59 |
| *Pentidotea* | *resecata* | | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| *Podocerus* | | | 2 | 0 | 0 | 0 | 31 | 0 | 0 | 0 | 0 | 1 | 34 |
| | *cristatus* | | 2 | 5 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 9 |
| *Polycheria* | *osborni* | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| *Pontogeneia* | | | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 6 |
| | *rostrata* | | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| *Pugettia* | *producta* | | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| *Synidotea* | *laevidorsalis* | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 4 |
| *Uromunna* | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| *Zeuxo* | | | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 4 | 1 | 0 | 6 |
| family_Anthuridae | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| family_Balanidae | | | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 2 |

| | | | VialID | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Bay** | **BD** | **HB** | **MDR** | **MI** | **MO** | **Unk** | **MB** | **PH** | **SD** | **SF** | Total |
| **Genus (or lowest rank)** | **species** | **Phylum** | 1061 | 954 | 313 | 987 | 1203 | 60 | 39 | 278 | 958 | 5973 | 11826 |
| family_Caprellidae | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| family_Gammaridae | | | 0 | 0 | 5 | 0 | 1 | 0 | 0 | 1 | 10 | 0 | 17 |
| order_Amphipoda | | | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| order_Decapoda | | | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Alcyonidium | | Bryozoa | 0 | 51 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 51 |
| Amathia | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 17 | 17 |
| | *gracilis* | | 3 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | 2 | 0 | 8 |
| | *tertia* | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 3 |
| | *verticillata* | | 0 | 0 | 0 | 55 | 0 | 4 | 0 | 0 | 45 | 57 | 161 |
| | *vidovici* | | 1 | 0 | 0 | 18 | 17 | 0 | 0 | 0 | 2 | 0 | 38 |
| *Anguinella* | *palmata* | | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 21 | 23 |
| *Aspidelectra* | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 3 |
| *Bugula* | *flabellata* | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 0 | 6 |
| | *longirostrata* | | 1 | 36 | 0 | 7 | 51 | 0 | 0 | 6 | 1 | 14 | 116 |
| | *neritina* | | 28 | 13 | 9 | 85 | 41 | 4 | 0 | 19 | 28 | 339 | 566 |
| | *pacifica* | | 18 | 15 | 0 | 0 | 5 | 1 | 0 | 0 | 0 | 17 | 56 |
| | *stolonifera* | | 22 | 19 | 9 | 42 | 13 | 2 | 0 | 8 | 24 | 218 | 357 |
| *Bugulina* | *stolonifera* | | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 |
| *Buskia* | *seriata* | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 3 |
| *Caulibugula* | *ciliata* | | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 8 |
| *Celleporaria* | *brunnea* | | 0 | 0 | 29 | 37 | 13 | 2 | 1 | 7 | 38 | 21 | 148 |
| *Celleporella* | *hyalina* | | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 8 |
| *Conopeum* | | | 37 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 15 | 54 |
| | *reticulatum* | | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 |
| | *tenuissimum* | | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 25 | 35 |
| *Crisia* | *occidentalis* | | 0 | 19 | 0 | 8 | 19 | 0 | 2 | 21 | 9 | 0 | 78 |
| *Cryptosula* | *pallasiana* | | 3 | 5 | 15 | 20 | 7 | 2 | 0 | 2 | 11 | 87 | 152 |
| *Electra* | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 3 |
| *Fenestrulina* | *delicia* | | 0 | 9 | 0 | 0 | 17 | 0 | 0 | 0 | 0 | 5 | 31 |
| *Filicrisia* | *franciscana* | | 0 | 15 | 0 | 0 | 11 | 0 | 0 | 5 | 0 | 1 | 32 |
| *Fredericella* | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 |

| | | | VialID | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Bay** | **BD** | **HB** | **MDR** | **MI** | **MO** | **Unk** | **MB** | **PH** | **SD** | **SF** | Total |
| **Genus (or lowest rank)** | **species** | **Phylum** | 1061 | 954 | 313 | 987 | 1203 | 60 | 39 | 278 | 958 | 5973 | 11826 |
| *Membranipora* | *chesapeakensis* | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 33 | 33 |
| | *membranacea* | | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 4 |
| *Nolella* | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| *Parasmittina* | | | 0 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 1 | 0 | 7 |
| *Pectinatella* | *magnifica* | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 28 | 28 |
| *Schizoporella* | *errata* | | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 10 | 17 |
| | *japonica* | | 42 | 15 | 0 | 1 | 39 | 0 | 0 | 15 | 1 | 19 | 132 |
| *Scruparia* | | | 0 | 1 | 0 | 0 | 4 | 0 | 0 | 2 | 7 | 0 | 14 |
| *Scrupocellaria* | *diegensis* | | 0 | 23 | 0 | 4 | 24 | 0 | 0 | 0 | 9 | 9 | 69 |
| *Smittoidea* | *prolifica* | | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 42 | 47 |
| *Tricellaria* | *occidentalis* | | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 49 | 51 |
| *Victorella* | | | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 4 | 0 | 5 |
| *Watersipora* | | | 10 | 4 | 0 | 0 | 26 | 1 | 11 | 0 | 0 | 8 | 60 |
| | *arcuata* | | 0 | 0 | 0 | 7 | 4 | 0 | 0 | 0 | 30 | 7 | 48 |
| | *subovoidea* | | 0 | 0 | 2 | 4 | 0 | 0 | 0 | 0 | 10 | 0 | 16 |
| | *subtorquata* | | 40 | 50 | 19 | 120 | 32 | 2 | 25 | 39 | 72 | 160 | 559 |
| *family_Plumatellidae* | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 12 | 12 |
| *Aplidium* | | Chordata | 0 | 0 | 12 | 42 | 0 | 2 | 0 | 0 | 14 | 2 | 72 |
| *Ascidia* | *ceratodes* | | 39 | 0 | 0 | 8 | 14 | 1 | 0 | 3 | 13 | 1 | 79 |
| | *virginea* | | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 18 | 0 | 19 |
| | *zara* | | 3 | 0 | 1 | 1 | 0 | 2 | 0 | 0 | 17 | 308 | 332 |
| *Botrylloides* | *leachii* | | 9 | 5 | 7 | 25 | 4 | 1 | 0 | 1 | 18 | 321 | 391 |
| | *pizoni* | | 0 | 0 | 0 | 12 | 0 | 0 | 0 | 0 | 9 | 0 | 21 |
| | *violaceus* | | 91 | 49 | 11 | 16 | 41 | 0 | 0 | 10 | 7 | 283 | 508 |
| *Botryllus* | *schlosseri* | | 70 | 17 | 41 | 96 | 10 | 8 | 0 | 7 | 71 | 444 | 764 |
| *Ciona* | *intestinalis* | | 18 | 0 | 36 | 31 | 0 | 1 | 0 | 3 | 43 | 150 | 282 |
| | *savigni* | | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 2 | 4 |
| | *savignyi* | | 1 | 13 | 2 | 19 | 0 | 1 | 0 | 3 | 25 | 180 | 244 |
| *Corella* | *inflata* | | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 |
| *Didemnum* | *vexillum* | | 6 | 13 | 0 | 0 | 2 | 0 | 0 | 2 | 0 | 57 | 80 |
| *Diplosoma* | *listerianum* | | 28 | 12 | 13 | 17 | 7 | 0 | 0 | 1 | 10 | 84 | 172 |

| | | | VialID | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Bay | BD | HB | MDR | MI | MO | Unk | MB | PH | SD | SF | Total |
| **Genus (or lowest rank)** | **species** | **Phylum** | 1061 | 954 | 313 | 987 | 1203 | 60 | 39 | 278 | 958 | 5973 | 11826 |
| *Distaplia* | *occidentalis* | | 1 | 1 | 0 | 5 | 3 | 0 | 0 | 0 | 13 | 0 | 23 |
| *Microcosmus* | *squamiger* | | 0 | 0 | 1 | 3 | 0 | 0 | 0 | 0 | 9 | 0 | 13 |
| *Molgula* | *manhattensis* | | 12 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 191 | 205 |
| *Perophora* | *japonica* | | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 12 |
| | *viridis* | | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 15 | 0 | 16 |
| *Polyandrocarpa* | *zorritensis* | | 0 | 0 | 14 | 50 | 0 | 3 | 0 | 0 | 55 | 0 | 122 |
| *Styela* | *canopus* | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 3 |
| | *clava* | | 0 | 0 | 0 | 13 | 0 | 0 | 0 | 0 | 9 | 51 | 73 |
| | *plicata* | | 0 | 0 | 14 | 33 | 0 | 2 | 0 | 0 | 12 | 0 | 61 |
| class_Ascidiacea | | | 2 | 4 | 0 | 11 | 38 | 0 | 0 | 2 | 1 | 31 | 89 |
| family_Styelidae | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 0 | 6 |
| *Anthopleura* | *elegantissima* | Cnidaria | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| *Aurelia* | | | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| | *aurita* | | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 1 | 1 | 4 |
| | *labiata* | | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| *Bougainvillia* | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 16 | 8 | 24 |
| | *muscus* | | 0 | 0 | 9 | 23 | 0 | 0 | 0 | 2 | 9 | 4 | 47 |
| *Cordylophora* | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 24 | 24 |
| | *caspia* | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 |
| *Diadumene* | | | 4 | 0 | 10 | 5 | 1 | 1 | 0 | 2 | 9 | 103 | 135 |
| | *franciscana* | | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 1 | 0 | 23 | 27 |
| | *leucolena* | | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 24 | 26 |
| | *lineata* | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 8 |
| *Ectopleura* | *crocea* | | 4 | 0 | 5 | 4 | 10 | 0 | 0 | 5 | 5 | 10 | 43 |
| *Gonothyraea* | *loveni* | | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| *Hydra* | *hymanae* | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| | *vulgaris* | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 4 |
| *Laomedea* | *calceoli* | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 4 |
| | *calceolifera* | | 1 | 3 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 3 | 11 |
| *Metridium* | *senile* | | 0 | 23 | 0 | 0 | 7 | 0 | 0 | 0 | 0 | 7 | 37 |
| *Moerisia* | *inkermanica* | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 8 |

| | | | VialID | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Bay | BD | HB | MDR | MI | MO | Unk | MB | PH | SD | SF | Total |
| **Genus (or lowest rank)** | **species** | **Phylum** | 1061 | 954 | 313 | 987 | 1203 | 60 | 39 | 278 | 958 | 5973 | 11826 |
| *Obelia* | | | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| | *bidentata* | | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 12 |
| | *dichotoma* | | 0 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 1 | 4 |
| | *longissima* | | 33 | 28 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 64 |
| *Stauridiosarsia* | *cliffordi* | | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| class_Hydrozoa | | | 3 | 9 | 0 | 4 | 0 | 0 | 0 | 3 | 5 | 0 | 24 |
| *Amphipholis* | *squamata* | Echinodermata | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 5 | 6 |
| *Pisaster* | *ochraceus* | | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| *Strongylocentrotus* | *purpuratus* | | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| *Barentsia* | *benedeni* | Entoprocta | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| phylum_Entoprocta | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 |
| *Acanthodoris* | *nanaimoensis* | Mollusca | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | *rhodoceras* | | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| *Aeolidia* | | | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| *Alia* | *carinata* | | 1 | 1 | 0 | 0 | 14 | 0 | 0 | 0 | 1 | 1 | 18 |
| *Amphissa* | *reticulata* | | 0 | 1 | 0 | 0 | 9 | 0 | 0 | 0 | 0 | 0 | 10 |
| *Caprella* | | | 1 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 |
| *Crepidula* | *nummaria* | | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| | *plana* | | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 5 |
| *Crepipatella* | *lingulata* | | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 2 | 0 | 5 |
| *Cuthona* | | | 0 | 6 | 0 | 0 | 9 | 0 | 0 | 0 | 1 | 0 | 16 |
| *Dendronotus* | *venustus* | | 13 | 8 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 24 |
| *Diaphorodoris* | *lirulatocauda* | | 0 | 4 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 5 |
| *Dirona* | *picta* | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 3 |
| *Doto* | | | 0 | 0 | 0 | 1 | 4 | 0 | 0 | 1 | 1 | 0 | 7 |
| *Flabellina* | *trilineata* | | 2 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 |
| | *verrucosa* | | 1 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 |
| *Geukensia* | *demissa* | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 |
| *Haminoea* | *japonica* | | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 33 | 39 |
| *Hermissenda* | | | 1 | 31 | 0 | 2 | 21 | 0 | 0 | 0 | 4 | 0 | 59 |
| *Hiatella* | *arctica* | | 0 | 5 | 0 | 0 | 8 | 0 | 0 | 0 | 0 | 0 | 13 |

| | | | VialID | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Bay | BD | HB | MDR | MI | MO | Unk | MB | PH | SD | SF | Total |
| **Genus (or lowest rank)** | **species** | **Phylum** | 1061 | 954 | 313 | 987 | 1203 | 60 | 39 | 278 | 958 | 5973 | 11826 |
| *Lacuna* | | | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 1 | 4 |
| *Littorina* | *littorea* | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| *Musculista* | *senhousia* | | 13 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 3 | 41 | 59 |
| *Mya* | *arenaria* | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| *Mytilus* | *edulis* | | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| | *galloprovincialis* | | 7 | 0 | 2 | 8 | 25 | 1 | 0 | 14 | 5 | 5 | 67 |
| | *trossulus* | | 3 | 80 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 42 | 129 |
| *Onchidoris* | *bilamellata* | | 0 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 9 |
| *Ostrea* | *lurida* | | 1 | 2 | 2 | 44 | 0 | 5 | 0 | 1 | 33 | 108 | 196 |
| *Placida* | *dendritica* | | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| *Pododesmus* | *macrochisma* | | 0 | 0 | 0 | 0 | 36 | 0 | 0 | 0 | 0 | 0 | 36 |
| *Polycera* | *atra* | | 0 | 1 | 0 | 6 | 26 | 1 | 0 | 0 | 8 | 3 | 45 |
| | *hedgpethi* | | 0 | 1 | 0 | 4 | 7 | 0 | 0 | 0 | 1 | 7 | 20 |
| *Ruditapes* | *philippinarum* | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 7 |
| *Tenellia* | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 5 | 10 |
| *Triopha* | *maculata* | | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 4 |
| *Urosalpinx* | *cinerea* | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 |
| class_Bivalvia | | | 4 | 0 | 0 | 0 | 7 | 1 | 0 | 0 | 0 | 0 | 12 |
| class_Gastropoda | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| family_Fionidae | | | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 4 |
| family_Terebellidae | | | 6 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 57 | 73 |
| family_Veneridae | | | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| order_Nudibranchia | | | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 3 | 5 |
| *Cephalothrix* | *simula* | Nemertea | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 43 | 45 |
| phylum_Nemertea | | | 4 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 2 | 9 |
| *Euplana* | *gracilis* | Platyhelminthes | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 4 |
| *Pseudoceros* | | | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 5 |
| phylum_Platyhelminthes | | | 18 | 12 | 0 | 4 | 14 | 0 | 0 | 0 | 2 | 3 | 53 |
| *Callyspongia* | *siphonella* | Porifera | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 1 | 6 | 10 |
| *Eunapius* | *fragilis* | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 63 | 63 |
| *Grantia* | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 22 | 22 |

| | | | VialID | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Bay** | **BD** | **HB** | **MDR** | **MI** | **MO** | **Unk** | **MB** | **PH** | **SD** | **SF** | Total |
| **Genus (or lowest rank)** | **species** | **Phylum** | 1061 | 954 | 313 | 987 | 1203 | 60 | 39 | 278 | 958 | 5973 | 11826 |
| *Halichondria* | *sitiens* | | 6 | 4 | 3 | 15 | 2 | 1 | 0 | 5 | 9 | 136 | 181 |
| *Haliclona* | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| | *cinerea* | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| | *tubifera* | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| | *xena* | | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| *Terpios* | *hoshinota* | | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| phylum_Porifera | | | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |

**Table 5.3. Concordance of morphological identifications (Morpho-genus and Morpho-species) and molecular identifications (Molec-genus and Molec-species) for vouchers, limited to vouchers given morphological binomial names**. Morpho-species highlighted in red were not confirmed by molecular analysis. Molec-species in green were confirmation of at least one Morpho-species. Percent-mismatch values in yellow are highlighted as high frequency mismatches between morphological and molecular identifications, with both numerous specimens and high rate of mismatch. Most cases of discordance involved few specimens and were improbable misidentifications; these are likely due contamination of DNA templates or database entries.

| Phylum | Morpho-genus | Morpho-species | Molec-genus | Molec-species | Specimen Count: Match | Specimen Count: Mismatch | Percent of Specimens: Match | Percent of Specimens: Mismatch |
|---|---|---|---|---|---|---|---|---|
| **All** | | | | | 6636 | 1500 | 82 | 18 |
| **Annelida** | *Alitta* | *succinea* | *Alitta* | *succinea* | 18 | | 69 | |
| | | | *Capitella* | *capitata* | | 1 | | 4 |
| | | | *Cirriformia* | *moorei* | | 2 | | 8 |
| | | | *Glycinde* | *picta* | | 1 | | 4 |
| | | | *Nereis* | *latescens* | | 1 | | 4 |
| | | | *Notomastus* | *lineatus* | | 1 | | 4 |
| | | | *Sabaco* | *elongatus* | | 1 | | 4 |
| | | | *Scoloplos* | *acmeceps* | | 1 | | 4 |
| | *Barantolla* | *americana* | *Cirriformia* | *moorei* | | 1 | | 50 |
| | | | *Pectinaria* | *californiensis* | | 1 | | 50 |
| | *Bergstroemia* | *nigromaculata* | *Pterocirrus* | *montereyensis* | | 1 | | 100 |
| | *Capitella* | *capitata* | *Capitella* | *capitata* | 10 | | 100 | |
| | | *teleta* | *Capitella* | *capitata* | | 18 | | 95 |
| | | | *Megasyllis* | *nipponica* | | 1 | | 5 |
| | *Chone* | *magna* | *Euchone* | *limnicola* | | 1 | | 14 |
| | | | *Megasyllis* | *nipponica* | | 1 | | 14 |
| | | | *Paradialychone* | *ecaudata* | | 4 | | 57 |
| | | | *Pseudochitinopoma* | *occidentalis* | | 1 | | 14 |
| | *Ctenodrilus* | *serratus* | *Harmothoe* | *imbricata* | | 3 | | 75 |
| | | | *Polydora* | *cornuta* | | 1 | | 25 |
| | *Eulalia* | *levicor* | *Eulalia* | *quadrioculata* | | 13 | | 87 |
| | | | *Halosydna* | *brevisetosa* | | 1 | | 7 |
| | | | *Odontosyllis* | *phosphorea* | | 1 | | 7 |
| | *Eupolymnia* | *heterobranchia* | *Eupolymnia* | *heterobranchia* | 18 | | 95 | |
| | | | *Pseudochitinopoma* | *occidentalis* | | 1 | | 5 |

| Phylum | Morpho-genus | Morpho-species | Molec-genus | Molec-species | Specimen Count: Match | Specimen Count: Mismatch | Percent of Specimens: Match | Percent of Specimens: Mismatch |
|---|---|---|---|---|---|---|---|---|
| | *Ficopomatus* | *enigmaticus* | *Ficopomatus* | *enigmaticus* | 15 | | 100 | |
| | *Halosydna* | *brevisetosa* | *Eulalia* | *quadrioculata* | | 1 | | 7 |
| | | | *Halosydna* | *brevisetosa* | 13 | | 93 | |
| | *Harmothoe* | *imbricata* | *Branchiomma* | *nigromaculatum* | | 1 | | |
| | | | *Cirriformia* | *moorei* | | 1 | | |
| | | | *Euchone* | *limnicola* | | 1 | | |
| | | | *Harmothoe* | *imbricata* | 260 | | 1 | |
| | | | *Lumbrineris* | *californiensis* | | 1 | | |
| | | | *Malmgreniella* | *macginitiei* | | 1 | | |
| | | | *Megasyllis* | *nipponica* | | 3 | | 1 |
| | | | *Nephtys* | *californiensis* | | 1 | | |
| | | | *Polydora* | *cornuta* | | 1 | | |
| | | | *Sabaco* | *elongatus* | | 4 | | 1 |
| | | | *Salmacina* | *tribranchiata* | | 1 | | |
| | *Hydroides* | *elegans* | *Hydroides* | *elegans* | 30 | | 94 | |
| | | | | *gracilis* | | 1 | | 3 |
| | | | *Salmacina* | *tribranchiata* | | 1 | | 3 |
| | *Leitoscoloplos* | *pugettensis* | *Nephtys* | *caecoides* | | 1 | | 20 |
| | | | | *ferruginea* | | 1 | | 20 |
| | | | *Pilargis* | *berkeleyae* | | 1 | | 20 |
| | | | *Scoletoma* | *tetraura* | | 1 | | 20 |
| | *Lumbrineris* | *perkinsi* | *Lumbrineris* | *perkinsi* | 3 | | 75 | |
| | | | *Salmacina* | *tribranchiata* | | 1 | | 25 |
| | *Marphysa* | *sanguine* | *Harmothoe* | *imbricata* | | 1 | | 100 |
| | *Megasyllis* | *nipponica* | *Branchiomma* | *boholense* | | 1 | | |
| | | | | *nigromaculatum* | | 4 | | 2 |
| | | | *Capitella* | *capitata* | | 2 | | 1 |
| | | | *Glycinde* | *picta* | | 2 | | 1 |
| | | | *Harmothoe* | *imbricata* | | 10 | | 4 |
| | | | *Hydroides* | *elegans* | | 1 | | |
| | | | | *gracilis* | | 1 | | |
| | | | *Leitoscoloplos* | *pugettensis* | | 1 | | |
| | | | *Megasyllis* | *nipponica* | 226 | | 85 | |

| Phylum | Morpho-genus | Morpho-species | Molec-genus | Molec-species | Specimen Count | | Percent of Specimens | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Match | Mismatch | Match | Mismatch |
| | | | *Neanthes* | *acuminata* | | 7 | | 3 |
| | | | *Nephtys* | *caecoides* | | 2 | | 1 |
| | | | *Odontosyllis* | *phosphorea* | | 1 | | |
| | | | *Parasabella* | *pallida* | | 4 | | 2 |
| | | | *Platynereis* | *bicanaliculata* | | 1 | | |
| | | | *Polydora* | *cornuta* | | 3 | | 1 |
| | *Myrianida* | *pachycera* | *Myrianida* | *pachycera* | 3 | | 100 | |
| | | *pentadentata* | *Harmothoe* | *imbricata* | | 1 | | 50 |
| | | | *Megasyllis* | *nipponica* | | 1 | | 50 |
| | *Naineris* | *dendritica* | *Naineris* | *dendritica* | 1 | 2 | 25 | 50 |
| | *Neanthes* | *acuminata* | *Megasyllis* | *nipponica* | | 3 | | 23 |
| | | | *Neanthes* | *acuminata* | | 7 | | 54 |
| | | | *Nereis* | *vexillosa* | | 2 | | 15 |
| | | | *Platynereis* | *bicanaliculata* | | 1 | | 8 |
| | *Nereis* | *vexillosa* | *Alitta* | *succinea* | | 5 | | 45 |
| | | | *Eulalia* | *quadrioculata* | | 1 | | 9 |
| | | | *Nereis* | *vexillosa* | 4 | | 36 | |
| | | | *Sabaco* | *elongatus* | | 1 | | 9 |
| | *Ophryotrocha* | *labronica* | *Polydora* | *cornuta* | | 1 | | 50 |
| | | | *Salmacina* | *tribranchiata* | | 1 | | 50 |
| | *Oxydromus* | *pugettensis* | *Megasyllis* | *nipponica* | | 1 | | 20 |
| | *Platynereis* | *bicaniculata* | *Platynereis* | *bicanaliculata* | | 2 | | 100 |
| | *Polydora* | *cornuta* | *Harmothoe* | *imbricata* | | 1 | | 33 |
| | | | *Megasyllis* | *nipponica* | | 1 | | 33 |
| | | | *Polydora* | *cornuta* | 1 | | 33 | |
| | *Protodorvillea* | *gracilis* | *Capitella* | *capitata* | | 1 | | 25 |
| | *Schistomeringos* | *longicornis* | *Branchiomma* | *boholense* | | 1 | | 4 |
| | | | *Cirriformia* | *moorei* | | 2 | | 7 |
| | | | *Ficopomatus* | *enigmaticus* | | 2 | | 7 |
| | | | *Glycinde* | *picta* | | 1 | | 4 |
| | | | *Leitoscoloplos* | *pugettensis* | | 1 | | 4 |
| | | | *Malmgreniella* | *nigralba* | | 1 | | 4 |
| | | | *Nephtys* | *caecoides* | | 3 | | 11 |

| Phylum | Morpho-genus | Morpho-species | Molec-genus | Molec-species | Specimen Count | | Percent of Specimens | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Match | Mismatch | Match | Mismatch |
| | | | Pherusa | neopapillata | | 1 | | 4 |
| | | | Platynereis | bicanaliculata | | 1 | | 4 |
| | | | Pseudopolydora | kempi | | 1 | | 4 |
| | | | Sabaco | elongatus | | 2 | | 7 |
| | | | Schistomeringos | longicornis | 8 | | 30 | |
| | | | Scoletoma | tetraura | | 3 | | 11 |
| | Schizobranchia | insignis | Halosydna | brevisetosa | | 1 | | 50 |
| | | | Schizobranchia | insignis | 1 | | 50 | |
| | Streblosoma | uncinatus | Capitella | capitata | | 1 | 0 | 25 |
| | | | Streblosoma | uncinatus | 3 | | 75 | |
| | Streblospio | benedicti | Scoloplos | acmeceps | | 1 | | 100 |
| | Syllis | alternata | Halosydna | brevisetosa | | 1 | | 33 |
| | | | Megasyllis | nipponica | | 1 | | 33 |
| | | | Pseudochitinopoma | occidentalis | | 1 | | 33 |
| **Arthropoda** | Ampelisca | abdita | Gnorimosphaeroma | oregonensis | | 1 | | 25 |
| | | | Grandidierella | japonica | | 2 | | 50 |
| | | | Photis | brevipes | | 1 | | 25 |
| | Amphibalanus | amphitrite | Amphibalanus | amphitrite | 10 | | 77 | |
| | | | | improvisus | | 2 | | 15 |
| | | | Balanus | crenatus | | 1 | | 8 |
| | | improvisus | Amphibalanus | amphitrite | | 1 | | 1 |
| | | | | improvisus | 69 | | 92 | |
| | | | Balanus | crenatus | | 5 | | 7 |
| | Ampithoe | lacertosa | Ampithoe | lacertosa | 7 | | 70 | |
| | | | | valida | | 1 | | 10 |
| | | | Photis | brevipes | | 1 | | 10 |
| | | | Stenothoe | valida | | 1 | | 10 |
| | | sectiman | Pugettia | producta | | 1 | | 100 |
| | | valida | Ampithoe | valida | 3 | | 100 | |
| | Aoroides | columbiae | Aoroides | columbiae | 38 | | 97 | |
| | | | | secunda | | 1 | | 3 |
| | Aruga | holmesi | Aoroides | secunda | | 2 | | 33 |
| | | | Aruga | holmesi | 2 | | 33 | |

| Phylum | Morpho-genus | Morpho-species | Molec-genus | Molec-species | Specimen Count | | Percent of Specimens | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Match | Mismatch | Match | Mismatch |
| | | | *Colidotea* | *rostrata* | | 1 | | 17 |
| | | | *Synidotea* | *laticauda* | | 1 | | 17 |
| | *Balanus* | *crenatus* | *Amphibalanus* | *improvisus* | | 4 | | 2 |
| | | | *Balanus* | *crenatus* | 194 | | 97 | |
| | | | | *nubilus* | | 3 | | 1 |
| | | *glandula* | *Balanus* | *crenatus* | | 1 | | 3 |
| | | | | *glandula* | 30 | | 94 | |
| | | | | *nubilus* | | 1 | | 3 |
| | | *trigonus* | *Balanus* | *trigonus* | 21 | | 100 | |
| | *Cancer* | *antennarius* | *Ampithoe* | *valida* | | 1 | | 9 |
| | | | *Cancer* | *jordani* | | 6 | | 55 |
| | | | *Pachycheles* | *rudis* | | 1 | | 9 |
| | | | *Romaleon* | *branneri* | | 3 | | 27 |
| | *Caprella* | *californica* | *Caprella* | *californica* | 4 | 1 | 78 | 2 |
| | | *equilibra* | *Caprella* | *equilibra* | 13 | | 100 | |
| | | *mutica* | *Caprella* | *mutica* | 102 | | 99 | |
| | | | Gammaropsis | thompsoni | | 1 | 0 | 1 |
| | | *scaura* | *Caprella* | *scaura* | 1 | | 100 | |
| | | *simia* | *Amphibalanus* | *improvisus* | | 1 | | 1 |
| | | | *Caprella* | *californica* | | 3 | | 3 |
| | | | | *equilibra* | | 1 | | 1 |
| | | | | *simia* | 92 | | 93 | |
| | | | *Dissiminassa* | *dissimilis* | | 1 | | 1 |
| | | | *Paranthura* | *japonica* | | 1 | | 1 |
| | *Deutella* | *californica* | *Deutella* | *californica* | 10 | | 20 | |
| | *Gammaropsis* | *shoemakeri* | *Elasmopus* | *bampo* | | 1 | | 9 |
| | | | *Gammaropsis* | *shoemakeri* | 10 | | 91 | |
| | | *thompsoni* | *Gammaropsis* | *thompsoni* | 2 | | 100 | |
| | *Gammarus* | *daiberi* | *Gammarus* | *daiberi* | 5 | | 100 | |
| | *Gnorimosphaeroma* | *oregonensis* | *Gnorimosphaeroma* | *oregonensis* | 12 | | 67 | |
| | *Grandidierella* | *japonica* | *Gnorimosphaeroma* | *oregonensis* | | 2 | | 1 |
| | | | *Grandidierella* | *japonica* | 10 | | 5 | |

| | | | | | Specimen Count | | Percent of Specimens | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Match | Mismatch | Match | Mismatch |
| Phylum | Morpho-genus | Morpho-species | Molec-genus | Molec-species | | | | |
| | *Hemigrapsus* | *oregonensis* | *Deutella* | *californica* | | 1 | | 6 |
| | | | *Gammaropsis* | *thompsoni* | | 2 | | 11 |
| | | | *Gammarus* | *daiberi* | | 2 | | 11 |
| | | | *Hemigrapsus* | *oregonensis* | 1 | | 6 | |
| | *Hyalella* | *azteca* | *Hyalella* | *azteca* | 1 | | 100 | |
| | *Ianiropsis* | *serricaudis* | *Heptacarpus* | *paludicola* | | 1 | | 6 |
| | | | *Ianiropsis* | *analoga* | | 3 | | 19 |
| | | | | *montereyensis* | | 3 | | 19 |
| | | | | *serricaudis* | 5 | | 31 | |
| | | | *Incisocalliope* | *derzhavini* | | 1 | | 6 |
| | | | *Janiralata* | *occidentalis* | | 1 | | 6 |
| | | | *Jassa* | *slatteryi* | | 1 | | 6 |
| | | | *Laticorophium* | *baconi* | | 1 | | 6 |
| | *Jassa* | *marmorata* | *Jassa* | *marmorata* | | 1 | | 100 |
| | | *slatteryi* | *Ericthonius* | *punctatus* | | 1 | | 3 |
| | | | *Ianiropsis* | *analoga* | | 1 | | 3 |
| | | | *Incisocalliope* | *derzhavini* | | 1 | | 3 |
| | | | *Jassa* | *marmorata* | | 1 | | 3 |
| | | | | *slatteryi* | 35 | | 88 | |
| | | | *Metopa* | *cistella* | | 1 | | 3 |
| | | *staudei* | *Jassa* | *marmorata* | | 1 | | 9 |
| | | | | *staudei* | 10 | | 91 | |
| | *Leucothoe* | *alata* | *Ampithoe* | *lacertosa* | | 1 | | 1 |
| | | | *Incisocalliope* | *derzhavini* | | 1 | | 1 |
| | | | *Jassa* | *slatteryi* | | 1 | | 1 |
| | | | *Laticorophium* | *baconi* | | 1 | | 1 |
| | | | *Leucothoe* | *alata* | 82 | | 93 | |
| | | | *Paranthura* | *japonica* | | 1 | | 1 |
| | | | *Sinocorophium* | *heteroceratum* | | 1 | | 1 |
| | *Megabalanus* | *rosa* | *Amphibalanus* | *improvisus* | | 1 | | 6 |
| | | | *Balanus* | *nubilus* | | 1 | | 6 |
| | | | | *trigonus* | | 1 | | 6 |
| | | | *Megabalanus* | *californicus* | | 14 | | 82 |

| Phylum | Morpho-genus | Morpho-species | Molec-genus | Molec-species | Specimen Count: Match | Specimen Count: Mismatch | Percent of Specimens: Match | Percent of Specimens: Mismatch |
|---|---|---|---|---|---|---|---|---|
| | *Melitida* | *rylovae* | *Melita* | *rylovae* | 5 | | 100 | 0 |
| | *Metacarcinus* | *magister* | *Gammarus* | *daiberi* | | 1 | | 100 |
| | *Monocorophium* | *acherusicum* | *Ampithoe* | *valida* | | 1 | | 1 |
| | | | *Laticorophium* | *baconi* | | 8 | | 11 |
| | | | *Metopa* | *cistella* | | 1 | | 1 |
| | | | *Monocorophium* | *acherusicum* | 56 | | 78 | |
| | | | | *insidiosum* | | 2 | | 3 |
| | | | | *uenoi* | | 2 | | 3 |
| | | | *Photis* | *brevipes* | | 1 | | 1 |
| | | | *Podocerus* | *cristatus* | | 1 | | 1 |
| | | *insidiosum* | *Monocorophium* | *acherusicum* | | 1 | | 9 |
| | | | | *insidiosum* | 7 | | 64 | |
| | | | | *uenoi* | | 3 | | 27 |
| | | *uenoi* | *Monocorophium* | *uenoi* | 4 | | 100 | |
| | *Munna* | *japonica* | *Monocorophium* | *acherusicum* | | 1 | | 1 |
| | *Pachygrapsus* | *crassipes* | *Hemigrapsus* | *oregonensis* | | 1 | | 100 |
| | *Paracerceis* | *cordata* | *Ampithoe* | *valida* | | 1 | | 8 |
| | | | *Paracerceis* | *cordata* | 10 | | 83 | |
| | | | *Photis* | *brevipes* | | 1 | | 8 |
| | | *sculpta* | *Paracerceis* | *sculpta* | 12 | | 100 | |
| | *Pentidotea* | *resecata* | *Idotea* | *resecata* | 1 | | 100 | |
| | *Podocerus* | *cristatus* | *Podocerus* | *brasiliensis* | | 2 | | 22 |
| | | | | *cristatus* | 7 | | 78 | |
| | *Polycheria* | *osborni* | *Polycheria* | *osborni* | 1 | | 100 | |
| | *Pontogeneia* | *rostrata* | *Pontogeneia* | *rostrata* | 1 | | 100 | |
| | *Synidotea* | *laevidorsalis* | *Caprella* | *californica* | | 1 | | 25 |
| | | | | *equilibra* | | 1 | | 25 |
| | | | *Idotea* | *rufescens* | | 1 | | 25 |
| | | | *Stenothoe* | *valida* | | 1 | | 25 |
| **Bryozoa** | *Amathia* | *gracilis* | *Amathia* | *verticillata* | | 1 | | 25 |
| | | | *Fenestrulina* | *delicia* | | 1 | | 25 |
| | | | *Thalamoporella* | *californica* | | 1 | | 25 |
| | | *verticillata* | *Alcyonidium* | *polyoum* | | 2 | | 1 |

| Phylum | Morpho-genus | Morpho-species | Molec-genus | Molec-species | Specimen Count: Match | Specimen Count: Mismatch | Percent of Specimens: Match | Percent of Specimens: Mismatch |
|---|---|---|---|---|---|---|---|---|
| | | | *Amathia* | *verticillata* | 123 | | 79 | |
| | | | *Bugula* | *neritina* | | 2 | | 1 |
| | | | | *stolonifera* | | 1 | | 1 |
| | | | *Celleporaria* | *brunnea* | | 2 | | 1 |
| | | | *Cradoscrupocellaria* | *tenuirostris* | | 2 | | 1 |
| | | | *Crisulipora* | *occidentalis* | | 8 | | 5 |
| | | | *Disporella* | *buskiana* | | 1 | | 1 |
| | | | *Hippopodina* | *feegeensis* | | 1 | | 1 |
| | | | *Schizoporella* | *errata* | | 1 | | 1 |
| | | | *Scrupocellaria* | *bertholettii* | | 2 | | 1 |
| | | | *Smittoidea* | *prolifica* | | 1 | | 1 |
| | | | *Thalamoporella* | *californica* | | 7 | | 5 |
| | | | *Tubulipora* | *pacifica* | | 1 | | 1 |
| | | | *Watersipora* | *subtorquata* | | 1 | | 1 |
| | | *vidovici* | *Amathia* | *verticillata* | | 1 | | 50 |
| | | | *Bugulina* | *longirostrata* | | 1 | | 50 |
| | *Anguinella* | *palmata* | *Anguinella* | *palmata* | 22 | | 96 | |
| | | | *Bugula* | *stolonifera* | | 1 | | 4 |
| | *Bugula* | *flabellata* | *Amathia* | *verticillata* | | 1 | | 33 |
| | | | *Bugula* | *flabellata* | 1 | | 33 | |
| | | | | *stolonifera* | | 1 | | 33 |
| | | *longirostrata* | *Bugula* | *flabellata* | | 1 | | 1 |
| | | | | *neritina* | | 5 | | 4 |
| | | | | *stolonifera* | | 18 | | 16 |
| | | | *Bugulina* | *longirostrata* | 77 | | 69 | |
| | | | *Celleporaria* | *brunnea* | | 1 | | 1 |
| | | | *Celleporella* | *hyalina* | | 1 | | 1 |
| | | | *Cheilopora* | *praelonga* | | 1 | | 1 |
| | | | *Crisularia* | *pacifica* | | 2 | | 2 |
| | | | *Cryptosula* | *pallasiana* | | 1 | | 1 |
| | | | *Licornia* | *diegensis* | | 1 | | 1 |
| | | | *Pomocellaria* | *varians* | | 1 | | 1 |
| | | | *Schizoporella* | *japonica* | | 1 | | 1 |

| Phylum | Morpho-genus | Morpho-species | Molec-genus | Molec-species | Specimen Count | | Percent of Specimens | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Match | Mismatch | Match | Mismatch |
| | | | *Watersipora* | *subtorquata* | | 2 | | 2 |
| | | *neritina* | *Bugula* | *neritina* | 526 | | 92 | 3 |
| | | | | *stolonifera* | | 4 | | 1 |
| | | | *Bugulina* | *longirostrata* | | 2 | | |
| | | | *Celleporaria* | *brunnea* | | 2 | | |
| | | | *Crisulipora* | *occidentalis* | | 3 | | 1 |
| | | | *Cryptosula* | *pallasiana* | | 5 | | 1 |
| | | | *Smittoidea* | *prolifica* | | 1 | | |
| | | | *Thalamoporella* | *californica* | | 2 | | |
| | | | *Tricellaria* | *occidentalis* | | 4 | | 1 |
| | | | *Tubulipora* | *pacifica* | | 1 | | |
| | | | *Watersipora* | *subtorquata* | | 3 | | 1 |
| | | *pacifica* | *Amathia* | *verticillata* | | 1 | | 2 |
| | | | *Bugula* | *neritina* | | 1 | | 2 |
| | | | | *stolonifera* | | 1 | | 2 |
| | | | *Crisularia* | *pacifica* | 50 | | 91 | |
| | | | *Tricellaria* | *occidentalis* | | 1 | | 2 |
| | | | *Watersipora* | *subtorquata* | | 1 | | 2 |
| | | *stolonifera* | *Amathia* | *verticillata* | | 1 | | |
| | | | *Anguinella* | *palmata* | | 1 | | |
| | | | *Bugula* | *californica* | | 1 | | |
| | | | | *neritina* | | 11 | | 3 |
| | | | | *stolonifera* | 307 | | 88 | |
| | | | *Bugulina* | *longirostrata* | | 2 | | 1 |
| | | | *Celleporaria* | *brunnea* | | 3 | | 1 |
| | | | *Celleporella* | *hyalina* | | 1 | | |
| | | | *Conopeum* | *reticulum* | | 1 | | |
| | | | *Crisia* | *occidentalis* | | 1 | | |
| | | | *Crisularia* | *pacifica* | | 2 | | 1 |
| | | | *Cryptosula* | *pallasiana* | | 4 | | 1 |
| | | | *Pomocellaria* | *varians* | | 1 | | |
| | | | *Schizoporella* | *japonica* | | 1 | | |
| | | | *Scrupocellaria* | *bertholettii* | | 1 | | |

| Phylum | Morpho-genus | Morpho-species | Molec-genus | Molec-species | Specimen Count: Match | Specimen Count: Mismatch | Percent of Specimens: Match | Percent of Specimens: Mismatch |
|---|---|---|---|---|---|---|---|---|
| | | | *Smittoidea* | *prolifica* | | 2 | | 1 |
| | | | *Thalamoporella* | *californica* | | 2 | | 1 |
| | | | *Tricellaria* | *occidentalis* | | 5 | | 1 |
| | | | *Watersipora* | *subtorquata* | | 2 | | 1 |
| | *Bugulina* | *stolonifera* | *Bugulina* | *longirostrata* | | 2 | | 1 |
| | | | *Watersipora* | *subtorquata* | | 1 | | |
| | *Buskia* | *seriata* | *Buskia* | *seriata* | 2 | | 100 | |
| | *Caulibugula* | *ciliata* | *Caulibugula* | *ciliata* | 7 | | 100 | |
| | *Celleporaria* | *brunnea* | *Celleporaria* | *brunnea* | 138 | | 93 | |
| | | | *Celleporella* | *hyalina* | | 2 | | 1 |
| | | | *Crisulipora* | *occidentalis* | | 1 | | 1 |
| | | | *Hippopodina* | *feegeensis* | | 1 | | 1 |
| | | | *Schizoporella* | *errata* | | 1 | | 1 |
| | | | | *japonica* | | 1 | | 1 |
| | | | *Thalamoporella* | *californica* | | 2 | | 1 |
| | | | *Watersipora* | *subtorquata* | | 2 | | 1 |
| | *Celleporella* | *hyalina* | *Celleporella* | *hyalina* | 8 | | 100 | |
| | *Conopeum* | *reticulatum* | *Conopeum* | *tenuissimum* | | 1 | | 100 |
| | | *tenuissimum* | *Bugula* | *stolonifera* | | 1 | | 5 |
| | | | *Conopeum* | *reticulum* | | 1 | | 5 |
| | | | | *tenuissimum* | 15 | | 75 | |
| | | | *Cryptosula* | *pallasiana* | | 3 | | 15 |
| | *Crisia* | *occidentalis* | *Crisia* | *occidentalis* | 63 | | 43 | |
| | | | *Crisulipora* | *occidentalis* | 11 | | 7 | |
| | | | *Licornia* | *diegensis* | | 1 | | 1 |
| | *Cryptosula* | *pallasiana* | *Celleporaria* | *brunnea* | | 3 | | 2 |
| | | | *Celleporella* | *hyalina* | | 1 | | 1 |
| | | | *Cryptosula* | *pallasiana* | 138 | | 93 | |
| | | | *Hippopodina* | *feegeensis* | | 2 | | 1 |
| | | | *Schizoporella* | *japonica* | | 1 | | 1 |
| | | | *Scrupocellaria* | *bertholettii* | | 1 | | 1 |
| | | | *Smittoidea* | *prolifica* | | 1 | | 1 |
| | | | *Thalamoporella* | *californica* | | 1 | | 1 |

| | | | | | Specimen Count | | Percent of Specimens | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Match | Mismatch | Match | Mismatch |
| Phylum | Morpho-genus | Morpho-species | Molec-genus | Molec-species | | | | |
| | | | *Tubulipora* | *pacifica* | | 1 | | 1 |
| | *Fenestrulina* | *delicia* | *Fenestrulina* | *delicia* | 22 | | 100 | |
| | *Filicrisia* | *franciscana* | *Crisulipora* | *occidentalis* | | 1 | | 2 |
| | | | *Filicrisia* | *franciscana* | 25 | | 61 | |
| | *Membranipora* | *chesapeakensis* | *Membranipora* | *chesapeakensis* | 32 | | 100 | |
| | | *membranacea* | *Membranipora* | *villosa* | | 2 | | 100 |
| | *Pectinatella* | *magnifica* | *Pectinatella* | *magnifica* | 23 | | 100 | |
| | *Schizoporella* | *errata* | *Schizoporella* | *errata* | 14 | | 93 | |
| | | | | *japonica* | | 1 | | 7 |
| | | *japonica* | *Bugula* | *neritina* | | 1 | | 1 |
| | | | *Cryptosula* | *pallasiana* | | 2 | | 1 |
| | | | *Schizoporella* | *japonica* | 124 | | 66 | |
| | *Scrupocellaria* | *diegensis* | *Celleporaria* | *brunnea* | | 1 | | 1 |
| | | | *Crisia* | *occidentalis* | | 2 | | 3 |
| | | | *Licornia* | *diegensis* | 64 | | 94 | |
| | | | *Tricellaria* | *occidentalis* | | 1 | | 1 |
| | *Smittoidea* | *prolifica* | *Smittoidea* | *prolifica* | 45 | | 100 | |
| | *Tricellaria* | *occidentalis* | *Bugula* | *neritina* | | 1 | | 1 |
| | | | | *stolonifera* | | 5 | | 3 |
| | | | *Tricellaria* | *occidentalis* | 44 | | 30 | |
| | | | *Watersipora* | *subtorquata* | | 1 | | 1 |
| | *Watersipora* | *arcuata* | *Bugula* | *neritina* | | 3 | | 7 |
| | | | | *stolonifera* | | 1 | | 2 |
| | | | *Celleporaria* | *aperta* | | 1 | | 2 |
| | | | *Crisulipora* | *occidentalis* | | 1 | | 2 |
| | | | *Cryptosula* | *pallasiana* | | 1 | | 2 |
| | | | *Thalamoporella* | *californica* | | 2 | | 4 |
| | | | *Tricellaria* | *occidentalis* | | 1 | | 2 |
| | | | *Watersipora* | *arcuata* | 33 | | 72 | |
| | | | | *subtorquata* | | 3 | | 7 |
| | | *subovoidea* | *Watersipora* | *subovoidea* | 1 | | 13 | |
| | | | | *subtorquata* | | 7 | | 88 |
| | | *subtorquata* | *Bugula* | *neritina* | | 3 | | 1 |

| Phylum | Morpho-genus | Morpho-species | Molec-genus | Molec-species | Specimen Count: Match | Specimen Count: Mismatch | Percent of Specimens: Match | Percent of Specimens: Mismatch |
|---|---|---|---|---|---|---|---|---|
| | | | | *stolonifera* | | 2 | | |
| | | | *Celleporella* | *hyalina* | | 1 | | |
| | | | *Crisia* | *occidentalis* | | 2 | | |
| | | | *Crisulipora* | *occidentalis* | | 6 | | 1 |
| | | | *Cryptosula* | *pallasiana* | | 5 | | 1 |
| | | | *Fenestrulina* | *delicia* | | 1 | | |
| | | | *Licornia* | *diegensis* | | 4 | | 1 |
| | | | *Schizoporella* | *japonica* | | 1 | | |
| | | | *Smittoidea* | *prolifica* | | 1 | | |
| | | | *Thalamoporella* | *californica* | | 5 | | 1 |
| | | | *Tubulipora* | *pacifica* | | 4 | | 1 |
| | | | *Watersipora* | *subovoidea* | | 1 | | |
| | | | | *subtorquata* | 495 | | 93 | |
| **Chordata** | *Ascidia* | *ceratodes* | *Ascidia* | *ceratodes* | 56 | | 89 | |
| | | | | *zara* | | 5 | | 8 |
| | | | *Ciona* | *intestinalis* | | 1 | | 2 |
| | | | *Distaplia* | *occidentalis* | | 1 | | 2 |
| | | *virginea* | *Ascidia* | *ceratodes* | | 12 | | 67 |
| | | | | *zara* | | 4 | | 22 |
| | | | *Ciona* | *intestinalis* | | 2 | | 11 |
| | | *zara* | *Ascidia* | *ceratodes* | | 8 | | 3 |
| | | | | *zara* | 223 | | 70 | |
| | | | *Botrylloides* | *diegensis* | | 2 | | 1 |
| | | | | *violaceus* | | 5 | | 2 |
| | | | *Botryllus* | *schlosseri* | | 9 | | 3 |
| | | | *Ciona* | *intestinalis* | | 4 | | 1 |
| | | | | *savignyi* | | 8 | | 3 |
| | | | *Corella* | *inflata* | | 1 | | |
| | | | *Didemnum* | *vexillum* | | 18 | | 6 |
| | | | *Diplosoma* | *listerianum* | | 2 | | 6 |
| | | | *Distaplia* | *occidentalis* | | 3 | | 1 |
| | | | *Molgula* | *ficus* | | 1 | | |
| | | | | *manhattensis* | | 6 | | 2 |

| Phylum | Morpho-genus | Morpho-species | Molec-genus | Molec-species | Specimen Count | | Percent of Specimens | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Match | Mismatch | Match | Mismatch |
| | | | *Perophora* | *annectens* | | 1 | | |
| | | | *Styela* | *clava* | | 11 | | 3 |
| | *Botrylloides* | *leachii* | *Ascidia* | *zara* | | 1 | | |
| | | | *Botrylloides* | *diegensis* | 200 | | 70 | |
| | | | | *perspicuus* | | 1 | | |
| | | | | *violaceus* | | 54 | | 19 |
| | | | *Botryllus* | *schlosseri* | | 22 | | 8 |
| | | | *Ciona* | *intestinalis* | | 1 | | |
| | | | *Didemnum* | *vexillum* | | 1 | | |
| | | | *Diplosoma* | *listerianum* | | 4 | | 1 |
| | | | *Distaplia* | *occidentalis* | | 1 | | |
| | | | *Styela* | *clava* | | 2 | | 1 |
| | | *pizoni* | *Botrylloides* | *diegensis* | | 2 | | 13 |
| | | | | *perspicuus* | | 4 | | 27 |
| | | | | *violaceus* | | 4 | | 27 |
| | | | *Botryllus* | *schlosseri* | | 1 | | 7 |
| | | | *Diplosoma* | *listerianum* | | 1 | | 7 |
| | | | *Styela* | *plicata* | | 1 | | 7 |
| | | | *Symplegma* | *reptans* | | 2 | | 13 |
| | | *violaceus* | *Ascidia* | *ceratodes* | | 1 | | |
| | | | *Botrylloides* | *diegensis* | | 12 | | 3 |
| | | | | *violaceus* | 346 | | 76 | |
| | | | *Botryllus* | *schlosseri* | | 27 | | 6 |
| | | | *Ciona* | *intestinalis* | | 2 | | 0 |
| | | | | *savignyi* | | 4 | | 1 |
| | | | *Corella* | *inflata* | | 2 | | |
| | | | *Didemnum* | *vexillum* | | 2 | | 4 |
| | | | *Diplosoma* | *listerianum* | | 11 | | 2 |
| | | | *Distaplia* | *occidentalis* | | 18 | | 4 |
| | | | *Molgula* | *manhattensis* | | 3 | | 1 |
| | | | *Polyandrocarpa* | *zorritensis* | | 1 | | |
| | | | *Styela* | *clava* | | 2 | | |
| | | | | *truncata* | | 3 | | 1 |

| Phylum | Morpho-genus | Morpho-species | Molec-genus | Molec-species | Specimen Count: Match | Specimen Count: Mismatch | Percent of Specimens: Match | Percent of Specimens: Mismatch |
|---|---|---|---|---|---|---|---|---|
| | | | *Symplegma* | *reptans* | | 1 | | |
| | *Botryllus* | *schlosseri* | *Ascidia* | *ceratodes* | | 1 | | |
| | | | | *zara* | | 1 | | |
| | | | *Botrylloides* | *diegensis* | | 2 | | |
| | | | | *perspicuus* | | 1 | | |
| | | | | *violaceus* | | 13 | | 2 |
| | | | *Botryllus* | *schlosseri* | 697 | | 94 | |
| | | | *Ciona* | *savignyi* | | 2 | | |
| | | | *Didemnum* | *vexillum* | | 3 | | |
| | | | *Diplosoma* | *listerianum* | | 6 | | 1 |
| | | | *Distaplia* | *occidentalis* | | 4 | | 1 |
| | | | *Microcosmus* | *squamiger* | | 3 | | |
| | | | *Molgula* | *ficus* | | 1 | | |
| | | | | *manhattensis* | | 3 | | |
| | | | *Styela* | *canopus* | | 3 | | |
| | | | | *clava* | | 2 | | |
| | *Ciona* | *intestinalis* | *Ascidia* | *ceratodes* | | 2 | | 1 |
| | | | | *zara* | | 5 | | 2 |
| | | | *Botrylloides* | *violaceus* | | 1 | | |
| | | | *Botryllus* | *schlosseri* | | 1 | | |
| | | | *Ciona* | *intestinalis* | 252 | | 94 | |
| | | | | *savignyi* | | 5 | | 2 |
| | | | *Diplosoma* | *listerianum* | | 1 | | |
| | | | *Styela* | *clava* | | 1 | | |
| | | *savignyi* | *Ascidia* | *zara* | | 1 | | |
| | | | *Botrylloides* | *violaceus* | | 1 | | |
| | | | *Botryllus* | *schlosseri* | | 1 | | |
| | | | *Ciona* | *intestinalis* | | 3 | | 1 |
| | | | | *savignyi* | 235 | | 97 | |
| | *Corella* | *inflata* | *Corella* | *inflata* | 5 | | 83 | |
| | | | *Diplosoma* | *listerianum* | | 1 | | 17 |
| | *Didemnum* | *vexillum* | *Didemnum* | *vexillum* | 36 | | 97 | 0 |
| | | | *Diplosoma* | *listerianum* | | 1 | | 3 |

| Phylum | Morpho-genus | Morpho-species | Molec-genus | Molec-species | Specimen Count Match | Specimen Count Mismatch | Percent of Specimens Match | Percent of Specimens Mismatch |
|---|---|---|---|---|---|---|---|---|
| | *Diplosoma* | *listerianum* | *Botryllus* | *schlosseri* | | 1 | | 1 |
| | | | *Ciona* | *savignyi* | | 1 | | 1 |
| | | | *Didemnum* | *vexillum* | | 1 | | 1 |
| | | | *Diplosoma* | *listerianum* | 163 | | 87 | 9 |
| | | | *Microcosmus* | *squamiger* | | 1 | | 1 |
| | | | *Molgula* | *manhattensis* | | 2 | | 1 |
| | | | *Styela* | *clava* | | 1 | | 1 |
| | *Distaplia* | *occidentalis* | *Didemnum* | *vexillum* | | 14 | | 9 |
| | | | *Diplosoma* | *listerianum* | | 2 | | 1 |
| | | | *Distaplia* | *occidentalis* | 4 | | 3 | 0 |
| | | | *Symplegma* | *reptans* | | 2 | | 1 |
| | *Microcosmus* | *squamiger* | *Microcosmus* | *squamiger* | 10 | | 77 | 0 |
| | | | *Styela* | *canopus* | | 3 | | 23 |
| | *Molgula* | *manhattensis* | *Ascidia* | *zara* | | 1 | | 0 |
| | | | *Botrylloides* | *violaceus* | | 2 | | 1 |
| | | | *Botryllus* | *schlosseri* | | 1 | | 5 |
| | | | *Ciona* | *intestinalis* | | 2 | | 1 |
| | | | | *savignyi* | | 6 | | 3 |
| | | | *Didemnum* | *vexillum* | | 12 | | 6 |
| | | | *Diplosoma* | *listerianum* | | 5 | | 2 |
| | | | *Distaplia* | *occidentalis* | | 1 | | 0 |
| | | | *Molgula* | *manhattensis* | 161 | 1 | 79 | 0 |
| | | | *Styela* | *clava* | | 3 | | 1 |
| | *Perophora* | *japonica* | *Didemnum* | *vexillum* | | 1 | | 1 |
| | | | *Perophora* | *annectens* | | 7 | | 4 |
| | | *viridis* | *Microcosmus* | *squamiger* | | 3 | | 25 |
| | | | *Perophora* | *annectens* | | 6 | | 50 |
| | | | *Styela* | *canopus* | | 3 | | 25 |
| | *Polyandrocarpa* | *zorritensis* | *Botryllus* | *schlosseri* | | 1 | | 1 |
| | | | *Didemnum* | *vexillum* | | 2 | | 2 |
| | | | *Diplosoma* | *listerianum* | | 5 | | 4 |
| | | | *Distaplia* | *occidentalis* | | 1 | | 1 |
| | | | *Molgula* | *ficus* | | 5 | | 4 |

| | | | | | Specimen Count | | Percent of Specimens | |
|---|---|---|---|---|---|---|---|---|
| | | | | | **Match** | **Mismatch** | **Match** | **Mismatch** |
| **Phylum** | **Morpho-genus** | **Morpho-species** | **Molec-genus** | **Molec-species** | | | | |
| | | | | *manhattensis* | | 1 | | 1 |
| | | | *Polyandrocarpa* | *zorritensis* | 93 | | 78 | |
| | | | *Styela* | *canopus* | | 9 | | 8 |
| | | | | *clava* | | 1 | | 1 |
| | | | *Symplegma* | *reptans* | | 1 | | 1 |
| | *Styela* | *canopus* | *Microcosmus* | *squamiger* | | 2 | | 67 |
| | | | *Styela* | *canopus* | | 1 | | 33 |
| | | *clava* | *Microcosmus* | *squamiger* | | 1 | | 2 |
| | | | *Molgula* | *manhattensis* | | 1 | | 2 |
| | | | *Styela* | *canopus* | | 9 | | 14 |
| | | | | *clava* | 54 | | 83 | |
| | | *plicata* | *Botryllus* | *schlosseri* | | 1 | | 2 |
| | | | *Ciona* | *intestinalis* | | 2 | | 4 |
| | | | | *savignyi* | | 1 | | 2 |
| | | | *Didemnum* | *vexillum* | | 1 | | 2 |
| | | | *Diplosoma* | *listerianum* | | 4 | | 7 |
| | | | *Distaplia* | *occidentalis* | | 3 | | 5 |
| | | | *Microcosmus* | *squamiger* | | 1 | | 2 |
| | | | *Molgula* | *ficus* | | 1 | | 2 |
| | | | *Polyandrocarpa* | *zorritensis* | | 2 | | 4 |
| | | | *Styela* | *clava* | | 1 | | 2 |
| | | | | *plicata* | 37 | | 65 | |
| | | | *Symplegma* | *reptans* | | 3 | | 5 |
| **Cnidaria** | *Bougainvillia* | *muscus* | *Garveia* | *franciscana* | | 11 | | 100 |
| | *Diadumene* | *franciscana* | *Diadumene* | *franciscana* | 4 | | 10 | |
| | | | | *leucolena* | | 2 | | 5 |
| | | | *Zaolutus* | *actius* | | 9 | | 22 |
| | | *leucolena* | *Diadumene* | *franciscana* | | 4 | | 57 |
| | | | | *leucolena* | 1 | | 14 | |
| | | | *Zaolutus* | *actius* | | 2 | | 29 |
| | | *lineata* | *Diadumene* | *franciscana* | | 4 | | 67 |
| | | | | *lineata* | 2 | | 33 | |
| | *Ectopleura* | *crocea* | *Ectopleura* | *crocea* | 24 | | 100 | |

| Phylum | Morpho-genus | Morpho-species | Molec-genus | Molec-species | Specimen Count | | Percent of Specimens | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Match | Mismatch | Match | Mismatch |
| | *Metridium* | *senile* | *Diadumene* | *franciscana* | | 10 | | 59 |
| | | | | *leucolena* | | 2 | | 12 |
| | | | *Zaolutus* | *actius* | | 5 | | 29 |
| **Entoprocta** | *Barentsia* | *benedeni* | *Barentsia* | *benedeni* | 1 | | 100 | |
| **Mollusca** | *Acanthodoris* | *nanaimoensis* | *Acanthodoris* | *nanaimoensis* | 1 | | 100 | |
| | | *rhodoceras* | *Acanthodoris* | *rhodoceras* | 1 | | 100 | |
| | *Alia* | *carinata* | *Astyris* | *aurantiaca* | | 5 | | 45 |
| | | | *Haminoea* | *japonica* | | 1 | | 9 |
| | | | *Hermissenda* | *crassicornis* | | 1 | | 9 |
| | | | *Leptopecten* | *latiauratus* | | 1 | | 9 |
| | | | *Urosalpinx* | *cinerea* | | 3 | | 27 |
| | *Amphissa* | *reticulata* | *Alia* | *carinata* | | 1 | | 20 |
| | | | *Astyris* | *aurantiaca* | | 4 | | 80 |
| | *Crepidula* | *nummaria* | *Crepidula* | *convexa* | | 1 | | 100 |
| | | *plana* | *Crepidula* | *plana* | 4 | | 80 | |
| | | | *Ostrea* | *lurida* | | 1 | | 20 |
| | *Crepipatella* | *lingulata* | *Crepidula* | *plana* | | 1 | | 100 |
| | *Dendronotus* | *venustus* | *Dendronotus* | *frondosus* | | 2 | | 29 |
| | | | *Eubranchus* | *doriae* | | 4 | | 57 |
| | | | *Flabellina* | *trilineata* | | 1 | | 14 |
| | *Diaphorodoris* | *lirulatocauda* | *Acanthodoris* | *hudsoni* | | 1 | | 33 |
| | | | | *rhodoceras* | | 1 | | 33 |
| | | | *Diaphorodoris* | *lirulatocauda* | 1 | | 33 | |
| | *Dirona* | *picta* | *Dirona* | *picta* | 1 | | 50 | |
| | | | *Okenia* | *plana* | | 1 | | 50 |
| | *Flabellina* | *trilineata* | *Flabellina* | *trilineata* | 6 | | 86 | |
| | | | *Hermissenda* | *crassicornis* | | 1 | | 14 |
| | | *verrucosa* | *Flabellina* | *trilineata* | | 3 | | 60 |
| | | | *Hermissenda* | *crassicornis* | | 2 | | 40 |
| | *Geukensia* | *demissa* | *Geukensia* | *demissa* | 2 | | 100 | |
| | *Haminoea* | *japonica* | *Haminoea* | *japonica* | 38 | | 20 | |
| | | | *Okenia* | *plana* | | 1 | | 1 |
| | *Hiatella* | *arctica* | *Hiatella* | *arctica* | 13 | | 100 | |

| Phylum | Morpho-genus | Morpho-species | Molec-genus | Molec-species | Specimen Count | | Percent of Specimens | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Match | Mismatch | Match | Mismatch |
| | *Musculista* | *senhousia* | *Arcuatula* | *senhousia* | 55 | | 100 | |
| | *Mya* | *arenaria* | *Mya* | *arenaria* | 1 | | 100 | |
| | *Mytilus* | *edulis* | *Doto* | *amyra* | | 1 | | 100 |
| | | *galloprovincialis* | *Hiatella* | *arctica* | | 2 | | 50 |
| | | | *Mytilus* | *californianus* | | 1 | | 25 |
| | | | *Ostrea* | *lurida* | | 1 | | 25 |
| | | *trossulus* | *Arcuatula* | *senhousia* | | 2 | | 22 |
| | | | *Crassadoma* | *gigantea* | | 1 | | 11 |
| | | | *Modiolus* | *modiolus* | | 5 | | 56 |
| | | | *Mytilus* | *californianus* | | 1 | | 11 |
| | *Onchidoris* | *bilamellata* | *Acanthodoris* | *rhodoceras* | | 2 | | 33 |
| | | | *Okenia* | *plana* | | 1 | | 17 |
| | | | *Onchidoris* | *bilamellata* | 3 | | 50 | |
| | *Ostrea* | *lurida* | *Clinocardium* | *nuttallii* | | 1 | | 1 |
| | | | *Macoma* | *petalum* | | 1 | | 1 |
| | | | *Ostrea* | *lurida* | 167 | | 99 | |
| | *Placida* | *dendritica* | *Placida* | *dendritica* | 1 | | 25 | |
| | *Pododesmus* | *macrochisma* | *Crepidula* | *plana* | | 1 | | 50 |
| | | | *Ostrea* | *lurida* | | 1 | | 50 |
| | *Polycera* | *atra* | *Mytilus* | *californianus* | | 1 | | 2 |
| | | | *Polycera* | *atra* | 43 | | 96 | |
| | | | | *hedgpethi* | | 1 | | 2 |
| | | *hedgpethi* | *Doto* | *amyra* | | 1 | | 5 |
| | | | *Polycera* | *atra* | | 1 | | 5 |
| | | | | *hedgpethi* | 17 | | 89 | |
| | *Ruditapes* | *philippinarum* | *Ruditapes* | *philippinarum* | 7 | | 100 | |
| | *Triopha* | *maculata* | *Triopha* | *maculata* | 3 | | 100 | |
| | *Urosalpinx* | *cinerea* | *Urosalpinx* | *cinerea* | 2 | | 100 | |

**Table 5.4. Failed Identifications**. 9283 vouchers, listed by their morphological assignment, were not genetically identified for the following causes: (A) Failed assemblies, n=2993 vials. A failed assembly results from poor quality sequencing data which is typically due to a poor PCR results; (B) Bacterial or human origin, n=2 vials; (C) No BLAST hit, n=6269 vials. (D) Alignment too short; n=19 vials. If no species name for a voucher is shown, none was provided. Taxonomy here is based on prior morphological assessment.

***(A) Failed assemblies.***

| Phylum | Genus | Species | Count |
|---|---|---|---|
| None given | | | 59 |
| Annelida | None given | | 128 |
| | *Alitta* | *succinea* | 1 |
| | *Amaeana* | | 2 |
| | *Amblyosyllis* | | 4 |
| | *Armandia* | *brevis* | 1 |
| | *Bispira* | | 3 |
| | *Branchiomma* | | 17 |
| | | *boholense* | 5 |
| | *Branchiosyllis* | | 4 |
| | *Capitella* | *capitata* | 6 |
| | *Chone* | *gracilis* | 1 |
| | *Cirriformia* | | 3 |
| | | *moorei* | 14 |
| | *Dipolydora* | *caulleryi* | 1 |
| | *Dorvillea* | | 4 |
| | *Euchone* | *limnicola* | 7 |
| | *Eulalia* | | 1 |
| | | *quadrioculata* | 14 |
| | *Eumida* | | 2 |
| | *Eupolymnia* | | 1 |
| | *Ficopomatus* | *enigmaticus* | 12 |
| | *Glycera* | *tenuis* | 1 |
| | *Glycinde* | | 1 |
| | | *picta* | 5 |
| | *Halosydna* | | 1 |
| | | *brevisetosa* | 7 |
| | | *johnsoni* | 1 |
| | *Harmothoe* | *imbricata* | 30 |
| | *Heteromastus* | | 2 |
| | | *filobranchus* | 1 |
| | *Hydroides* | | 3 |
| | | *elegans* | 5 |
| | | *gracilis* | 13 |
| | *Leitoscoloplos* | *pugettensis* | 6 |
| | *Lumbrineris* | *perkinsi* | 3 |
| | *Marphysa* | | 5 |
| | *Megasyllis* | *nipponica* | 36 |

| Phylum | Genus | Species | Count |
|---|---|---|---|
| | *Micronereis* | | 1 |
| | *Myrianida* | *pachycera* | 1 |
| | *Myxicola* | *infundibulum* | 1 |
| | *Naineris* | | 2 |
| | *Neanthes* | *acuminata* | 2 |
| | *Neoamphitrite* | | 11 |
| | *Nephtys* | *caecoides* | 11 |
| | *Nereis* | *latescens* | 13 |
| | | *vexillosa* | 1 |
| | *Nicolea* | | 25 |
| | *Odontosyllis* | *phosphorea* | 12 |
| | *Ophryotrocha* | | 9 |
| | *Paleanotus* | *bellis* | 7 |
| | *Parasabella* | | 13 |
| | | *pallida* | 13 |
| | *Pectinaria* | *californiensis* | 1 |
| | *Pettiboneia* | | 4 |
| | *Platynereis* | | 13 |
| | | *bicanaliculata* | 26 |
| | *Polycirrus* | | 2 |
| | *Polydora* | | 15 |
| | | *cornuta* | 2 |
| | *Pseudochitinopoma* | *occidentalis* | 3 |
| | *Pseudopolydora* | *paucibranchiata* | 2 |
| | *Pterocirrus* | *montereyensis* | 2 |
| | *Sabaco* | *elongatus* | 28 |
| | *Salmacina* | *tribranchiata* | 21 |
| | *Scoletoma* | *tetraura* | 2 |
| | *Serpula* | | 1 |
| | *Streblosoma* | | 3 |
| | | *uncinatus* | 1 |
| | *Timarete* | | 6 |
| | *Trypanosyllis* | | 3 |
| Arthropoda | None given | | 11 |
| | *Aciconula* | *acanthosoma* | 1 |
| | *Americorophium* | | 5 |
| | *Ammothea* | *hilgendorfi* | 1 |
| | *Ampelisca* | | 1 |
| | *Amphibalanus* | *amphitrite* | 6 |
| | | *improvisus* | 31 |
| | *Ampithoe* | *lacertosa* | 16 |
| | | *plumulosa* | 3 |
| | | *sectimana* | 1 |
| | | *valida* | 4 |
| | *Aoroides* | | 5 |

| Phylum | Genus | Species | Count |
|---|---|---|---|
| | | *columbiae* | 3 |
| | | *secunda* | 22 |
| | *Apolochus* | *picadurus* | 2 |
| | *Aruga* | *holmesi* | 2 |
| | *Balanus* | *crenatus* | 23 |
| | | *nubilus* | 1 |
| | | *trigonus* | 5 |
| | *Calanus* | *pacificus* | 1 |
| | *Cancer* | *jordani* | 2 |
| | *Caprella* | | 4 |
| | | *californica* | 13 |
| | | *equilibra* | 1 |
| | | *mutica* | 12 |
| | | *scaura* | 1 |
| | | *simia* | 35 |
| | *Clausocalanus* | *parapergens* | 1 |
| | *Deutella* | *californica* | 1 |
| | *Diaphanosoma* | | 1 |
| | *Dissiminassa* | *dissimilis* | 7 |
| | *Ditrichocorycaeus* | *anglicus* | 1 |
| | *Dulichia* | | 1 |
| | *Elasmopus* | | 1 |
| | | *bampo* | 52 |
| | *Ericthonius* | *punctatus* | 35 |
| | *Eurylana* | | 1 |
| | *Gammaropsis* | *shoemakeri* | 4 |
| | | *thompsoni* | 1 |
| | *Gammarus* | *daiberi* | 1 |
| | *Gnorimosphaeroma* | *oregonensis* | 9 |
| | *Grandidierella* | *japonica* | 9 |
| | *Heptacarpus* | | 1 |
| | *Ianiropsis* | | 4 |
| | | *analoga* | 1 |
| | *Jassa* | *slatteryi* | 2 |
| | *Laticorophium* | *baconi* | 3 |
| | *Leptochelia* | | 1 |
| | *Leucothoe* | | 2 |
| | *Leucothoe* | *alata* | 25 |
| | *Liljeborgia* | *geminata* | 1 |
| | *Lophopanopeus* | | 1 |
| | *Maera* | | 1 |
| | *Megabalanus* | *californicus* | 10 |
| | *Melita* | *nitida* | 1 |
| | *Monocorophium* | | 1 |
| | | *acherusicum* | 16 |

| Phylum | Genus | Species | Count |
|---|---|---|---|
| | | *insidiosum* | 3 |
| | *Nippoleucon* | *hinumensis* | 1 |
| | *Oithona* | *similis* | 1 |
| | *Pachycheles* | | 3 |
| | *Palaemon* | *macrodactylus* | 2 |
| | *Paracalanus* | *parvus* | 1 |
| | *Paracerceis* | *cordata* | 1 |
| | | *sculpta* | 37 |
| | *Paradexamine* | | 13 |
| | *Paranthura* | *japonica* | 49 |
| | *Podocerus* | *brasiliensis* | 7 |
| | | *cristatus* | 10 |
| | *Protohyale* | | 1 |
| | | *frequens* | 1 |
| | *Pyromaia* | *tuberculata* | 1 |
| | *Quadrimaera* | *reishi* | 2 |
| | *Sinelobus* | | 2 |
| | *Sinocalanus* | | 1 |
| | *Sphaeroma* | *quoianum* | 1 |
| | *Stenothoe* | *valida* | 3 |
| | *Synidotea* | *laticauda* | 4 |
| | *Zeuxo* | | 2 |
| | | *normani* | 1 |
| Bryozoa | None given | | 8 |
| | *Amathia* | | 11 |
| | | *verticillata* | 10 |
| | *Anguinella* | *palmata* | 3 |
| | *Bugula* | *flabellata* | 1 |
| | | *neritina* | 110 |
| | | *stolonifera* | 30 |
| | *Bugulina* | *longirostrata* | 5 |
| | *Caulibugula* | *ciliata* | 3 |
| | *Celleporaria* | | 1 |
| | | *aperta* | 2 |
| | | *brunnea* | 21 |
| | *Celleporella* | *hyalina* | 4 |
| | *Celleporina* | | 1 |
| | *Conopeum* | | 11 |
| | | *reticulum* | 2 |
| | | *tenuissimum* | 2 |
| | *Cradoscrupocellaria* | *tenuirostris* | 1 |
| | *Crisia* | *occidentalis* | 8 |
| | *Crisularia* | *pacifica* | 4 |
| | *Crisulipora* | *occidentalis* | 9 |
| | *Cryptosula* | *pallasiana* | 28 |

| Phylum | Genus | Species | Count |
|---|---|---|---|
| | *Cyclostomella* | | 1 |
| | *Electra* | *monostachys* | 1 |
| | *Fenestrulina* | *delicia* | 3 |
| | *Filicrisia* | | 2 |
| | | *franciscana* | 6 |
| | *Hippopodina* | *feegeensis* | 3 |
| | *Lichenopora* | | 4 |
| | *Licornia* | *diegensis* | 3 |
| | *Membranipora* | *chesapeakensis* | 4 |
| | *Nolella* | | 1 |
| | *Pacificincola* | | 4 |
| | *Parasmittina* | | 8 |
| | *Pectinatella* | *magnifica* | 3 |
| | *Schizoporella* | | 1 |
| | | *errata* | 2 |
| | | *japonica* | 11 |
| | *Scruparia* | | 2 |
| | *Scrupocellaria* | *bertholettii* | 1 |
| | *Smittoidea* | *prolifica* | 16 |
| | *Thalamoporella* | *californica* | 6 |
| | *Tricellaria* | *occidentalis* | 17 |
| | *Tubulipora* | *pacifica* | 7 |
| | *Watersipora* | | 4 |
| | | *arcuata* | 5 |
| | | *subtorquata* | 77 |
| Chlorophyta | *Bryopsis* | | 1 |
| | *Enteromorpha* | | 1 |
| | *Ulva* | | 1 |
| Chordata | None given | | 19 |
| | *Aplidium* | | 7 |
| | *Ascidia* | | 1 |
| | | *ceratodes* | 15 |
| | | *zara* | 19 |
| | *Botrylloides* | *diegensis* | 23 |
| | | *perspicuus* | 3 |
| | | *violaceus* | 44 |
| | *Botryllus* | *schlosseri* | 56 |
| | *Ciona* | | 3 |
| | | *intestinalis* | 28 |
| | | *savignyi* | 42 |
| | *Corella* | *inflata* | 6 |
| | *Didemnum* | *vexillum* | 24 |
| | *Diplosoma* | *listerianum* | 87 |
| | *Distaplia* | | 14 |
| | | *occidentalis* | 66 |

| Phylum | Genus | Species | Count |
|---|---|---|---|
| | *Microcosmus* | *squamiger* | 5 |
| | *Molgula* | *ficus* | 3 |
| | | *manhattensis* | 54 |
| | *Perophora* | | 5 |
| | | *annectens* | 3 |
| | *Polyandrocarpa* | *zorritensis* | 5 |
| | *Styela* | | 15 |
| | | *canopus* | 5 |
| | | *clava* | 27 |
| | | *plicata* | 11 |
| | | *truncata* | 3 |
| | *Symplegma* | *reptans* | 10 |
| Cnidaria | None given | | 34 |
| | *Aglaophenia* | | 4 |
| | *Bougainvillia* | | 1 |
| | *Clytia* | | 1 |
| | *Cordylophora* | | 16 |
| | *Coryne* | | 1 |
| | *Diadumene* | | 9 |
| | | *franciscana* | 10 |
| | | *leucolena* | 5 |
| | | *lineata* | 3 |
| | *Ectopleura* | *crocea* | 5 |
| | *Garveia* | *franciscana* | 12 |
| | *Gonothyraea* | | 2 |
| | *Hydra* | | 1 |
| | *Obelia* | | 31 |
| | *Pennaria* | | 1 |
| | *Phialidium* | | 2 |
| | *Polysiphonia* | | 1 |
| | *Zaolutus* | *actius* | 3 |
| Echinodermata | None given | | 18 |
| Entoprocta | None given | | 5 |
| | *Barentsia* | *benedeni* | 6 |
| "Lophophorata" | None given | | 1 |
| Mollusca | None given | | 37 |
| | *Alia* | *carinata* | 6 |
| | *Anomia* | | 4 |
| | *Arcuatula* | *senhousia* | 22 |
| | *Astyris* | *aurantiaca* | 8 |
| | *Crepidula* | *convexa* | 5 |
| | *Crepipatella* | *lingulata* | 1 |
| | *Cryptomya* | *californica* | 1 |
| | *Cuthona* | | 3 |
| | | *albocrusta* | 1 |

| Phylum | Genus | Species | Count |
|---|---|---|---|
| | *Dendronotus* | | 2 |
| | | *frondosus* | 1 |
| | *Diaphorodoris* | *lirulatocauda* | 1 |
| | *Doto* | | 1 |
| | | *amyra* | 3 |
| | *Eubranchus* | *misakiensis* | 1 |
| | *Flabellina* | | 1 |
| | | *trilineata* | 1 |
| | *Gemma* | *gemma* | 1 |
| | *Haminoea* | *japonica* | 10 |
| | *Hermissenda* | *crassicornis* | 9 |
| | *Hiatella* | *arctica* | 16 |
| | *Lacuna* | *unifasciata* | 3 |
| | *Leptopecten* | *latiauratus* | 2 |
| | *Littorina* | *saxatilis* | 1 |
| | *Lyonsia* | *californica* | 1 |
| | *Mytilus* | | 79 |
| | | *californianus* | 15 |
| | *Okenia* | *angelensis* | 1 |
| | *Ostrea* | *lurida* | 48 |
| | *Philine* | *orientalis* | 5 |
| | *Polycera* | *atra* | 12 |
| | | *hedgpethi* | 4 |
| | *Ruditapes* | *philippinarum* | 1 |
| | *Triopha* | *maculata* | 1 |
| | *Urosalpinx* | *cinerea* | 4 |
| Nematoda | None given | | 1 |
| Nemertea | None given | | 10 |
| Platyhelminthes | None given | | 18 |
| | *Eurylepta* | *aurantiaca* | 2 |
| | *Hoploplana* | | 3 |
| | *Pseudoceros* | | 34 |
| | *Stylochus* | | 6 |
| Porifera | None given | | 86 |
| | *Grantia* | | 10 |
| | *Halichondria* | | 13 |
| | *Haliclona* | | 12 |
| Porifera | *Leucosolenia* | | 1 |
| | *Sycon* | | 19 |

***(B) Human or bacterial Origin***

| Phylum | Genus | Species | Count |
|---|---|---|---|
| Bryozoa | *Bugula* | *neritina* | 1 |
| | *Tubulipora* | | 1 |

***(C) No BLAST hit.***

| Phylum | Genus | Species | Count |
|---|---|---|---|
| None given | | | 262 |
| *Annelida* | None given | | 342 |
| | *Alitta* | *succinea* | 11 |
| | *Amaeana* | | 26 |
| | | *occidentalis* | 3 |
| | *Amblyosyllis* | | 4 |
| | *Armandia* | *brevis* | 12 |
| | *Boccardiella* | *ligerica* | 1 |
| | *Branchiomma* | | 32 |
| | | *nigromaculatum* | 1 |
| | *Branchiosyllis* | | 18 |
| | *Branchiura* | *sowerbyi* | 1 |
| | *Capitella* | *capitata* | 7 |
| | *Chone* | *gracilis* | 1 |
| | *Cirriformia* | | 5 |
| | | *moorei* | 13 |
| | *Crucigera* | *zygophora* | 2 |
| | *Dipolydora* | *caulleryi* | 2 |
| | | *socialis* | 1 |
| | *Dorvillea* | | 11 |
| | *Drilonereis* | | 2 |
| | *Euchone* | *limnicola* | 19 |
| | *Eulalia* | | 9 |
| | | *quadrioculata* | 25 |
| | *Eumida* | | 4 |
| | *Eupolymnia* | | 2 |
| | | *heterobranchia* | 1 |
| | *Ficopomatus* | *enigmaticus* | 67 |
| | *Glycera* | *americana* | 50 |
| | | *tenuis* | 1 |
| | *Glycinde* | | 8 |
| | | *picta* | 25 |
| | *Halosydna* | | 15 |
| | | *brevisetosa* | 20 |
| | | *johnsoni* | 6 |
| | | *leius* | 1 |
| | *Harmothoe* | *imbricata* | 51 |
| | *Hesperonoe* | | 3 |

| Phylum | Genus | Species | Count |
|---|---|---|---|
| | | *laevis* | 1 |
| | *Heteromastus* | | 11 |
| | *Hobsonia* | *florida* | 2 |
| | *Hydroides* | | 10 |
| | | *elegans* | 5 |
| | | *gracilis* | 54 |
| | *Laonome* | | 1 |
| | *Leitoscoloplos* | *pugettensis* | 37 |
| | *Lumbrineris* | *perkinsi* | 4 |
| | *Malmgreniella* | *bansei* | 1 |
| | | *nigralba* | 1 |
| | *Marenzelleria* | *viridis* | 6 |
| | *Marphysa* | | 28 |
| | *Mediomastus* | *acutus* | 1 |
| | *Megalomma* | *pigmentum* | 2 |
| | *Megasyllis* | *nipponica* | 35 |
| | *Micronereis* | *nanaimoensis* | 1 |
| | *Myrianida* | *pachycera* | 1 |
| *Annelida* | *Neanthes* | | 1 |
| | | *acuminata* | 13 |
| | *Neoamphitrite* | | 3 |
| | *Neosabellaria* | *cementarium* | 1 |
| | *Nephtys* | | 1 |
| | | *caecoides* | 37 |
| | | *californiensis* | 6 |
| | *Nereis* | | 2 |
| | | *latescens* | 1 |
| | | *vexillosa* | 1 |
| | *Nicolea* | | 8 |
| | *Notomastus* | *lineatus* | 1 |
| | | *magnus* | 1 |
| | *Odontosyllis* | *phosphorea* | 17 |
| | *Ophryotrocha* | | 8 |
| | *Paleanotus* | *bellis* | 2 |
| | *Paraprionospio* | *alata* | 1 |
| | *Parasabella* | | 12 |
| | | *pallida* | 48 |
| | *Petaloproctus* | *neoborealis* | 1 |
| | *Phyllodoce* | *williamsi* | 1 |
| | *Piromis* | | 8 |
| | *Pista* | *brevibranchiata* | 6 |
| | *Platynereis* | | 8 |
| | | *bicanaliculata* | 17 |
| | *Polycirrus* | | 4 |
| | *Polydora* | | 55 |
| | | *cornuta* | 8 |

| Phylum | Genus | Species | Count |
|---|---|---|---|
| | *Pseudochitinopoma* | *occidentalis* | 41 |
| | *Pseudopolydora* | *paucibranchiata* | 6 |
| | *Pterocirrus* | *montereyensis* | 2 |
| | *Sabaco* | *elongatus* | 67 |
| | *Salmacina* | *tribranchiata* | 36 |
| | *Schistomeringos* | *longicornis* | 1 |
| | *Scoletoma* | *tetraura* | 16 |
| | *Scoloplos* | *acmeceps* | 33 |
| | *Serpula* | | 1 |
| | *Streblosoma* | | 3 |
| | | *uncinatus* | 1 |
| | *Syllis* | | 2 |
| | *Thormora* | *johnstoni* | 2 |
| | *Timarete* | | 1 |
| | *Trypanosyllis* | | 24 |
| Arthropoda | None given | | 31 |
| | *Allorchestes* | *angusta* | 2 |
| | *Ampelisca* | | 4 |
| | *Amphibalanus* | | 4 |
| | | *amphitrite* | 7 |
| | | *improvisus* | 48 |
| | *Ampithoe* | | 1 |
| | | *lacertosa* | 1 |
| | | *plumulosa* | 1 |
| | | *valida* | 6 |
| | *Aoroides* | | 8 |
| | | *columbiae* | 2 |
| | | *inermis* | 5 |
| | | *secunda* | 5 |
| | *Apohyale* | *anceps* | 1 |
| | *Apolochus* | *picadurus* | 2 |
| | *Aruga* | *holmesi* | 4 |
| | *Balanus* | *crenatus* | 10 |
| | | *nubilus* | 25 |
| | | *trigonus* | 13 |
| | *Cancer* | *jordani* | 1 |
| | | *magister* | 1 |
| | *Caprella* | | 12 |
| | | *californica* | 9 |
| | | *equilibra* | 2 |
| | | *mutica* | 20 |
| | | *scaura* | 16 |
| | | *simia* | 5 |
| | | *verrucosa* | 1 |
| | *Chthamalus* | | 1 |
| | *Crangon* | *nigricauda* | 3 |

| Phylum | Genus | Species | Count |
|---|---|---|---|
| | *Deutella* | *californica* | 2 |
| | *Dissiminassa* | *dissimilis* | 4 |
| | *Elasmopus* | | 2 |
| | *Ericthonius* | | 1 |
| | | *punctatus* | 22 |
| | *Exopalaemon* | *modestus* | 1 |
| | *Gammaropsis* | *thompsoni* | 2 |
| | *Gammarus* | *daiberi* | 2 |
| | *Gnorimosphaeroma* | *oregonensis* | 2 |
| | *Grandidierella* | *japonica* | 13 |
| | *Hemigrapsus* | *oregonensis* | 3 |
| | *Heptacarpus* | | 1 |
| | | *paludicola* | 4 |
| | *Heteropleustes* | *setosus* | 1 |
| | *Hourstonius* | *vilordes* | 1 |
| | *Hyalella* | *azteca* | 1 |
| | *Ianiropsis* | | 9 |
| | | *analoga* | 1 |
| | *Idotea* | *resecata* | 2 |
| | *Incisocalliope* | *derzhavini* | 7 |
| | *Ischyrocerus* | | 1 |
| | *Janiralata* | *occidentalis* | 1 |
| | *Jassa* | | 5 |
| | | *marmorata* | 5 |
| | | *slatteryi* | 4 |
| | *Joeropsis* | | 1 |
| | | *dubia* | 1 |
| | *Laticorophium* | *baconi* | 6 |
| | *Leptochelia* | | 2 |
| | *Leptodiaptomus* | | 1 |
| | *Leucothoe* | *alata* | 7 |
| | *Liljeborgia* | | 1 |
| | *Lophopanopeus* | | 4 |
| | *Maera* | | 1 |
| | *Megabalanus* | *californicus* | 6 |
| | *Melita* | *nitida* | 6 |
| | *Mesocyclops* | *edax* | 1 |
| | *Metopa* | *cistella* | 3 |
| | *Monocorophium* | | 4 |
| | | *acherusicum* | 7 |
| | | *uenoi* | 5 |
| | *Nebalia* | *gerkenae* | 1 |
| | *Nippoleucon* | *hinumensis* | 3 |
| | *Palaemon* | *macrodactylus* | 1 |
| | *Paracerceis* | *sculpta* | 1 |
| | *Paramicrodeutopus* | *schmitti* | 1 |

| Phylum | Genus | Species | Count |
|---|---|---|---|
| | *Paranthura* | *japonica* | 23 |
| | *Photis* | | 8 |
| | | *brevipes* | 20 |
| | *Podocerus* | *brasiliensis* | 12 |
| | | *cristatus* | 1 |
| | *Polycheria* | *osborni* | 1 |
| | *Pseudodiaptomus* | *forbesi* | 1 |
| | *Pugettia* | *producta* | 1 |
| | *Pyromaia* | *tuberculata* | 2 |
| | *Quadrimaera* | *reishi* | 2 |
| | *Romaleon* | *branneri* | 2 |
| | *Scleroplax* | *granulata* | 3 |
| | *Sinelobus* | | 9 |
| | | *stanfordi* | 4 |
| | *Sinocalanus* | | 2 |
| | *Sinocorophium* | *alienense* | 1 |
| | | *heteroceratum* | 6 |
| | *Sphaeroma* | *quoianum* | 4 |
| | *Stenothoe* | *valida* | 16 |
| | *Synidotea* | *laticauda* | 4 |
| | *Uromunna* | | 6 |
| | *Zeuxo* | | 1 |
| | | *normani* | 12 |
| Bryozoa | None given | | 61 |
| | *Aetea* | | 2 |
| | *Amathia* | | 124 |
| | | *gracilis* | 1 |
| | | *verticillata* | 7 |
| | *Anguinella* | *palmata* | 1 |
| | *Aspidelectra* | | 1 |
| | *Bugula* | | 2 |
| | | *flabellata* | 1 |
| | | *neritina* | 88 |
| | | *stolonifera* | 12 |
| | *Bugulina* | *longirostrata* | 4 |
| | *Caulibugula* | *ciliata* | 1 |
| | *Celleporaria* | | 3 |
| | | *aperta* | 10 |
| | | *brunnea* | 51 |
| | *Celleporella* | *hyalina* | 68 |
| | *Celleporina* | | 5 |
| | *Conopeum* | | 9 |
| | *Crisia* | *occidentalis* | 8 |
| | *Crisularia* | *pacifica* | 1 |
| | *Crisulipora* | *occidentalis* | 83 |
| | *Cryptosula* | *pallasiana* | 57 |

| Phylum | Genus | Species | Count |
|---|---|---|---|
| | *Cyclostomella* | | 1 |
| | *Electra* | *crustulenta* | 1 |
| | *Fenestrulina* | | 1 |
| | | *delicia* | 3 |
| | *Filicrisia* | | 11 |
| | *Hippopodina* | *feegeensis* | 11 |
| | *Lichenopora* | | 18 |
| | *Licornia* | *diegensis* | 4 |
| | *Pacificincola* | | 16 |
| | *Parasmittina* | | 26 |
| | *Pectinatella* | *magnifica* | 2 |
| | *Schizoporella* | | 8 |
| | | *errata* | 8 |
| | | *japonica* | 9 |
| | *Scruparia* | | 1 |
| | *Scrupocellaria* | | 1 |
| | | *bertholettii* | 14 |
| | *Smittoidea* | *prolifica* | 25 |
| | *Tegella* | *circumclathrata* | 3 |
| | *Thalamoporella* | *californica* | 29 |
| | *Tricellaria* | *occidentalis* | 23 |
| | *Tubulipora* | *pacifica* | 33 |
| | *Watersipora* | | 2 |
| | | *arcuata* | 1 |
| | | *subtorquata* | 47 |
| Chlorophyta | *Bryopsis* | | 1 |
| | *Enteromorpha* | | 2 |
| | *Ulva* | | 1 |
| Chordata | None given | | 36 |
| | *Aplidium* | | 12 |
| | *Ascidia* | *ceratodes* | 2 |
| | | *zara* | 15 |
| | *Botrylloides* | | 1 |
| | | *diegensis* | 6 |
| | | *perspicuus* | 2 |
| | | *violaceus* | 15 |
| | *Botryllus* | *schlosseri* | 43 |
| | *Ciona* | | 2 |
| | | *intestinalis* | 34 |
| | | *savignyi* | 37 |
| | *Corella* | *inflata* | 16 |
| | *Didemnum* | *vexillum* | 158 |
| | *Diplosoma* | *listerianum* | 129 |
| | *Distaplia* | | 16 |
| | | *occidentalis* | 102 |
| | *Metandrocarpa* | | 4 |

| Phylum | Genus | Species | Count |
|---|---|---|---|
| | *Microcosmus* | *squamiger* | 26 |
| | *Molgula* | *ficus* | 19 |
| | | *manhattensis* | 30 |
| | *Perophora* | | 5 |
| | | *annectens* | 40 |
| | *Polyandrocarpa* | *zorritensis* | 6 |
| | *Styela* | | 25 |
| | | *canopus* | 19 |
| | | *clava* | 27 |
| | | *montereyensis* | 7 |
| | | *plicata* | 4 |
| | | *truncata* | 10 |
| | *Symplegma* | *reptans* | 40 |
| *Ciliophora* | *Folliculina* | | 1 |
| Cnidaria | None given | | 146 |
| | *Aglaophenia* | | 10 |
| | *Alcyonidium* | | 2 |
| | *Bougainvillia* | | 21 |
| | *Clytia* | | 9 |
| | *Cordylophora* | | 25 |
| | | *caspia* | 1 |
| | *Diadumene* | *franciscana* | 8 |
| | | *leucolena* | 2 |
| | | *lineata* | 3 |
| | *Ectopleura* | *crocea* | 20 |
| | *Garveia* | *franciscana* | 21 |
| | *Gonothyraea* | | 11 |
| | *Hydra* | | 7 |
| | *Hydractinia* | | 3 |
| | *Metridium* | | 2 |
| | *Monostaechas* | | 1 |
| | *Obelia* | | 62 |
| | *Pennaria* | | 2 |
| | *Phialidium* | | 3 |
| | *Plumularia* | | 4 |
| | *Polysiphonia* | | 6 |
| | *Stylatula* | *elongata* | 3 |
| | *Zaolutus* | *actius* | 7 |
| Echinodermata | None given | | 47 |
| Entoprocta | | | 12 |
| | *Barentsia* | *benedeni* | 14 |
| *"Lophophorata"* | None given | | 9 |
| Mollusca | | | 70 |
| | *Alia* | *carinata* | 2 |
| | *Anomia* | | 13 |
| | *Arcuatula* | *senhousia* | 29 |

| Phylum | Genus | Species | Count |
|---|---|---|---|
| | *Astyris* | *aurantiaca* | 4 |
| | *Corbula* | *amurensis* | 6 |
| | *Crassadoma* | *gigantea* | 3 |
| | *Crepidula* | *convexa* | 4 |
| | | *plana* | 8 |
| | *Crepipatella* | *lingulata* | 8 |
| | *Cryptomya* | *californica* | 2 |
| | *Cuthona* | | 2 |
| | *Dendronotus* | | 4 |
| | | *frondosus* | 6 |
| | *Diaphorodoris* | *lirulatocauda* | 2 |
| | *Dirona* | *picta* | 1 |
| | *Doto* | *amyra* | 4 |
| | | *columbiana* | 2 |
| | *Eubranchus* | *doriae* | 1 |
| | | *misakiensis* | 1 |
| | *Flabellina* | *verrucosa* | 1 |
| | *Gemma* | *gemma* | 3 |
| | *Geukensia* | *demissa* | 1 |
| | *Haminoea* | *japonica* | 6 |
| | *Hermissenda* | *crassicornis* | 4 |
| | *Hiatella* | *arctica* | 43 |
| | *Ilyanassa* | *obsoleta* | 1 |
| | *Janolus* | *fuscus* | 1 |
| | *Lacuna* | *unifasciata* | 1 |
| | *Leptopecten* | *latiauratus* | 24 |
| | *Littorina* | | 6 |
| | *Lyonsia* | *californica* | 1 |
| | *Macoma* | *petalum* | 2 |
| | *Marsenina* | *rhombica* | 1 |
| | *Marseniopsis* | | 8 |
| | *Modiolus* | *modiolus* | 3 |
| | *Montereina* | *nobilis* | 1 |
| | *Mya* | *arenaria* | 3 |
| | *Mytilus* | | 16 |
| | | *californianus* | 28 |
| | *Okenia* | *angelensis* | 12 |
| | | *plana* | 4 |
| | *Onchidoris* | *bilamellata* | 1 |
| | *Ostrea* | | 1 |
| | | *lurida* | 50 |
| | *Philine* | *orientalis* | 17 |
| | *Polycera* | *atra* | 1 |
| | | *hedgpethi* | 2 |
| | *Potamopyrgus* | *antipodarum* | 1 |
| | *Ruditapes* | *philippinarum* | 5 |

| Phylum | Genus | Species | Count |
|---|---|---|---|
| | *Tenellia* | *adspersa* | 1 |
| | *Theora* | *lubrica* | 3 |
| | *Urosalpinx* | *cinerea* | 3 |
| Nematoda | | | 12 |
| Nemertea | | | 64 |
| | *Cephalothrix* | | 11 |
| | *Lineus* | *ruber* | 1 |
| | *Tubulanus* | | 1 |
| Platyhelminthes | | | 104 |
| | *Eurylepta* | *aurantiaca* | 28 |
| | *Hoploplana* | | 44 |
| | *Notocomplana* | *acticola* | 17 |
| | *Pseudoceros* | | 121 |
| | *Stylochus* | | 25 |
| Porifera | None given | | 368 |
| | *Euplectella* | | 1 |
| | *Grantia* | | 43 |
| | *Halichondria* | | 110 |
| | *Haliclona* | | 154 |
| | *Leucosolenia* | | 14 |
| | *Microciona* | *prolifera* | 3 |
| | *Sycon* | | 142 |
| Rhodophyta | *Ceramium* | | 1 |
| "Xenacoelomorpha" | None given | | 1 |

***(D) Short alignments.***

| Phylum | Genus | Species | 3 |
|---|---|---|---|
| Annelida | *Eupolymnia* | *heterobranchia* | 1 |
| | *Halosydna* | *brevisetosa* | 1 |
| | *Hydroides* | | 1 |
| | *Paradialychone* | *ecaudata* | 1 |
| | *Parasabella* | *pallida* | 2 |
| | *Pterocirrus* | *burtoni* | 1 |
| Arthropoda | *Balanus* | *trigonus* | 1 |
| Bryozoa | *Crisulipora* | *occidentalis* | 1 |
| | *Watersipora* | *subtorquata* | 1 |
| Chordata | | | 3 |
| | *Diplosoma* | *listerianum* | 1 |
| | *Perophora* | | 2 |

**Table 5.5. List of species considered common contaminants. DNA sequences identified as these species appeared in >1000 assemblies from vials of unrelated vouchers.** Source of each contamination result is not known, however impure tissue samples, exchange of tissue between vials, cross-sample movement of lysate during extraction or of DNA during PCR set up are possible. Evidence also exists for eDNA in settlement plate holding tank water during morphological analyses.

| | |
|---|---|
| Annelida | *Megasyllis nipponica* |
| | *Halosydna brevisetosa* |
| | *Ficopomatus enigmaticus* |
| | *Polydora cornuta* |
| Arthropoda | *Amphibalanus amphitrite* |
| | *Balanus glandula* |
| | *Caprella penantis* |
| | *Balanus crenatus* |
| | *Jassa marmorata* |
| | *Leucothoe alata* |
| | *Caprella scaura* |
| | *Caprella simian* |
| Bryozoa | *Watersipora subtorquata* |
| | *Bugula neritina* |
| | *Cryptosula pallasiana* |
| | *Amathia verticillata* |
| | *Schizoporella japonica* |
| | *Celleporaria brunnea* |
| Chordata | *Botrylloides violaceus* |
| | *Ciona intestinalis* |
| | *Botryllus schlosseri* |
| | *Ascidia zara* |
| | *Molgula manhattensis* |
| | *Botrylloides leachii* |
| | *Styela plicata* |
| Cnidaria | *Diadumene leucolena* |
| Mollusca | *Ostrea stentina* |
| | *Ostrea lurida* |
| | *Mytilus galloprovincialis* |
| | *Mytilus trossulus* |
| Porifera | *Halichondria sitiens* |


**Figure 5.1. Matrix of all provisional genetic identifications versus morphological identifications.** Each colored cell represents the number of vials with that morphological and genetic identification combination, where the intensity of red represents count. Scale is set to log for ease of viewing. Species are arranged by phylum, such that clusters of related species can be seen as blocks. Perfect agreement of morphological and genetic identification would produce a single diagonal line; points off the diagonal represent disagreement. There is not a perfect diagonal line because some taxonomic names were not found genetically, or vice versa. The phyla are, in order: Annelida, Arthropoda, Bryozoa, Chordata, Cnidaria, Entoprocta, Mollusca, Nemertea, Platyhelminthes, and Porifera (left to right, bottom to top). The subplots 5.2 through 5.11 show each phylum in more detail.

.

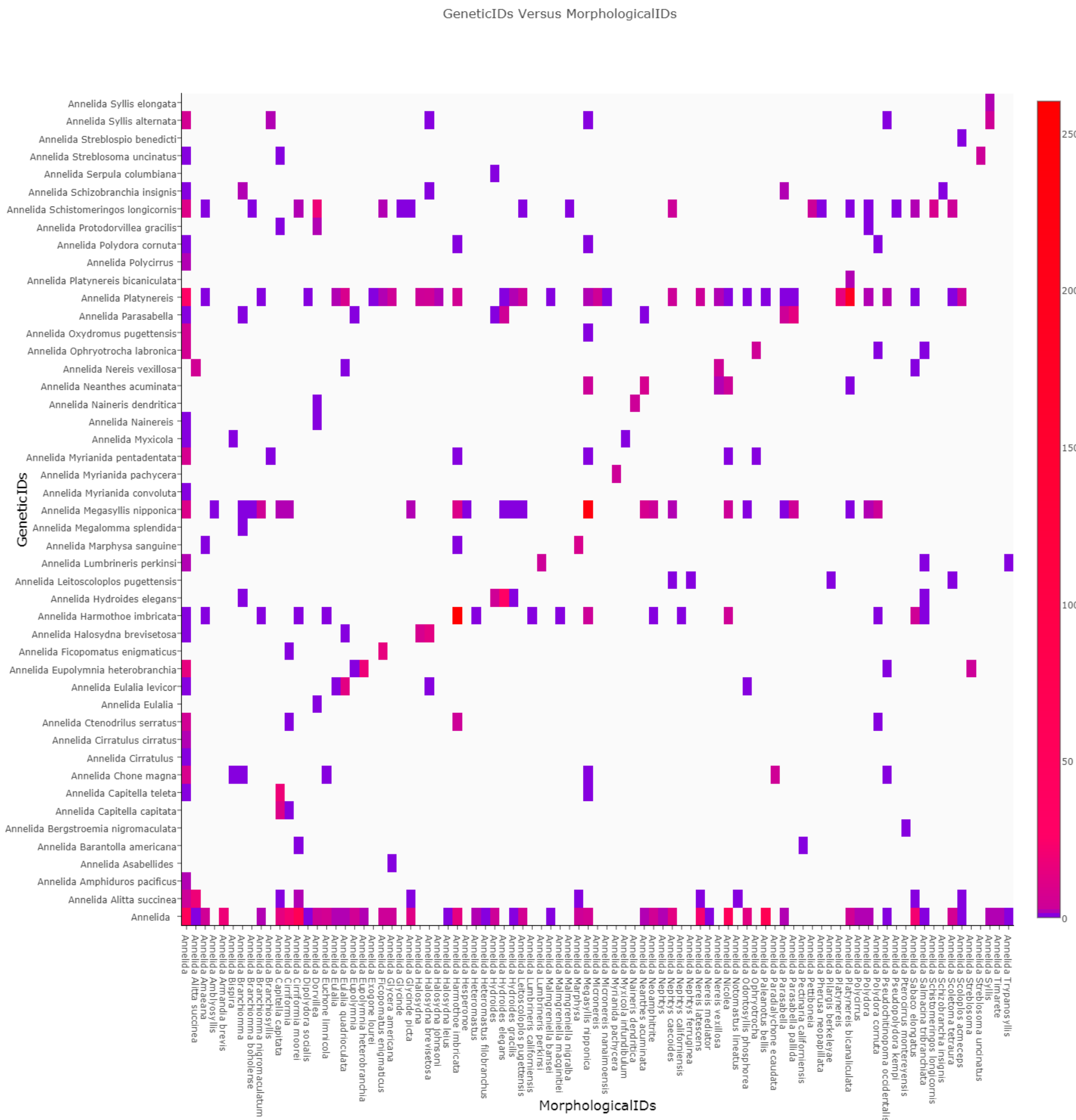


**Figure 5.2. Matrix of genetic vs. morphological ID for phylum Annelida.** See the caption of Figure 5.1 for more detail.

.

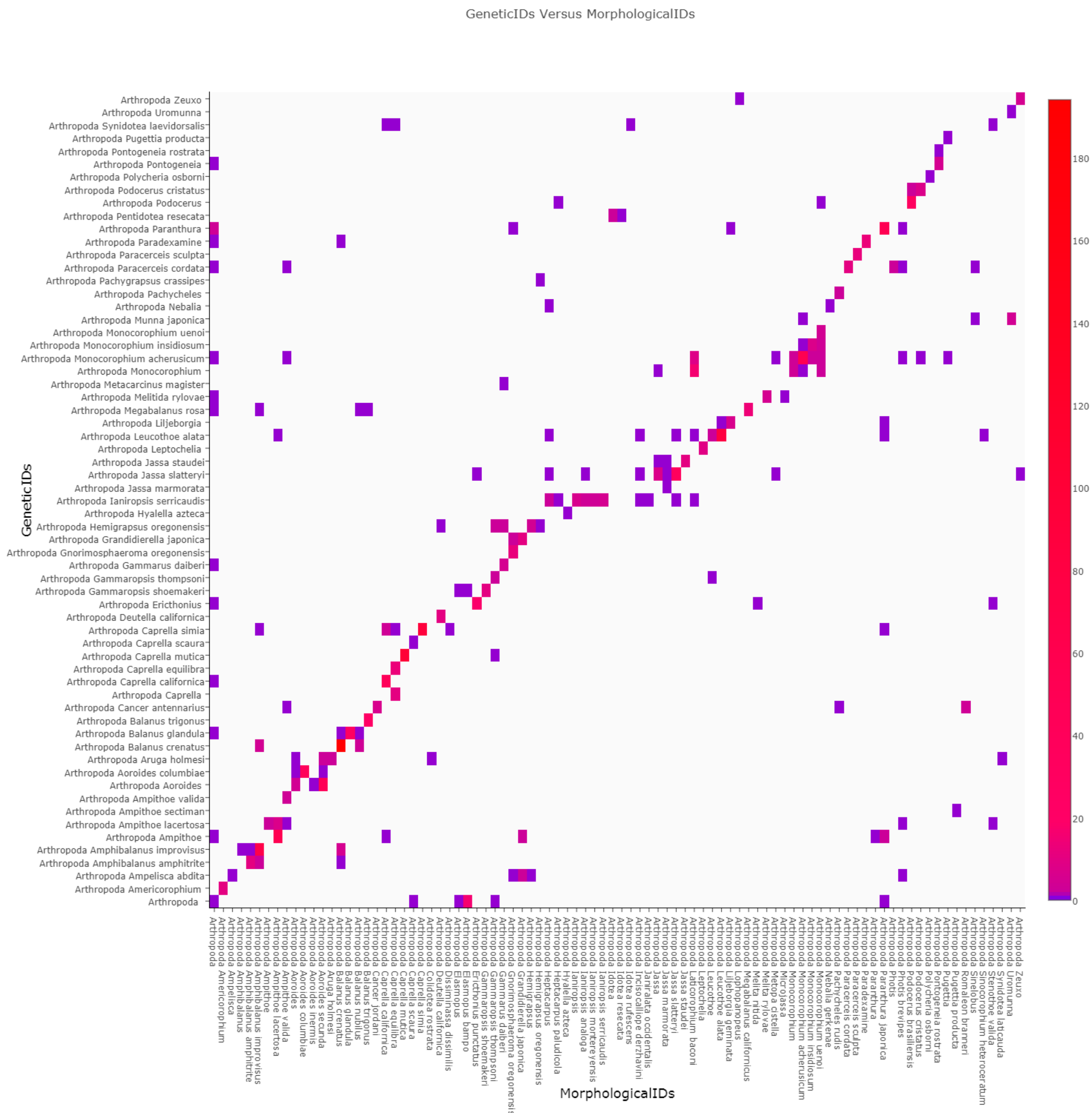


**Figure 5.3. Matrix of genetic vs. morphological ID for phylum Arthropoda.** See the caption of Figure 5.1 for more detail.

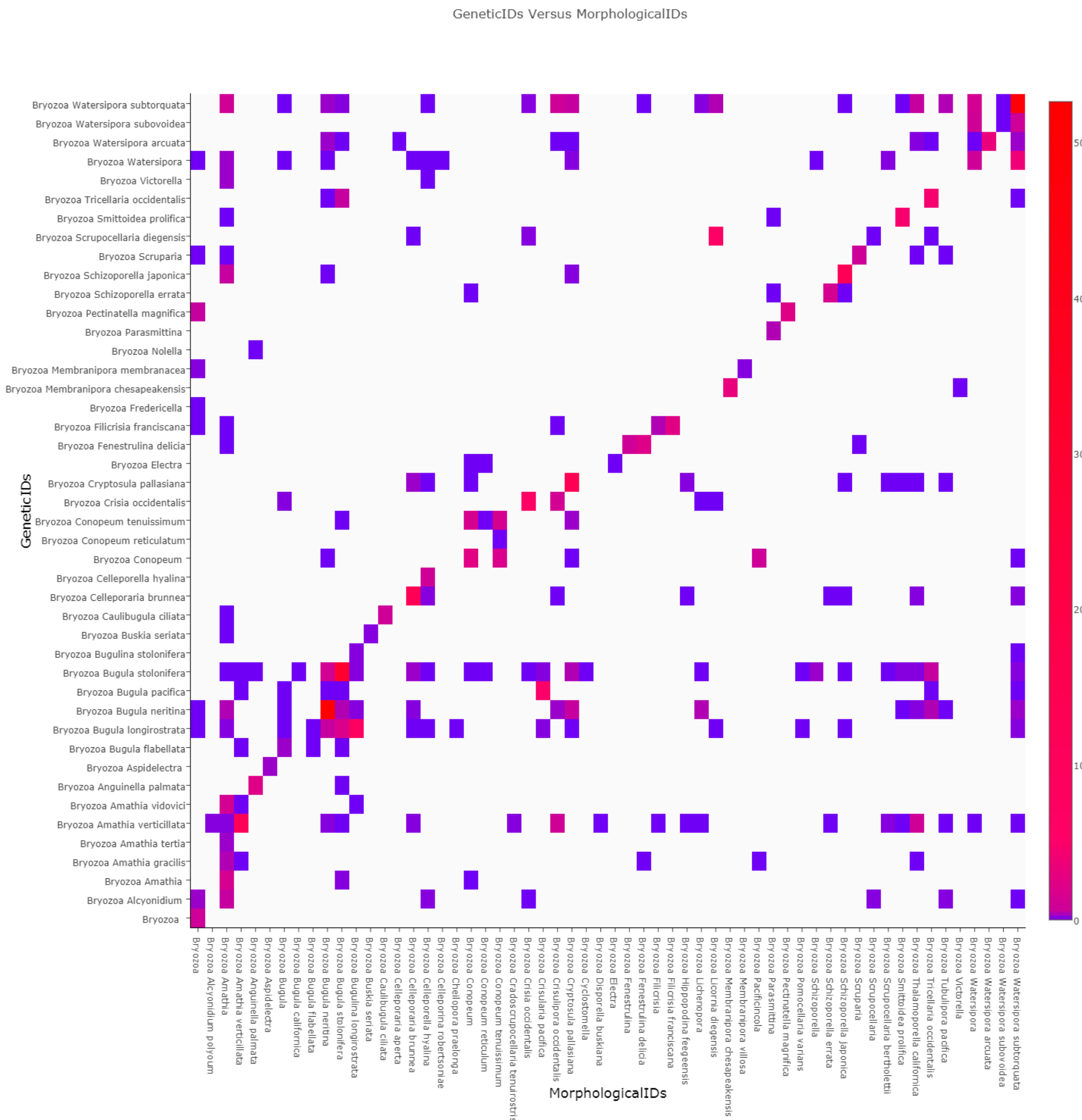


**Figure 5.4. Matrix of genetic vs. morphological ID for phylum Bryozoa.** See the caption of Figure 5.1 for more detail.

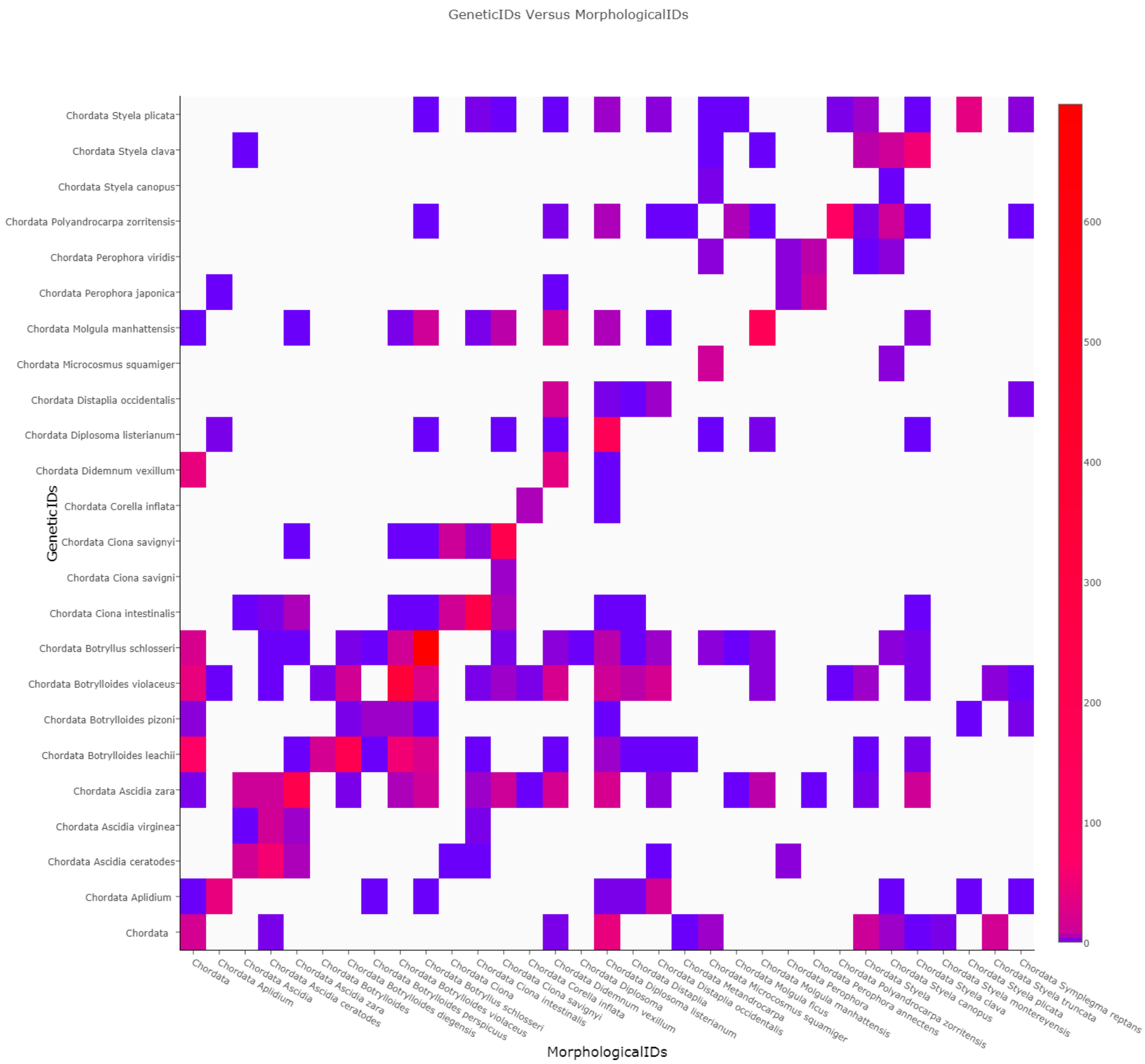


**Figure 5.5. Matrix of genetic vs. morphological ID for phylum Chordata**. See the caption of Figure 5.1 for more detail.

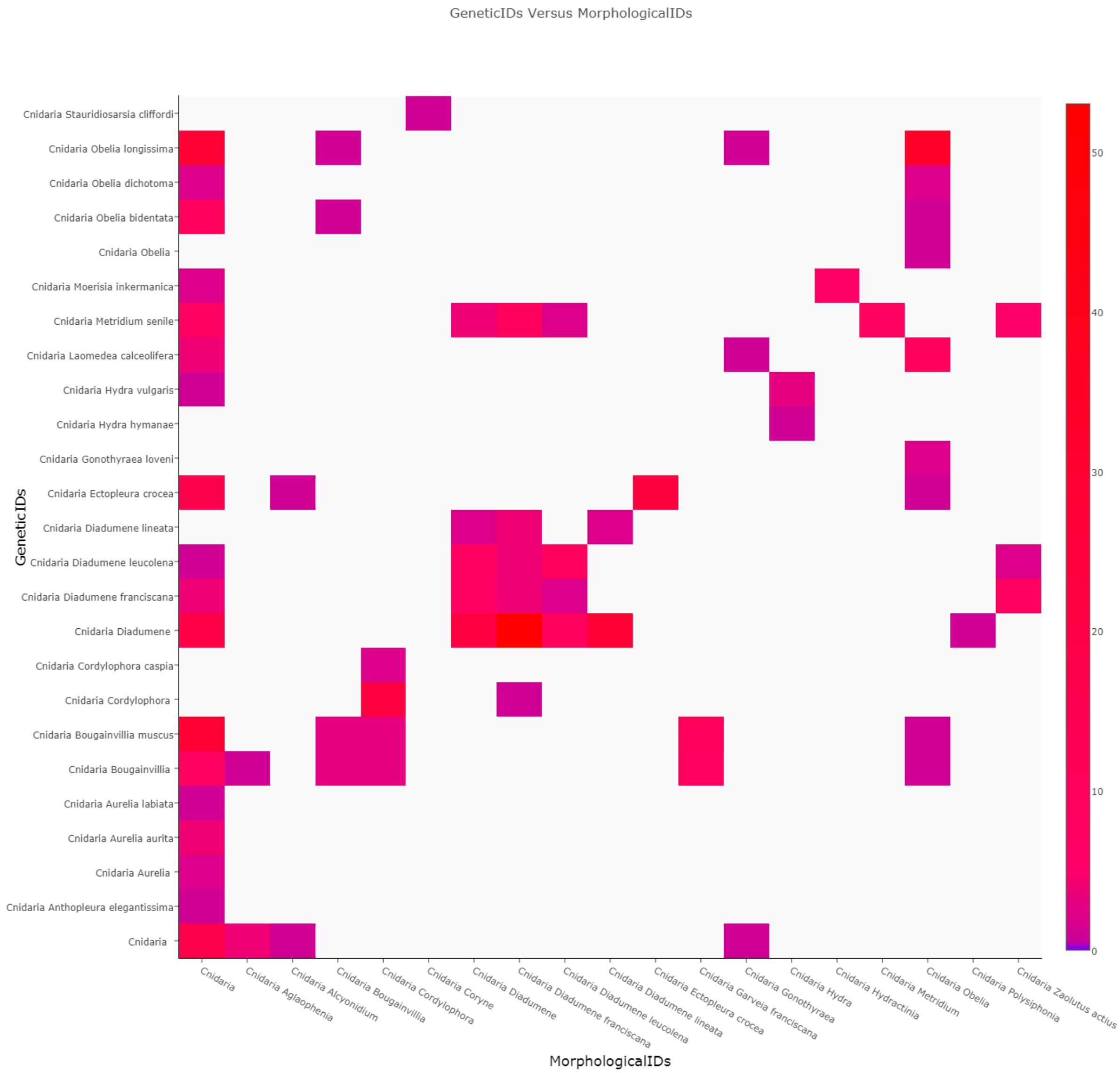


**Figure 5.6**. **Matrix of genetic vs. morphological ID for phylum Cnidaria.** See the caption of Figure 5.1 for more detail.

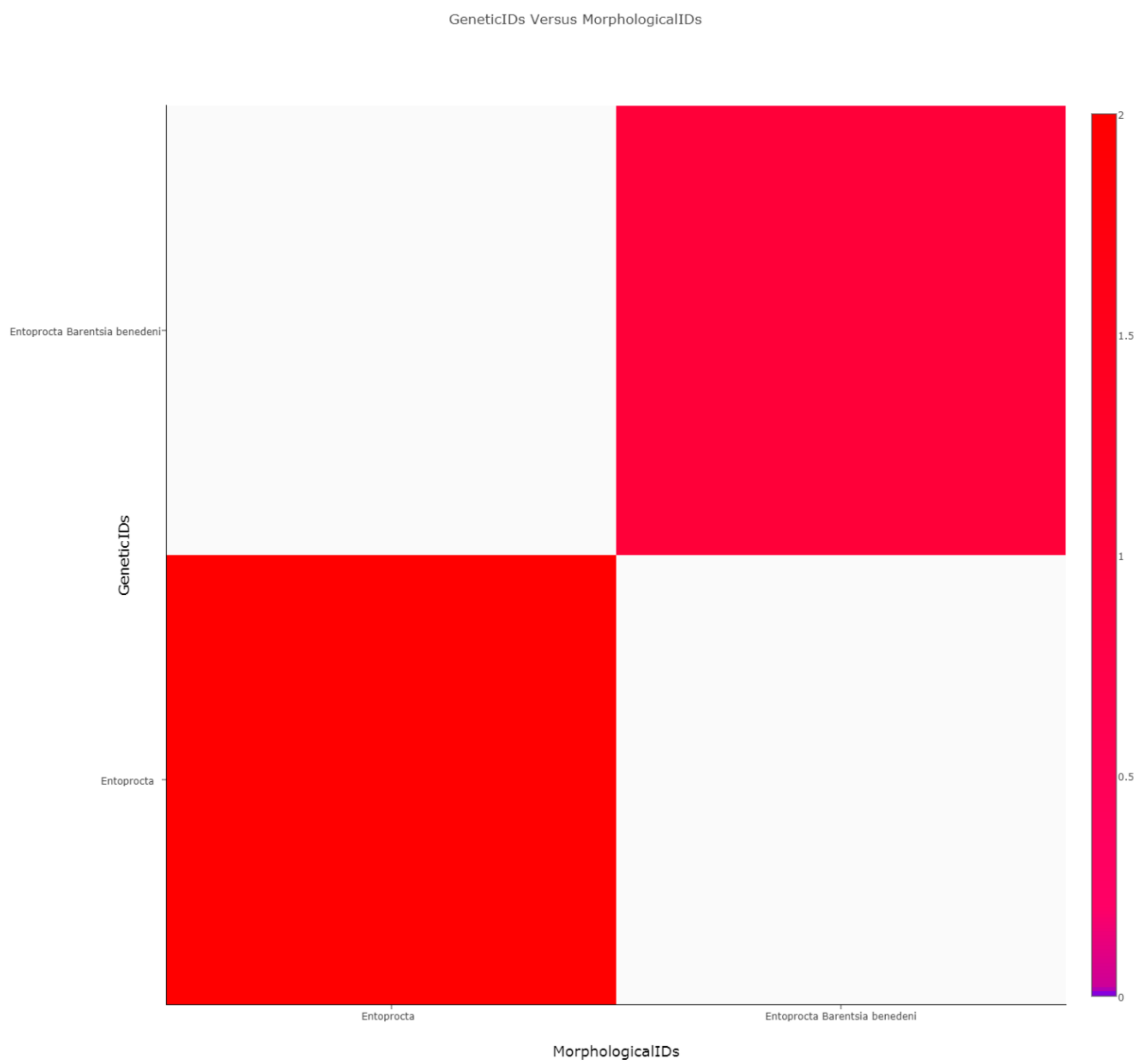


**Figure 5.7. Matrix of genetic vs. morphological ID for phylum Entoprocta.** See the caption of Figure 5.1 for more detail.

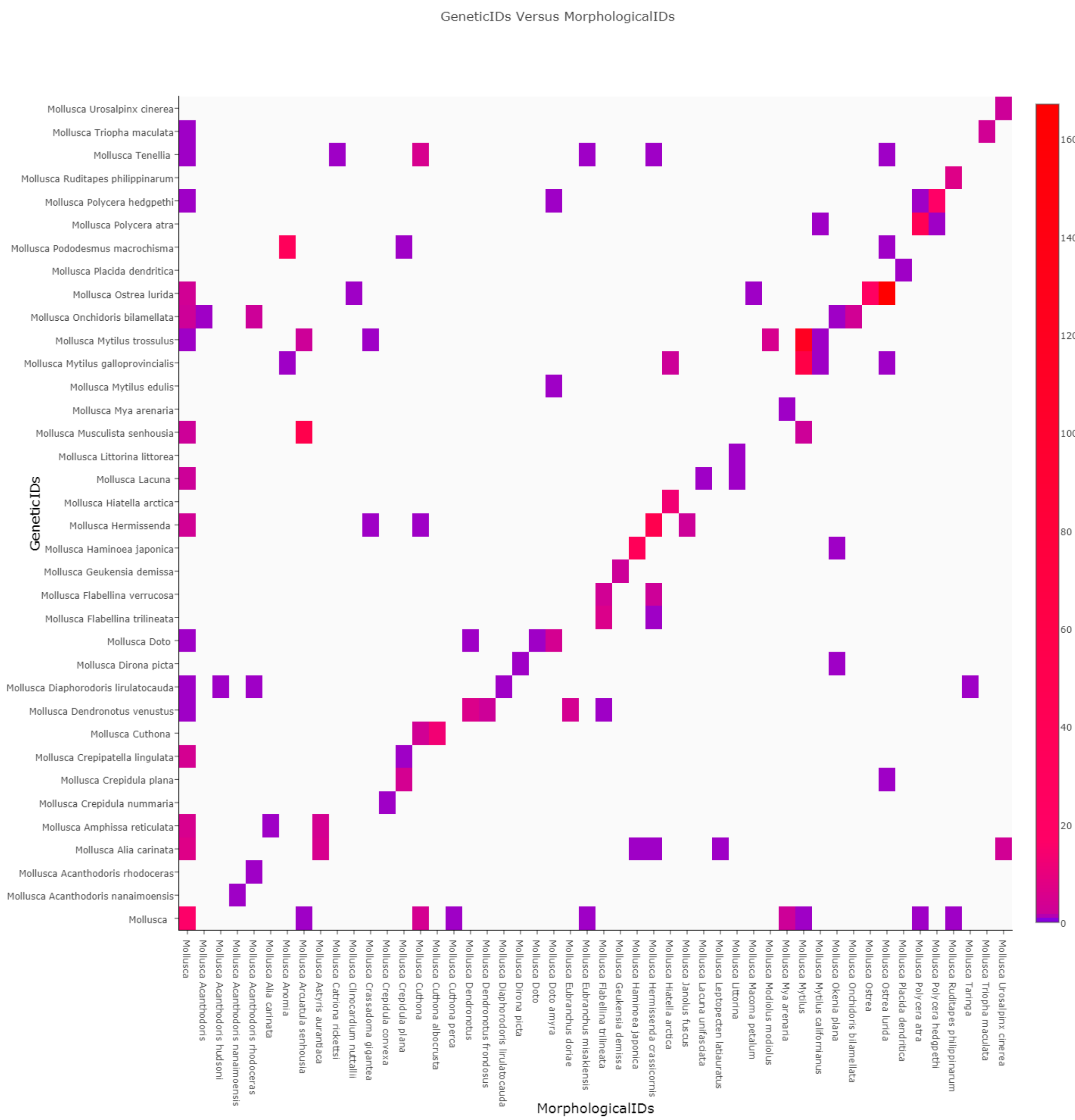


**Figure 5.8. Matrix of genetic vs. morphological ID for phylum Mollusca.** See the caption of Figure 5.1 for more detail.

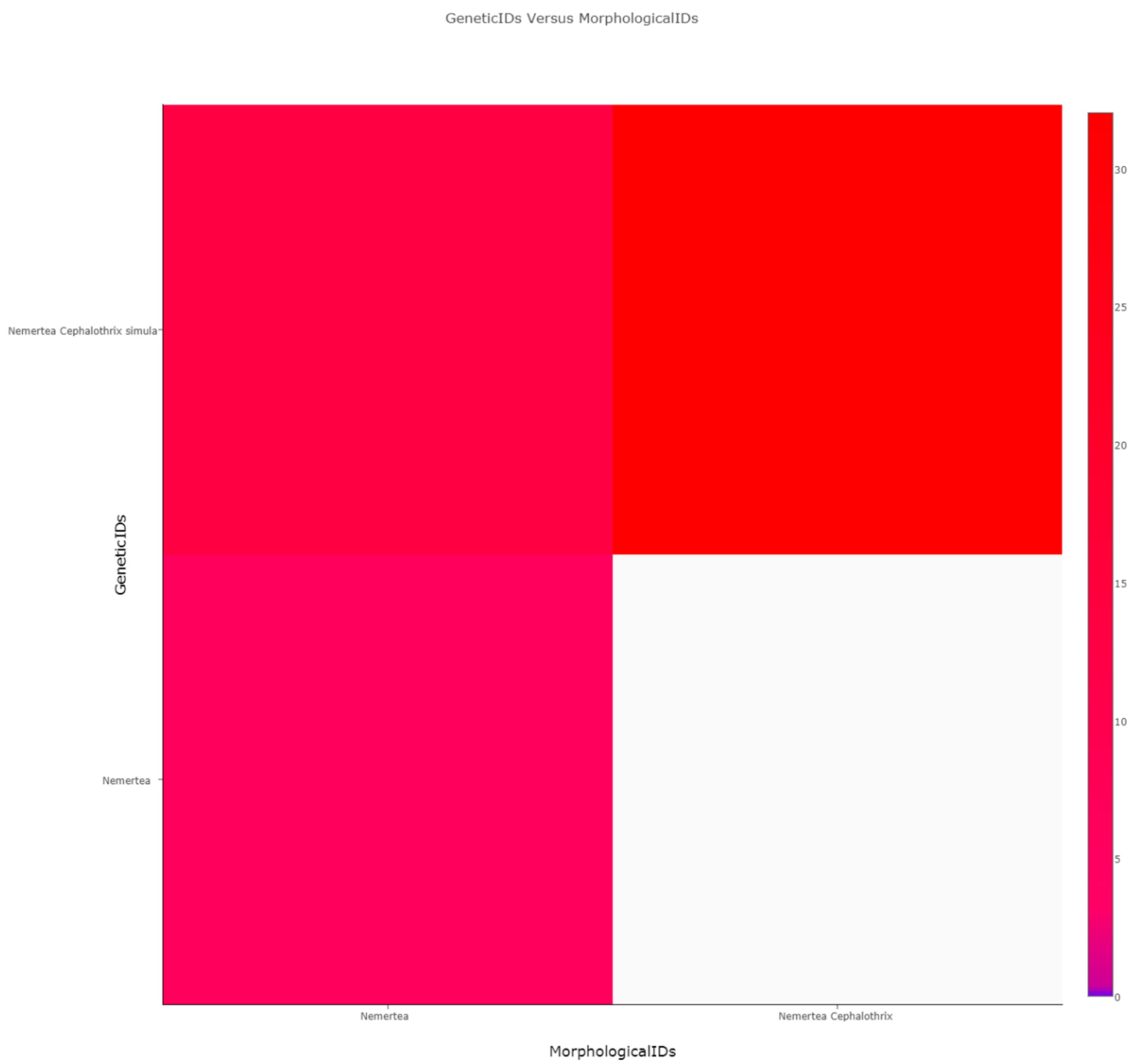


**Figure 5.9. Matrix of genetic vs. morphological ID for phylum Nemertea.** See the caption of Figure 5.1 for more detail.

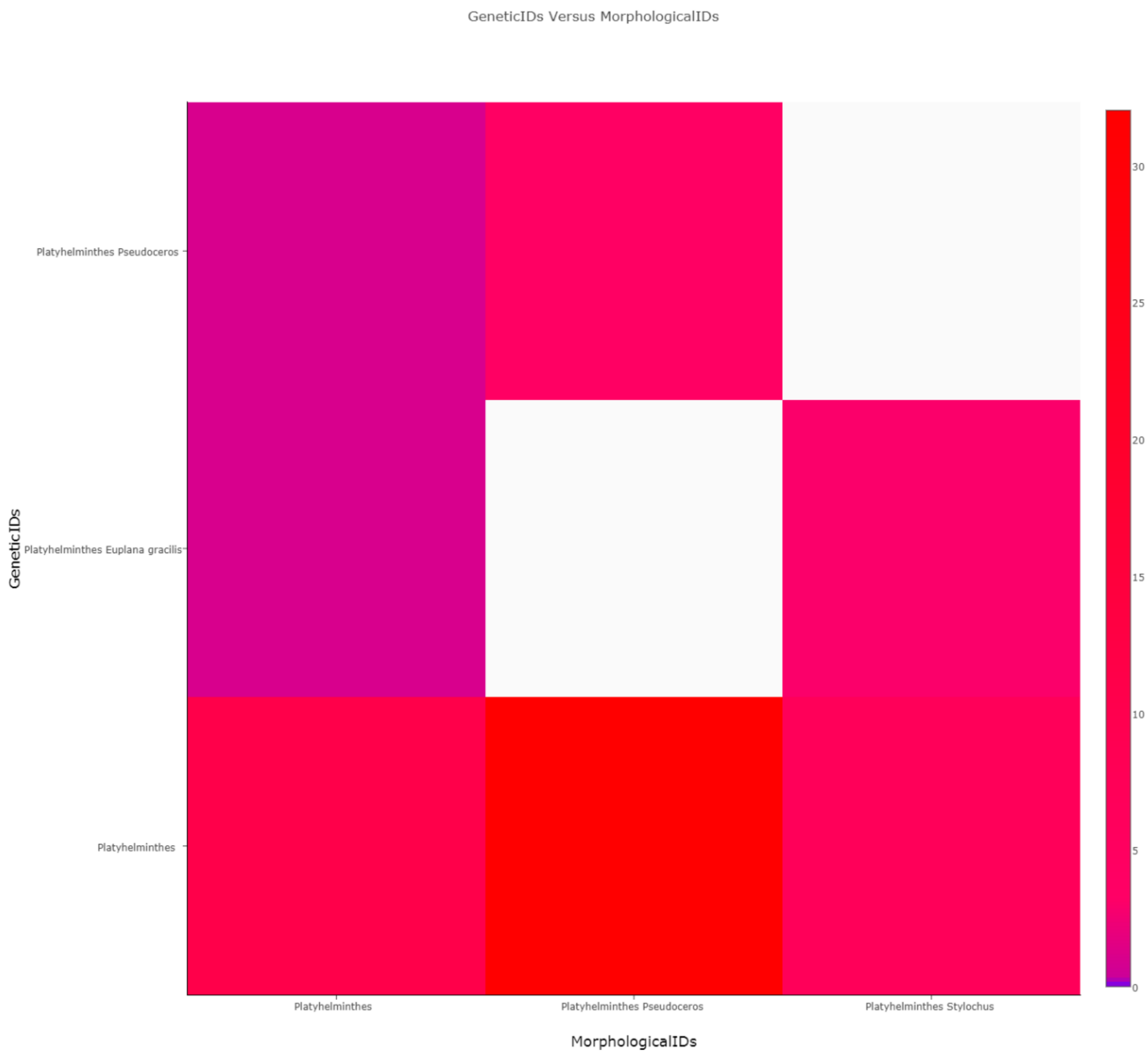


**Figure 5.10. Matrix of genetic vs. morphological ID for phylum Plathyhelminthes**. See the caption of Figure 5.1 for more detail.

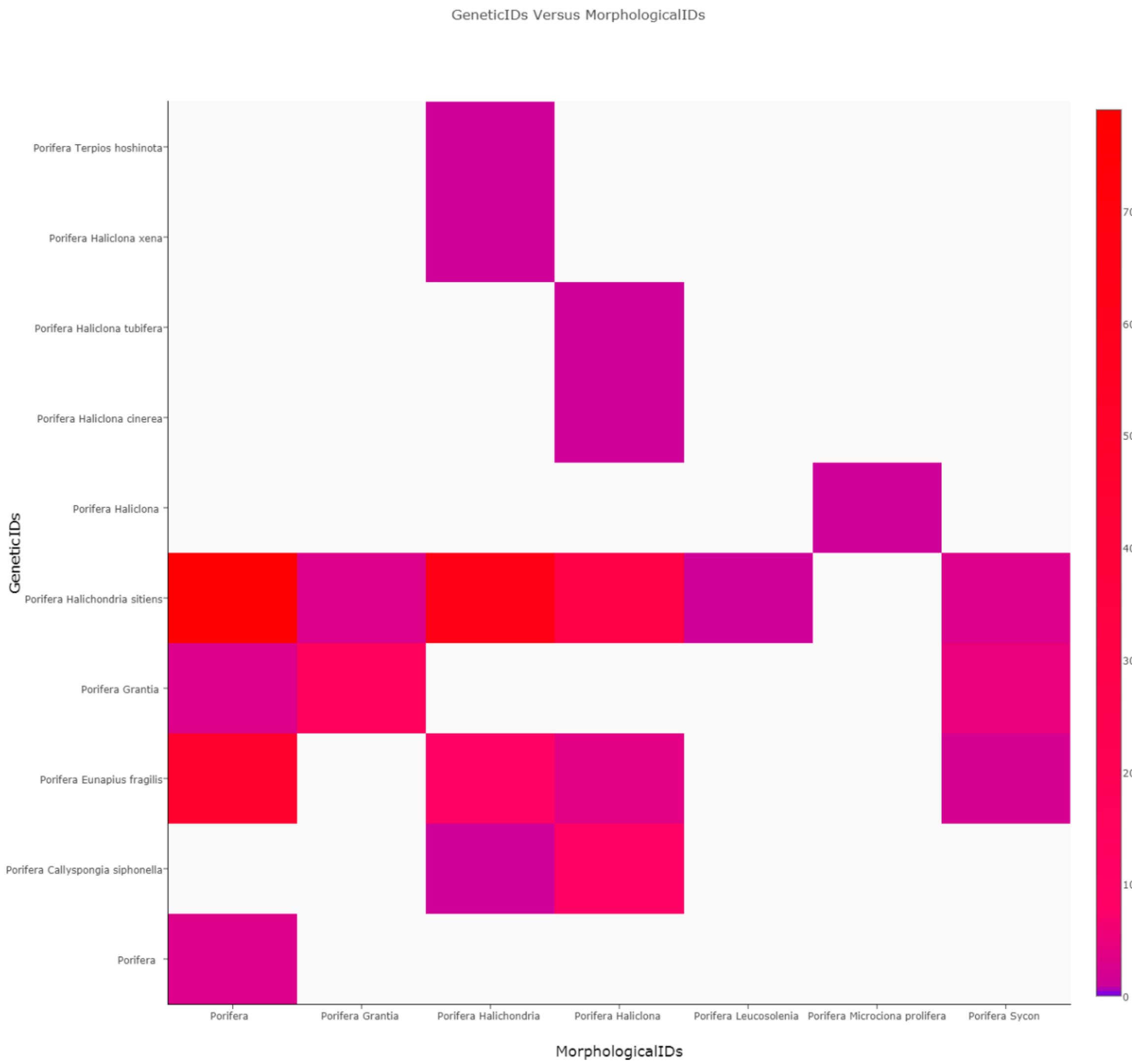


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**Figure 5.11. Matrix of genetic vs. morphological ID for phylum Porifera.** See the caption of Figure 5.1 for more detail.

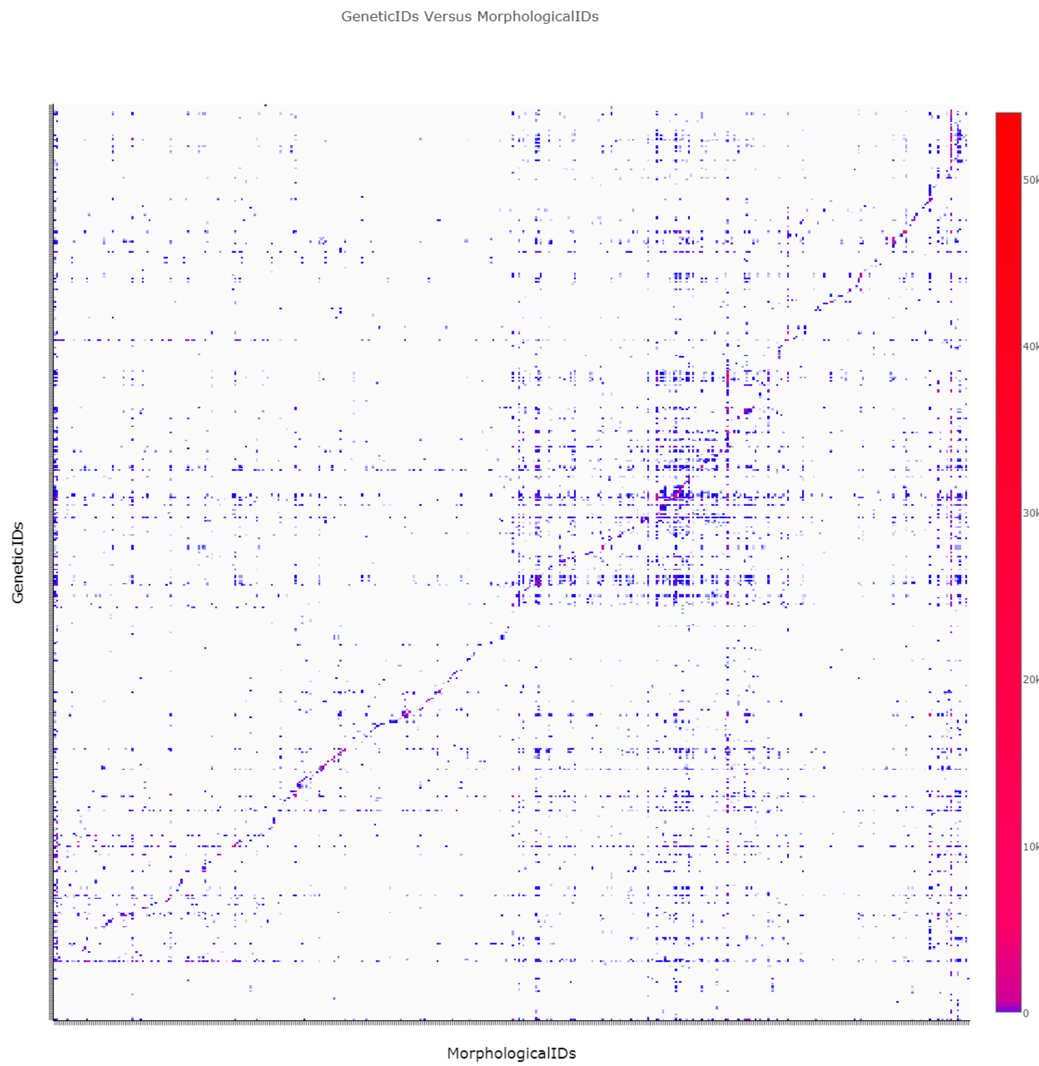


**Figure 5.12. Matrix of genetic vs morphological ID for all taxa without filtering of implausible taxa or multiple assemblies from individual vials.** See the caption of Figure 5.1 for more detail.

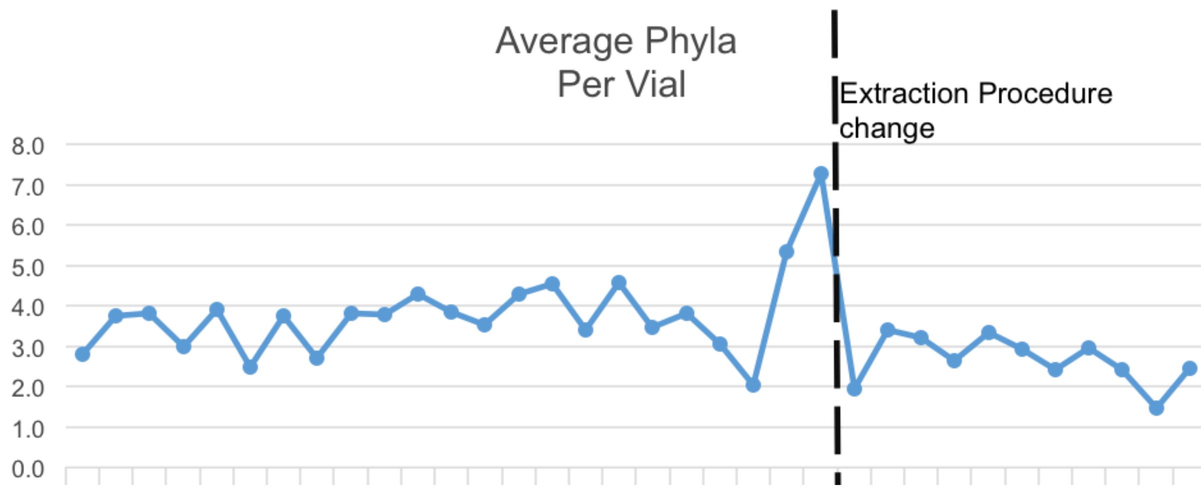


**Fig 5.13. Average number of Phyla detected per vial in a series of 96 well extraction plates, ordered chronologically.** The dashed vertical line denotes a change to extraction plates with screw-capped wells.

# Chapter 6: Metagenetic Analysis of Plankton

## Introduction

To inventory marine NIS, many sampling strategies may be used, and each will have strengths and weaknesses. Qualitative sampling (*e.g.*, "bioblitz" campaigns) may garner a large proportion of actual diversity but effort may vary among sites or personnel, and data are less amenable to statistical analysis. Quadrat based quantitative sampling can provide more consistency in effort, but different habitats may difficult to compare. Settling plates make uniform effort and habitat but select for primarily epibenthic species among the total biota. Sampling of plankton can complement these approaches by targeting both holoplanktonic NIS (completely missed in benthic sampling) and meroplankton (the larvae of benthic species). Meroplankton are contributed to the plankton by organisms in all habitats and thus expand the effective habitat space sampled in a NIS survey. Not all taxa produce planktonic larvae, and larval abundance is episodic, therefore plankton sampling for NIS is complementary to methods targeting benthic adults. Further, for many species, larvae are morphologically undescribed or simply difficult to identify. Genetic analysis is therefore ideally suited for species identification in plankton.

Organisms in plankton can be extraordinarily abundant, and even sorting into morphospecies groups, as a prelude to DNA sequencing, can be prohibitively laborious. Metagenetics, also known as metabarcoding, is the simultaneous sequencing of genetic loci from mixed template samples, such as a DNA extraction from a plankton sample. (Metagenomics is the sequencing of mixed genomic DNA and thus potentially includes all loci). Sequences derived from metagenetic sequencing can be compared to reference DNA barcode sequence databases to detect the presence of specific sequences that represent species of interest. Metagenetics is thus an attractive approach to genetic analysis of plankton.

In this chapter, we present results of metagenetic analysis of 617 cumulative plankton samples from Parts I and II of the California bays monitoring program. We attempted to identify all known non-indigenous species (NIS) present in each sample, potential NIS previously unknown in California, as well as native species represented in available sequence database. We also examined variation in total and NIS community structure across California bays.

## Methods

### ***<u>Collections</u>***

Samples were collected by either pumping surface (1 m depth) water through a 80 µm mesh, or by vertical tows from 5 or 10 m below the surface with 80 µm mesh net (Table 6.1). Samples were preserved in 95% ethanol and shipped to Moss Landing Marine Laboratories.

**Table 6.1. Samples included in this study, by (A) bay and year, (B) method, and (C) depth.** Some samples were repeated, bringing the total number of sequenced samples to 617.

| **A. Site and year** | **n** |
|---|---|
| Humboldt Bay 2015 | 40 |
| Bodega/Tomales Bay 2014 | 40 |
| San Francisco Bay 2013 | 45 |
| San Francisco Bay 2014 | 60 |
| San Francisco Bay 2015 | 64 |
| San Francisco Bay 2016 | 64 |
| Morro Bay 2013 | 40 |
| Mission Bay 2013 | 40 |
| Marina Del Rey 2015 | 40 |
| Port Hueneme 2015 | 40 |
| San Pedro 2015 | 40 |
| Newport Bay 2015 | 40 |
| San Diego Bay 2013 | 40 |
| | |
| **B. Method** | n |
| Pump | 315 |
| Vertical Tow | 278 |
| | |
| **C. Depth** | |
| 1 meter below surface | 315 |
| 5 meters below surface | 198 |
| 10 meters below surface | 80 |

***DNA extraction.***

Prior to extraction, each plankton sample was sieved through a clean 80-µm mesh (retaining the storage ethanol for each sample) and rinsed well with 1X TE (Tris-EDTA) buffer. Total sample weight was recorded, and approximately 0.25 grams (wet weight) of each sample was added to the PowerBead tube of a MoBio PowerSoil extraction kit. When total sample weight did not exceed 0.25 grams, the entire sample was used. Remaining material was stored in the original bottle with the 95% ethanol retained after sieving the sample. The extraction continued by following the manufacturer's protocol, except that samples were eluted into 80 µL of the provided elution buffer. A 20-µL aliquot of each DNA sample was transferred to a 96-well plate for downstream applications.

***Library preparation***

Genomic DNA was quantified using picogreen, according to the manufacturer's protocol and standardized to 5 ng µ$L^{-1}$. The COI gene was amplified, in triplicate, using primers with adapters for Nextera barcode indices (Table 6.2).

**Table 6.2.** Primers used for PCR amplification and Illumina sequencing.

| |
|---|
| Leray LCO forward primer [Nextera adapter]:<br>**[TCGTCGGCAGCGTCAGATGTGTATAAGAGACAG]**-GGWACWGGWTGAACWGTWTAYCCYCC |
| JG HCO reverse primer [Nextera adapted]:<br>**[GTCTCGTGGGCTCGGAGATGTGTATAAGAGACAG]**-TAIACYTCIGGRTGICCRAARAAYCA |

2.5 ng genomic DNA was amplified in a PCR cocktail comprising a final concentration of 1 x Kapa Robust Hot Start Ready Mix, 0.2 mg m$L^{-1}$ BSA, 2 mM $MgCl_2$, and 0.4 µM of each primer in a 25 µL reaction. Reaction conditions consisted of an initial 3 min melt at 95° C, followed by 27 cycles of a 1 min at 95° C, 45 sec at 47° C, and 1 min at 72° C with a final 72° C hold for 5 min. PCR amplicons were viewed on a 2% agarose gel stained with ethidium bromide. Triplicates were pooled and purified with 1.4 x the sample concentration of Agencourt Ampure beads, according to the manufacturer's protocol.

To attach the Nextera barcodes, 2.5 µL of pooled and purified amplicons were amplified in a PCR cocktail comprising a final concentration of 1 x Kapa Robust Hot Start Ready Mix, 0.2 mg m$L^{-1}$ BSA, 0.2 µM each forward and reverse barcode, and 2 mM $MgCl_2$ in a final volume of 25 µL. Reaction conditions consisted of an initial 3 min melt at 95° C, followed by 8 cycles of a 30 sec at 95° C, 30 sec at 55° C, and 30 sec at 72° C with a final 72° C hold for 5 min. PCR products were viewed on a 2% agarose gel stained with ethidium bromide. Amplicons were purified with 1.4 x the sample concentration of Agencourt Ampure beads, according to the manufacturer's protocol. Purified samples were quantified using picogreen, according the manufacturer's protocol. Barcoded amplicons were pooled evenly according to their concentration in ng µ$L^{-1}$.

The library was denatured and diluted to a concentration of 20 pM and run on an Illumina MiSeq using a 600 cycle v3 cartridge according to the manufacturer's recommended protocols.

***Bioinformatic analysis***

There were six Illumina sequencing runs for Phase 2 [BZS04, 05, 06, 07, 08, 09; BZS=Baywide Zooplankton Survey]. For each run, de-multiplexed forward and reverse read files were generated by the Illumina software and analyzed using USEARCH 9.0 and 10.0 (Edgar 2010). First, forward and reverse fastq files were merged, allowing for a maximum of 12 differences in the overlap and only keeping aligned reads between 352 and 376 base pairs (-fastq_mergepairs). At this time, sequences were also renamed by their sample name to facilitate downstream processing. Merged reads were then filtered (-fastq_filter) using a maximum expected error (max_ee) of 0.5, which is a stringent filtering criteria allowing for <1 error per read. Primers were removed from all merged reads (-fasx_truncate), which were dereplicated (-fastx_uniques).

In USEARCH v10.0, there is an algorithm that allows for the 'denoising' of amplicon-based Illumina reads (Edgar 2016), which generated zero-radius OTUs (or ZOTUs) that are biologically relevant sequences. This same algorithm includes a stringent chimera filter. We used the latest version of this algorithm to generate ZOTUs (-unoise3) for each run using the default parameters. To determine that all the ZOTUs were in fact COI sequences, we generated alignments for each run using the MAFFT plug-in (Katoh and Kuma 2002) in Geneious v10.2.3 (Biomatters, Ltd., San Francisco, California). Any sequences that did not appear to be COI in the alignment (*i.e.*, those sequences that did not align well with others) were extracted from the aligned set and blasted against NCBI GenBank through Geneious. Based on these results, if a sequence was identified as COI, it remained in the alignment. If it was not identified as COI, then it was removed from the alignment. If sequences were removed from the alignment, the alignment was remade with the new set of sequences and visually inspected for any sequences that did not align well until all sequences were confirmed to be COI either through proper alignment or identification via GenBank.

The ZOTUs were renamed with a unique identifier for each run to differentiate ZOTUs across runs. Then, in order to assign the same ZOTU across all runs in perpetuity, we created a Master ZOTU list using sequence data generated in Phase 1 and Phase 2. (Note that Phase 1 sequences were processed using the same pipeline as described above for each Phase 2 sequencing run.) To create the Master ZOTU list, we started with Phase 1 sequences as the first set and then mapped BZS04 sequences to them at 100% identity (-usearch_global). Those sequences that did not match at 100% were then appended to the Phase 1 sequence fasta file, which was renamed Master_ZOTU_list_v1. This process continued until all Phase 2 runs had individually mapped to the latest version of the Master ZOTU list and all sequences that did not match those on the list already had been appended. At the time of writing, the latest version of this list is v6.

To create a ZOTU table with all the runs from Phase 2, the merged, filtered, trimmed reads from each run were concatenated into a single file, which was then mapped to the v6 of the Master ZOTU list at 97% identity, as recommended in the software documentation (-usearch_global).

To determine the species-level clusters, all ZOTUs were reclustered into OTUs at a 95% similarity level using -usearch cluster_smallmem. Hereafter, “OTU” refers to these 95% clusters unless otherwise specified. Raw reads were then mapped to OTUs. To examine community-level analyses of ZOTUs across bays, reads for each sample were rarefied to 1000 and 10,000; the lower number retains the most sites, while the larger number results in loss of samples with fewer than 10,000 reads. Rarefied reads were then mapped to the 95%-OTUs and used in the software package PRIMER to produce nonmetric multiple dimensional scaling (nMDS) plots to illustrate patterns of similarity among OTU composition and abundance within and between bays. These data were also used for permutational analysis of variance (PERMANOVA) tests of differences among bays.

To identify taxa, OTUs were BLASTed against the MLML reference database and a curated COI database called CO-Arbitrator (Heller *et al.*, in review). We retained matches that exceeded 94.5% similarity and had 90-100% sequence length overlap with our query sequence. A similarity of 95% is commonly used as a threshold for biological species under the assumption of an interspecific “barcode gap.” (We chose 94.5% to allow for up to 0.5% sequencing error). However, some sequences that are 95% similar may belong to >1 species if divergence is low in a genus (for example if divergence is recent or rate of substitution is low). The converse error is possible too. Phylogenetic analysis, when possible, is superior to threshold analysis to detect reciprocally monophyletic clades - whether such clades represent species will remain to be determined independently.

Ecological patterns were investigated by PERMANOVA tests of differentiation of OTU composition among bays and the effect of additional factors of temperature and salinity. Patterns were also explored by nMDS. Both analyses used the software package PRIMER. An important caveat is that these analyses treat read abundance as equivalent to organismal abundance. PCR efficiency for different species and how this varies for different plankton samples (due to differences in species composition, for example) is not presently known. In addition, clustering of reads into OTUs may split some species that are highly genetically variable and lump some that are more conserved than typical. It may be best to consider these analyses as addressing community OTU composition in a strict sense of genetic clusters, rather than biological species.

We repeated ecological analyses while confining the analysis to the species known to be established NIS in California. NIS status was determined by reference to a list provided by SERC (Appendix 6.1).

**Results**

For the six Illumina runs that were performed for Phase 2, we generated 55,040,497 sequences. After merging and filtering out low quality sequences, the final dataset contained 28,605,589 sequences. These clustered into 14,635 ZOTUs and 3719 95%-threshold OTUs.

For Phase 1 and 2 combined (a total 617 samples), we retained ~94% of samples with rarefaction at 1,000, while at 10,000 we retained ~63% of samples (*i.e.*, 6% and 37% of samples, respectively, contained too few reads at those rarefaction levels). For Phase 2 only (a total 440 samples), we retained ~93% of samples with rarefaction at 1,000, and at depth of 10,000, we retained ~75% of samples.

***Community composition differences among sites***

At both the 1,000-read and 10,000 read levels of rarefaction, the OTU composition was significantly different across bays (Tables 6.3 and 6.4). The differentiation among sites is conspicuous in nMDS plots (Figure 6.1), although it is difficult to attribute community differences to latitude because of environmental differences among sites (below).

**Table 6.3**. One-way PERMANOVA results of community composition for all bays when reads were rarefied to 1,000.

| Factor | df | SS | MS | Pseudo-F | P(perm) |
|---|---|---|---|---|---|
| Bay | 9 | 64068 | 71187 | 32.403 | 0.001 |
| Residual | 553 | 1214900 | 2196.9 | | |
| Total | 562 | 1855600 | | | |

**Table 6.4.** One-way PERMANOVA results of community composition for all bays when reads were rarefied to 10,000 reads.

| Factor | df | SS | MS | Pseudo-F | P(perm) |
|---|---|---|---|---|---|
| Bay | 9 | 450780 | 50087 | 25.272 | 0.001 |
| Residual | 381 | 755110 | 1981.9 | | |
| Total | 390 | 1205900 | | | |

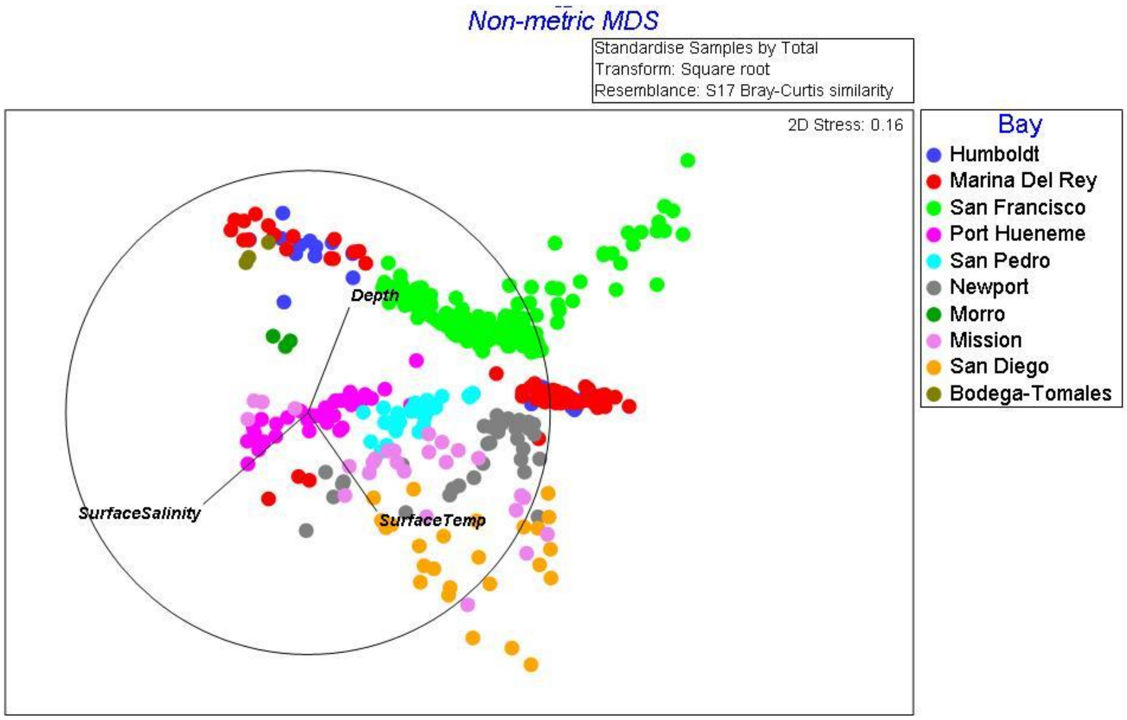


**Figure 6.1 nMDS plot of all samples and sites in Phase I and Phase II, with reads rarefied to 10,000 and with overlay of environmental data.** Site was a significant factor in community differentiation. Site effects include environmental differences (overlay) as well as biogeographic and invasion history.

With data rarefied to 1000 reads, samples were ~29-45% similar within sites (Table 6.5). Humboldt Bay samples showed the least internal consistency (28.77% similarity). Between sites, samples were ~12-29% similar, and every site was significantly different from any other. However, Humboldt Bay and Marina Del Rey were only marginally statistically different from each other.

**Table 6.5**. **Percent similarity within and between sites when rarefaction level = 1,000.** All pairs were significantly different (p<0.008).

| | Humboldt | Marina Del Rey | San Francisco | Port Hueneme | San Pedro | Newport |
|---|---|---|---|---|---|---|
| Humboldt | 28.77 | | | | | |
| Marina Del Rey | 28.96 | 40.17 | | | | |
| San Francisco | 17.21 | 20.41 | 35.95 | | | |
| Port Hueneme | 11.84 | 11.97 | 14.58 | 43.70 | | |
| San Pedro | 14.35 | 18.45 | 22.87 | 28.28 | 44.87 | |
| Newport | 15.15 | 22.79 | 20.15 | 16.14 | 24.85 | 42.68 |

With data rarefied to 10,000 reads, samples were ~33-50% similar within sites (Table 6.6). Humboldt Bay samples again the least internal consistency (33.75% similarity). Between sites, samples were ~14-36% similar, and Humboldt Bay and Marina Del Rey were not significantly different, presumably due to the low internal consistency in Humboldt Bay.

**Table 6.6**. **Percent similarity within and between sites when rarefaction level = 10,000**. All pairs were significantly different except Humboldt and Marina Del Rey (p=0.06, ns).

| | Humboldt | Marina Del Rey | San Francisco | Port Hueneme | San Pedro | Newport |
|---|---|---|---|---|---|---|
| Humboldt | 33.75 | | | | | |
| Marina Del Rey | 36.26,ns | 43.76 | | | | |
| San Francisco | 19.95 | 22.48 | 38.12 | | | |
| Port Hueneme | 13.61 | 13.35 | 15.45 | 47.60 | | |
| San Pedro | 17.52 | 20.73 | 24.19 | 31.18 | 49.50 | |
| Newport | 18.53 | 23.73 | 20.40 | 18.97 | 27.54 | 44.04 |

***Effects of environmental variables.***

Community composition was analyzed with respect to the influence of environmental factors. Salinity was binned into categories of <20, >20≤25, >25≤30, and >30 ppt, while temperature was binned into categories of 10≤13, >13≤16, >16≤19, >19≤22, >22≤25, and >25$^{o}$ C. Not all samples were provided with temperature and salinity data, so not all interaction terms could be evaluated. Temperature, or the interaction of temperature and bays, appeared to have a significant effect on community composition for data rarefied to both 1,000 and 10,000 reads (Table 6.7 and 6.8). The effect of salinity is ambiguous, with no signficant effect when more samples were included by rarefying to a lower level (1000 reads); when more reads were included, which necessarily reduced the number of samples, a marginally non-significant effect of salinity was observed (p=0.087).

**Table 6.7. PERMANOVA results of community composition for all bays when reads were rarefied to 1,000 per sample.** Unrepresented data bins precluded tests for some interactions.

| Factor | df | SS | MS | Pseudo-F | P(perm) |
|---|---|---|---|---|---|
| Bay-Year | 6 | 161250 | 26875 | 15.497 | 0.001 |
| Surface Temperature | 2 | 6665.2 | 3332.6 | 1.9216 | 0.022 |
| Surface Salinity | 1 | 1604 | 1604 | 0.92486 | 0.451 |
| Bay-Year x Surface Temperature * | 8 | 35069 | 4383.7 | 2.5277 | 0.001 |
| Surface Temperature x Surface Salinity* | 3 | 5017.5 | 1672.5 | 0.96438 | 0.484 |
| Residues | 282 | 489060 | 1734.3 | | |
| Total | 313 | 1060300 | | | |

*indicates uneven sample sizes

**Table 6.8. PERMANOVA results of community composition for all bays when reads were rarefied to 10,000 reads**. Unrepresented data bins precluded tests for some.

| Factor | df | SS | MS | Pseudo-F | P(perm) |
|---|---|---|---|---|---|
| Bay-Year | 6 | 122960 | 20494 | 13.374 | 0.001 |
| Surface Temperature | 2 | 4934.8 | 2467.4 | 1.6102 | 0.071 |
| Surface Salinity | 2 | 4836.7 | 2418.3 | 1.5782 | 0.087 |
| Bay x Surface Temperature* | 6 | 27252 | 4541.9 | 2.9641 | 0.001 |
| Residual | 191 | 292670 | 1532.3 | | |
| Total | 214 | 670320 | | | |

*indicates uneven sample sizes

***San Francisco Bay***

Focus on the most often sampled site, San Francisco Bay, facilitates consideration of environmental drivers apart from confounding historical factors, and year-to-year variation. Moreover, environmental metadata were more complete for San Francisco Bay. Main effects of year, surface temperature, and salinity all had significant effects on community composition in plankton samples, but almost all interactive terms were also significant (Table 6.9 and 6.10). nMDS plots indicate segregation of low salinity sites (Figure 6.2 and 6.3), and it appears that low salinity sites were more prevalent in 2015 and 2016 (Figure 6.4).

**Table 6.9. PERMANOVA results of community composition in San Francisco when a rarefaction level of 1000 reads was used**. Temperature and salinity data were binned into levels, therefore sample sizes for some combinations of year, temperature and salinity varied.

| Factor | df | SS | MS | Pseudo-F | P(perm) |
|---|---|---|---|---|---|
| Year | 1 | 6611.4 | 6611.4 | 6.2394 | 0.001 |
| Surface Temperature | 2 | 11249 | 5624.7 | 5.3082 | 0.001 |
| Surface Salinity | 1 | 3262.3 | 3262.3 | 3.0787 | 0.001 |
| Year x Surface Temperature* | 5 | 15650 | 3129.9 | 2.9538 | 0.001 |
| Year x Surface Salinity** | 6 | 16705 | 2784.2 | 2.6275 | 0.001 |
| Surface Temperature x Surface Salinity* | 2 | 3791.9 | 1896 | 1.7893 | 0.017 |
| Year x Surface Temperature x Surface Salinity** | 3 | 6189.5 | 2063.2 | 1.9471 | 0.003 |
| Residual | 163 | 172720 | 1059.6 | | |
| Total | 190 | 430190 | | | |

*indicates uneven sample sizes

**Table 6.10 PERMANOVA results of community composition in San Francisco when a rarefaction level of 10,000 reads was used.** Temperature and salinity data were binned into levels, therefore sample sizes for combinations of year, temperature and salinity varied.

| Factor | df | SS | MS | Pseudo-F | P(perm) |
|---|---|---|---|---|---|
| Year | 1 | 6365.4 | 6365.4 | 8.02 | 0.001 |
| Surface Temperature | 2 | 8174.1 | 4087.1 | 5.1494 | 0.001 |
| Surface Salinity | 1 | 4025.5 | 4025.5 | 5.0718 | 0.001 |
| Year x Surface Temperature* | 3 | 6237.5 | 2079.2 | 2.6196 | 0.001 |
| Year x Surface Salinity* | 5 | 12338 | 2467.6 | 3.109 | 0.001 |
| Surf Temp x Surface Salinity* | 1 | 1030.7 | 1030.7 | 1.2986 | 0.152 |
| Year x Surface Temperature x Surface Salinity** | 2 | 3841.5 | 1920.7 | 2.42 | 0.002 |
| Residues | 111 | 88100 | 793.7 | | |
| Total | 133 | 277170 | | | |

*indicates uneven sample sizes

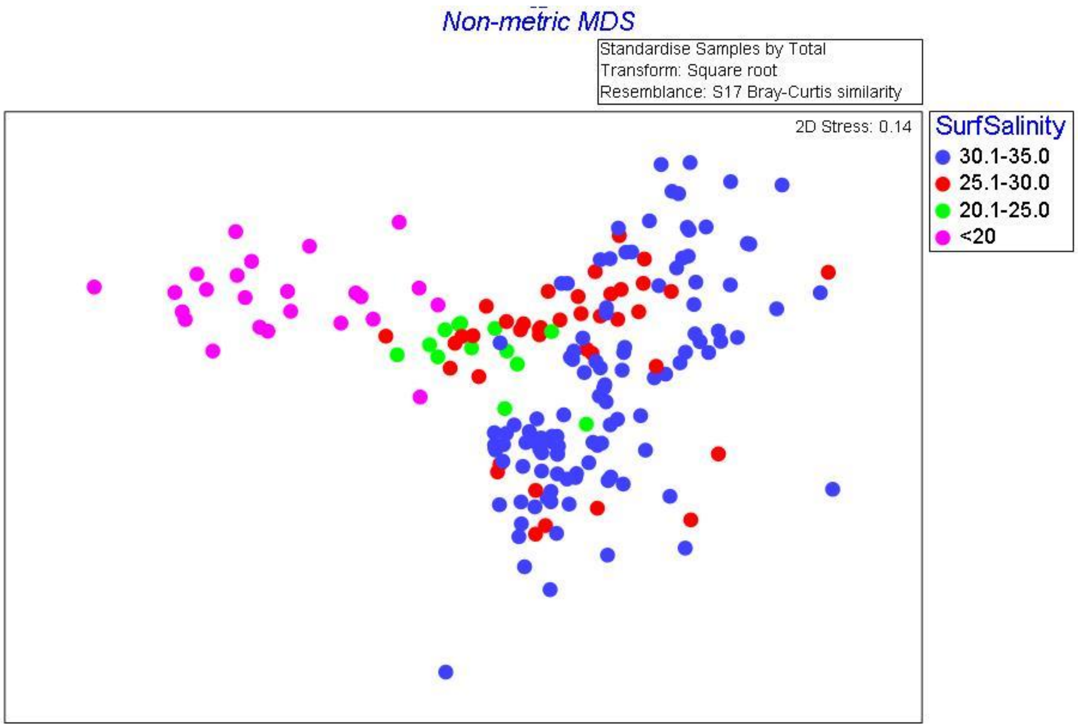


**Figure 6.2. nMDS plot representing community composition of plankton samples in San Francisco Bay, coded by salinity, based on data rarefied to 1,000 reads per sample.**

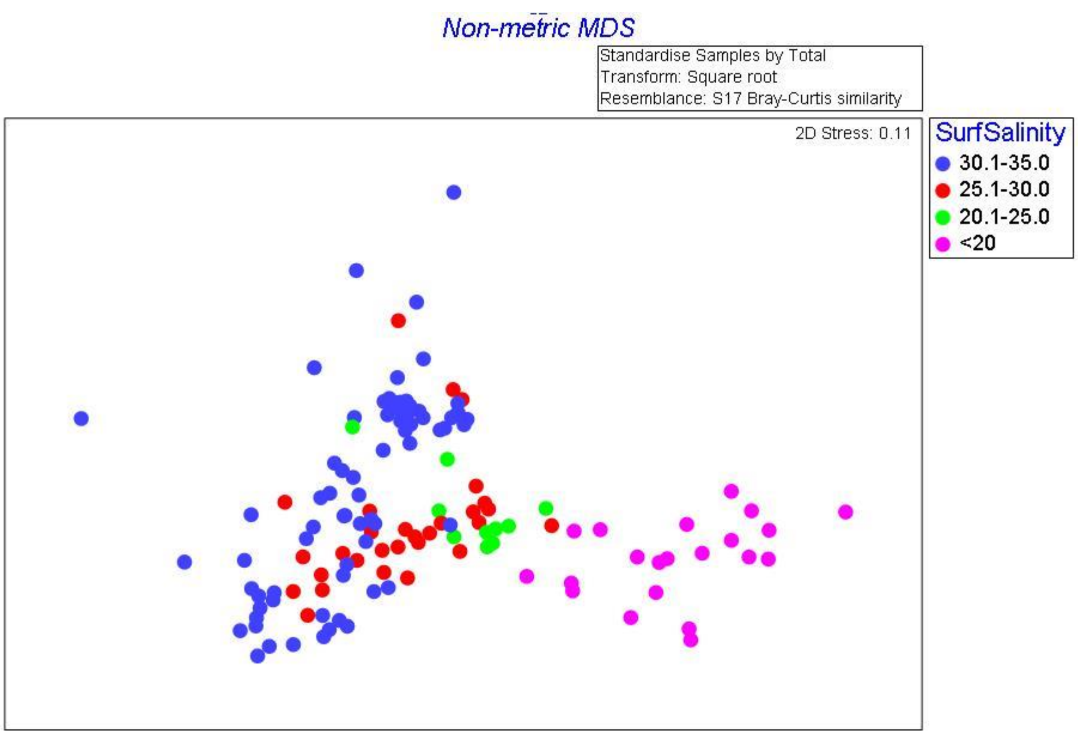


**Figure 6.3. nMDS plot representing community composition of plankton samples in San Francisco Bay, coded by salinity, based on data rarefied to 10,000 reads per sample.**

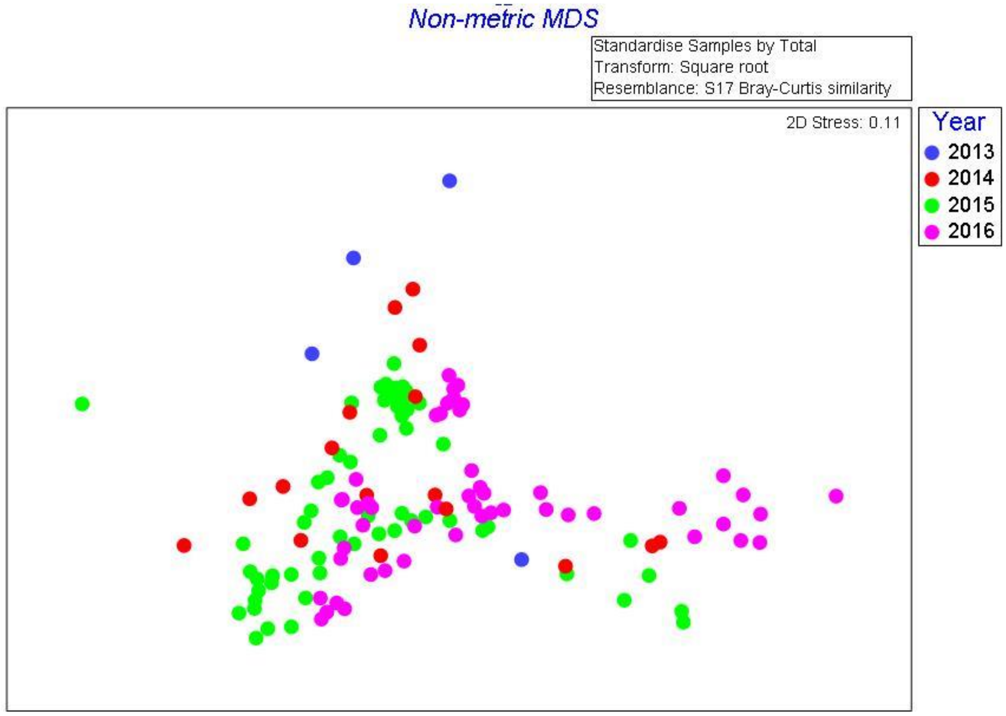


**Figure 6.4. nMDS from Phases I and II from San Francisco Bay, rarefied to 10,000 reads and coded by year.**

Plankton samples were differentiated by depth and method of collection (Figures 6.5 and 6.6). These were in part similar ways to bin data, as the pump method was used only at the surface, while vertical tows were used for both 5-meter and 10-meter depths. No obvious differences are seen in the 5- and 10-meter samples. The nature of the vertical tow will include 5-meter water in the 10-meter sample. This may contribute to the similarity of the 5- and 10-meter samples.

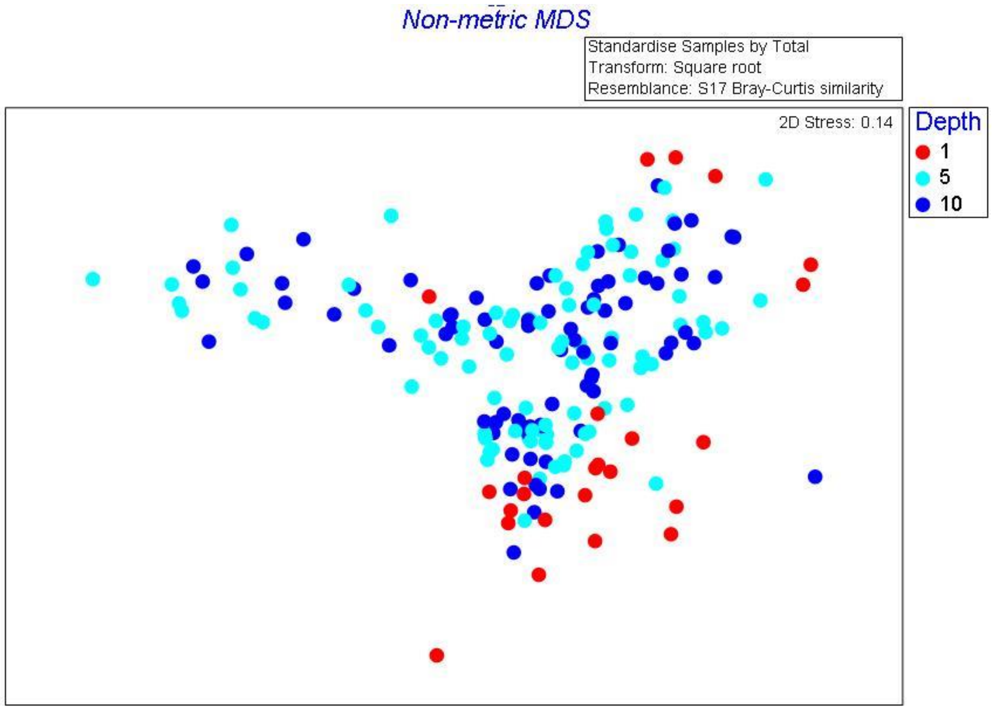


**Figure 6.5. nMDS from Phases I and II from San Francisco Bay, rarefied to 10,000 reads and coded by depth.**

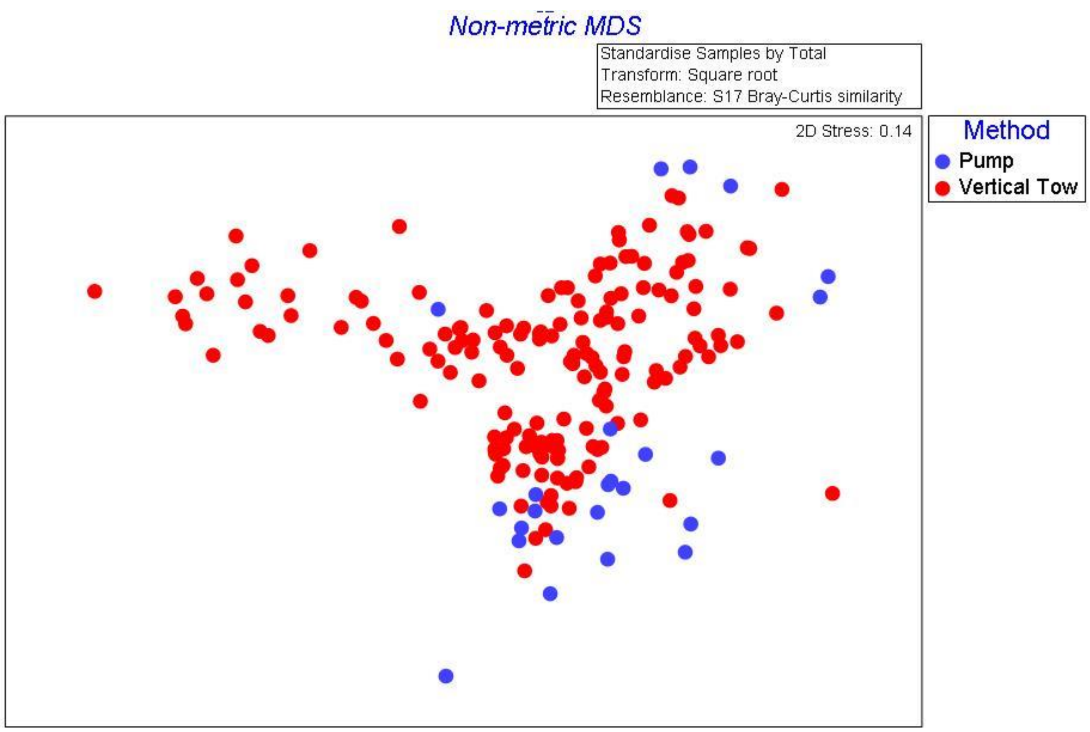


**Figure 6.6 nMDS from Phases I and II from San Francisco Bay, rarefied to 1,000 reads and coded by sample method.**

***NIS in plankton Samples***

We found 69 out of 252 marine invertebrate species from the SERC NIS list (Appendix 6.1), and two algal species (Table 6.11) (algae were not a focus, but were inevitably captured in plankton nets), using the top BLAST hit exceeding 95% similarity in reference databases. Some OTU may have had matches >95% to reference sequences from more than one taxon due to misidentification within Genbank, or lack of differentiation of COI within a group of closely related species. Therefore, it is possible that the single top hit may not be the correct identity of an OTU, leading to false positives and negatives in Table 6.11. Distribution of read counts of NIS among bays was highly uneven. Three species were detected in all 13-sampling site-dates: the barnacle *Amphibalanus amphitrite*, the copepod *Pseudodiaptomus marinus*, and the mussel *Musculista senhousia* (Figure 6.7). While every bay, as expected, contained NIS, a small minority of individual samples lacked NIS altogether (Table 6.12). Surprisingly absent from Table 6.11 is the mussel *Mytilus galloprovincialis*. It is possible that ZOTU of the *Mytilus galloprovincialis* were combined into the *M. trossulus* or *M. edulis* OTU by the 95% similarity criterion, and these species do not appear in the SERC NIS list as the former is native and the latter is unknown in California

**TABLE 6.11. NIS from SERC list (Appendix 6-1) found in 94.5% BLAST table.**

| OTU Name | BinomialName | Phylum | Class | San Francisco 2013 | Morro 2013 | Missio n 2013 | San Diego 2013 | Bodega Tomales 2014 | San Francisc o 2014 | Humbold t 2015 | San Francisco 2015 | Port Hueneme 2015 | Marina Del Rey 2015 | San Pedro 2015 | Newport 2015 | San Francisc o 2016 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| OTU_BZS05_135 | *Alitta succinea* | Annelida | Polychaeta | 9 | 0 | 0 | 0 | 0 | 1175 | 0 | 924 | 0 | 0 | 0 | 504 | 4798 |
| OTU_BZS05_230 | *Epigamia noroi* | Annelida | Polychaeta | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 38 | 0 | 0 | 0 | 0 |
| OTU_BZS06_400 | *Ficopomatus enigmaticu* | Annelida | Polychaeta | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 19 | 0 | 0 |
| OTU_BZS08_220 | *Marenzelleria neglecta* | Annelida | Polychaeta | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 22 |
| OTU_BZS09_529 | *Streblospio benedicti* | Annelida | Polychaeta | 16 | 3 | 0 | 0 | 1 | 16 | 18 | 4 | 4 | 14 | 0 | 0 | 17 |
| OTU_Phase1_14 | *Myrianida pachycera* | Annelida | Polychaeta | 0 | 0 | 67 | 1 | 0 | 0 | 6 | 0 | 0 | 23 | 44 | 7 | 0 |
| OTU_Phase1_53 | *Polydora cornuta* | Annelida | Polychaeta | 899 | 0 | 6 | 183 | 0 | 7001 | 20 | 19474 | 30 | 373 | 839 | 314 | 41907 |
| OTU_Phase1_71 | *Megasyllis nipponica* | Annelida | Polychaeta | 239 | 0 | 68 | 84 | 18 | 146 | 0 | 50 | 7 | 0 | 18 | 0 | 44 |
| OTU_Phase1_91 | *Myrianida pentadentata* | Annelida | Polychaeta | 1 | 0 | 1 | 126 | 0 | 1519 | 0 | 89 | 0 | 0 | 7 | 0 | 11 |
| OTU_Phase1_15 | *Amphibalanus amphitrit* | Arthropod | Hexanauplia | 106 | 3 | 8120 | 9676 | 2 | 16 | 2173 | 295 | 2642 | 19343 | 58618 | 168 | 639 |
| OTU_Phase1_23 | *Amphibalanus amphitrit* | Arthropod | Hexanauplia | 0 | 0 | 39 | 9 | 0 | 0 | 1 | 0 | 0 | 106 | 186 | 16 | 0 |
| OTU_Phase1_93 | *Amphibalanus improvisu* | Arthropod | Hexanauplia | 2932 | 1 | 1 | 0 | 0 | 75906 | 6 | 72661 | 172 | 11 | 40 | 0 | 42319 |
| OTU_BZS05_253 | *Rhithropanopeus harrisii* | Arthropod | Malacostraca | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 36 | 0 | 0 | 0 | 0 | 40 |
| OTU_BZS06_182 | *Ampelisca abdita* | Arthropod | Malacostraca | 2 | 0 | 0 | 0 | 0 | 13 | 0 | 135 | 0 | 0 | 0 | 0 | 3330 |
| OTU_BZS08_153 | *Grandidierella japonica* | Arthropod | Malacostraca | 0 | 26 | 0 | 0 | 2 | 13 | 2 | 16 | 3 | 11 | 0 | 2 | 26 |
| OTU_BZS08_209 | *Ampithoe valida* | Arthropod | Malacostraca | 0 | 0 | 0 | 0 | 0 | 32 | 0 | 0 | 0 | 0 | 0 | 0 | 1474 |
| OTU_BZS08_703 | *Carcinus maenas* | Arthropod | Malacostraca | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 155 |
| OTU_Phase1_11 | *Paradexamine sp* | Arthropod | Malacostraca | 0 | 0 | 2142 | 1144 | 0 | 0 | 0 | 1 | 1196 | 0 | 0 | 1064 | 0 |
| OTU_Phase1_11 | *Caprella simia* | Arthropod | Malacostraca | 74 | 38 | 201 | 38 | 1 | 0 | 0 | 0 | 148 | 0 | 130 | 0 | 15 |
| OTU_Phase1_18 | *Caprella mutica* | Arthropod | Malacostraca | 92 | 21 | 128 | 979 | 20 | 0 | 0 | 0 | 0 | 0 | 7 | 1 | 0 |
| OTU_Phase1_18 | *Orthione griffenis* | Arthropod | Malacostraca | 1 | 143 | 2 | 45 | 60 | 41 | 40 | 26 | 0 | 9 | 0 | 30 | 73 |
| OTU_Phase1_23 | *Palaemon macrodactylu* | Arthropod | Malacostraca | 28 | 0 | 0 | 26 | 0 | 1123 | 0 | 4151 | 1 | 4 | 0 | 0 | 6303 |
| OTU_Phase1_25 | *Monocorophium insidios* | Arthropod | Malacostraca | 20 | 14 | 0 | 1 | 0 | 1 | 18 | 35 | 0 | 6 | 0 | 0 | 0 |
| OTU_Phase1_76 | *Monocorophium acherus* | Arthropod | Malacostraca | 25 | 17 | 62 | 131 | 3 | 0 | 7 | 898 | 0 | 16 | 0 | 1 | 3449 |
| OTU_BZS05_283 | *Acartiella sinensis* | Arthropod | Maxillopoda | 22 | 0 | 0 | 0 | 0 | 5741 | 0 | 1586 | 0 | 0 | 0 | 0 | 42550 |
| OTU_BZS08_206 | *Mytilicola orientalis* | Arthropod | Maxillopoda | 0 | 0 | 0 | 0 | 0 | 6 | 0 | 3 | 0 | 0 | 0 | 0 | 50 |
| OTU_BZS08_249 | *Acartiella sinensis* | Arthropod | Maxillopoda | 0 | 0 | 0 | 0 | 0 | 18 | 0 | 1 | 0 | 0 | 0 | 0 | 406 |
| OTU_Phase1_21 | *Pseudodiaptomus marin* | Arthropod | Maxillopoda | 3656 | 10 | 23539 | 16005 | 16 | 115858 | 2988 | 197958 | 25742 | 93227 | 38493 | 25941 | 530570 |
| OTU_BZS06_225 | *Watersipora arcuata* | Bryozoa | Gymnolaemata | 0 | 0 | 0 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 53 | 0 | 0 |
| OTU_BZS08_601 | *Anguinella palmata* | Bryozoa | Gymnolaemata | 19 | 0 | 0 | 0 | 0 | 3 | 0 | 1 | 0 | 0 | 0 | 0 | 237 |
| OTU_BZS09_490 | *Cryptosula pallasiana* | Bryozoa | Gymnolaemata | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 12 | 0 | 0 |
| OTU_Phase1_13 | *Watersipora sp* | Bryozoa | Gymnolaemata | 3 | 28 | 0 | 0 | 55 | 5 | 9 | 402 | 0 | 1 | 0 | 0 | 0 |
| OTU_Phase1_25 | *Bugula neritina* | Bryozoa | Gymnolaemata | 7 | 2 | 0 | 7 | 0 | 0 | 0 | 0 | 14 | 0 | 2 | 10 | 0 |
| OTU_Phase1_28 | *Watersipora subtorquat* | Bryozoa | Gymnolaemata | 0 | 0 | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 11 | 0 | 0 |
| OTU_Phase1_39 | *Amathia verticillata* | Bryozoa | Gymnolaemata | 0 | 4 | 10112 | 6550 | 3 | 0 | 0 | 0 | 2 | 207 | 66 | 284 | 0 |
| OTU_Phase1_43 | *Watersipora subtorquat* | Bryozoa | Gymnolaemata | 3 | 1 | 394 | 783 | 88 | 0 | 3 | 0 | 59 | 1 | 88 | 9 | 0 |
| OTU_Phase1_58 | *Bugula neritina* | Bryozoa | Gymnolaemata | 112 | 18 | 163 | 128 | 29 | 0 | 3 | 0 | 29 | 2 | 79 | 6 | 0 |
| OTU_Phase1_60 | *Watersipora subovoidea* | Bryozoa | Gymnolaemata | 0 | 0 | 118 | 189 | 0 | 0 | 0 | 0 | 0 | 6 | 232 | 32 | 0 |
| OTU_BZS05_101 | *Tridentiger barbatus* | Chordata | Actinopterygii | 0 | 0 | 0 | 0 | 0 | 5192 | 0 | 7199 | 1 | 0 | 0 | 0 | 14757 |
| OTU_BZS05_111 | *Tridentiger trigonocepha* | Chordata | Actinopterygii | 0 | 0 | 0 | 23 | 0 | 586 | 0 | 474 | 0 | 0 | 13 | 0 | 2083 |
| OTU_Phase1_12 | *Molgula manhattensis* | Chordata | Ascidiacea | 82 | 0 | 0 | 0 | 0 | 12 | 0 | 11 | 0 | 0 | 0 | 0 | 17 |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| OTU_Phase1_134 | *Microcosmus squamiger* | Chordata | Ascidiacea | 0 | 0 | 68 | 60 | 0 | 0 | 1 | 1 | 17 | 23 | 1261 | 708 | 0 |
| OTU_Phase1_165 | *Corella inflata* | Chordata | Ascidiacea | 44 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| OTU_Phase1_166 | *Didemnum vexillum* | Chordata | Ascidiacea | 83 | 1 | 0 | 0 | 25 | 5 | 31 | 176 | 180 | 0 | 0 | 0 | 1 |
| OTU_Phase1_286 | *Botrylloides violaceus* | Chordata | Ascidiacea | 57 | 1 | 97 | 432 | 186 | 1 | 133 | 17 | 65 | 3 | 7 | 0 | 7 |
| OTU_Phase1_314 | *Ascidia zara* | Chordata | Ascidiacea | 1094 | 0 | 126 | 717 | 0 | 18 | 56 | 71 | 104 | 661 | 309 | 1198 | 377 |
| OTU_Phase1_403 | *Styela plicata* | Chordata | Ascidiacea | 0 | 0 | 47 | 978 | 0 | 1 | 11 | 0 | 41 | 729 | 4868 | 300 | 0 |
| OTU_Phase1_418 | *Botryllus schlosseri* | Chordata | Ascidiacea | 16 | 1 | 557 | 226 | 9 | 0 | 11 | 0 | 37 | 16 | 83 | 146 | 0 |
| OTU_Phase1_589 | *Ciona savignyi* | Chordata | Ascidiacea | 83 | 0 | 12 | 664 | 0 | 2 | 3 | 11 | 5722 | 54 | 3518 | 42 | 17 |
| OTU_Phase1_642 | *Diplosoma listerianum* | Chordata | Ascidiacea | 53 | 1 | 17 | 0 | 109 | 0 | 0 | 0 | 7 | 5 | 4 | 1 | 4 |
| OTU_Phase1_74 | *Polyandrocarpa zorritens* | Chordata | Ascidiacea | 1 | 1 | 948 | 5066 | 0 | 0 | 392 | 0 | 96 | 474 | 215 | 188 | 5 |
| OTU_Phase1_128 | *Diadumene sp* | Cnidaria | Anthozoa | 0 | 0 | 13 | 122 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| OTU_Phase1_47 | *Diadumene leucolena* | Cnidaria | Anthozoa | 0 | 1 | 3957 | 5 | 1 | 213 | 0 | 226 | 0 | 0 | 0 | 0 | 12990 |
| OTU_BZS04_1992 | *Ectopleura crocea* | Cnidaria | Hydrozoa | 0 | 2 | 0 | 0 | 0 | 7 | 16 | 1541 | 39 | 0 | 3 | 15 | 118 |
| OTU_BZS05_3365 | *Blackfordia virginica* | Cnidaria | Hydrozoa | 7 | 0 | 0 | 0 | 0 | 215 | 0 | 169 | 0 | 0 | 0 | 0 | 1064 |
| OTU_Phase1_275 | *Barentsia benedeni* | Entoprocta | | 22 | 0 | 0 | 0 | 0 | 2 | 0 | 9 | 0 | 0 | 0 | 0 | 0 |
| OTU_BZS05_496 | *Corbula amurensis* | Mollusca | Bivalvia | 9 | 0 | 0 | 0 | 0 | 581 | 0 | 24488 | 1 | 0 | 1 | 4 | 8051 |
| OTU_BZS06_4727 | *Macoma petalum* | Mollusca | Bivalvia | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 38 | 0 | 0 | 0 | 0 | 54 |
| OTU_Phase1_184 | *Crassostrea gigas* | Mollusca | Bivalvia | 0 | 1 | 11 | 54 | 1 | 0 | 4 | 0 | 16 | 55 | 129 | 130 | 0 |
| OTU_Phase1_230 | *Geukensia demissa* | Mollusca | Bivalvia | 163 | 0 | 0 | 0 | 0 | 0 | 0 | 18 | 3 | 0 | 23 | 2021 | 13 |
| OTU_Phase1_267 | *Mya arenaria* | Mollusca | Bivalvia | 5 | 0 | 0 | 0 | 15 | 0 | 45 | 19 | 14 | 37 | 0 | 0 | 0 |
| OTU_Phase1_293 | *Musculista senhousia* | Mollusca | Bivalvia | 1 | 1 | 635 | 76 | 0 | 9 | 0 | 3 | 0 | 0 | 0 | 666 | 3 |
| OTU_Phase1_73 | *Musculista senhousia* | Mollusca | Bivalvia | 30 | 1 | 5172 | 649 | 132 | 9 | 4 | 320 | 25 | 2 | 42 | 1478 | 105 |
| OTU_BZS05_1062 | *Sakuraeolis enosimensis* | Mollusca | Gastropoda | 0 | 0 | 0 | 0 | 0 | 87 | 0 | 846 | 0 | 0 | 0 | 0 | 258 |
| OTU_BZS05_179 | *Spurwinkia salsa* | Mollusca | Gastropoda | 1 | 0 | 0 | 0 | 0 | 4300 | 0 | 7880 | 0 | 0 | 0 | 0 | 2642 |
| OTU_Phase1_184 | *Crepidula plana* | Mollusca | Gastropoda | 47 | 0 | 0 | 0 | 0 | 7926 | 0 | 52211 | 0 | 4 | 1 | 1 | 3478 |
| OTU_Phase1_672 | *Haminoea japonica* | Mollusca | Gastropoda | 191 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| OTU_BZS06_1195 | *Grateloupia turuturu* | Rhodophyt | Florideophycea | 0 | 0 | 12 | 4 | 0 | 0 | 1 | 0 | 6 | 0 | 173 | 0 | 0 |
| OTU_BZS08_2481 | *Acrochaetium secundatu* | Rhodophyt | Florideophycea | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 21 |
| OTU_Phase1_206 | *Schizymenia dubyi* | Rhodophyt | Florideophycea | 0 | 0 | 2 | 46 | 0 | 0 | 0 | 0 | 3 | 0 | 3 | 0 | 0 |
| OTU_Phase1_353 | *Lomentaria hakodatensi* | Rhodophyt | Florideophycea | 28 | 0 | 7 | 349 | 0 | 0 | 0 | 1 | 26 | 0 | 76 | 0 | 0 |
| Total read number | | | | 10288 | 340 | 56861 | 45591 | 776 | 227802 | 6004 | 394475 | 36490 | 115423 | 109673 | 35287 | 724500 |

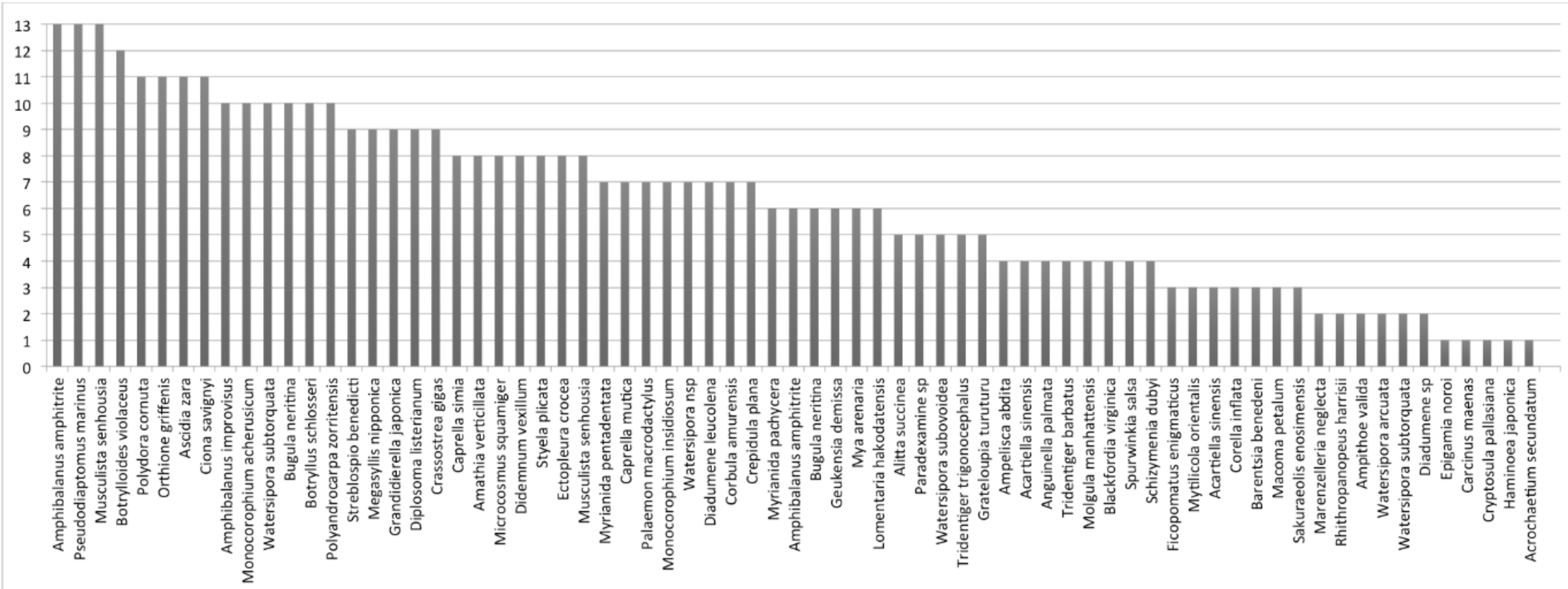


**Figure 6.7. Distribution of NIS detected in metagenetic analysis among site-dates in ten California bays.** San Francisco Bay was sampled in three years.

**Table 6.12. CalNIS Phase 1 and 2 plankton samples that contained no NIS on the SERC list (Appendix 6.1).**

| Sample ID | Bay | Site | Year | Method | Depth (m) |
|---|---|---|---|---|---|
| BZS000575 | San Francisco | SF-P12 | 2013 | Pump | 1 |
| BZS000581 | San Francisco | SF-P15 | 2013 | Pump | 1 |
| BZS000582 | San Francisco | SF-P15 | 2013 | Pump | 1 |
| BZS000601 | Morro | MO-P02 | 2013 | Pump | 1 |
| BZS000619 | Morro | MO-T03 | 2013 | Vertical Tow | 5 |
| BZS000633 | Morro | MO-P08 | 2013 | Pump | 1 |
| BZS000654 | Morro | MO-T09 | 2013 | Vertical Tow | 5 |
| BZS000663 | Morro | MO-T04 | 2013 | Vertical Tow | 5 |
| BZS000672 | San Diego | SD-P01 | 2013 | Pump | 1 |
| BZS001357 | Bodega-Tomales | BT-T05 | 2014 | Vertical Tow | 5 |
| BZS001359 | Bodega-Tomales | BT-T01 | 2014 | Vertical Tow | 5 |
| BZS001361 | Bodega-Tomales | BT-T02 | 2014 | Vertical Tow | 5 |
| BZS001377 | Bodega-Tomales | BT-T10 | 2014 | Vertical Tow | 5 |
| BZS001417 | Humboldt | HB-P03 | 2015 | Pump | 1 |
| BZS001426 | Humboldt | HB-P05 | 2015 | Pump | 1 |
| BZS001427 | Humboldt | HB-P05 | 2015 | Pump | 1 |
| BZS001445 | Humboldt | HB-P09 | 2015 | Pump | 1 |
| BZS001658 | San Francisco | SFHS-31 | 2015 | Vertical Tow | 5 |
| BZS001754 | Marina Del Rey | MDR-P04 | 2015 | Pump | 1 |
| BZS001757.1 | Marina Del Rey | MDR-P05 | 2015 | Pump | 1 |
| BZS001759.2 | Marina Del Rey | MDR-P05 | 2015 | Pump | 1 |
| BZS001764.3 | Marina Del Rey | MDR-P06 | 2015 | Pump | 1 |
| BZS001764.4 | Marina Del Rey | MDR-P06 | 2015 | Pump | 1 |
| BZS001772.3 | Marina Del Rey | MDR-P08 | 2015 | Pump | 1 |
| BZS001777.1 | Marina Del Rey | MDR-P09 | 2015 | Pump | 1 |
| BZS001791 | Marina Del Rey | MDR-T03 | 2015 | Vertical Tow | 5 |
| BZS001795 | Marina Del Rey | MDR-T05 | 2015 | Vertical Tow | 5 |
| BZS001848rD | San Pedro | SP-P09 | 2015 | Pump | 1 |
| BZS001943 | Newport | NP-P05 | 2015 | Pump | 1 |
| BZS002061 | San Francisco | SFHS-05 | 2016 | Vertical Tow | 10 |

***Differences in NIS composition among Bays.***

We observed significant differences in NIS composition and abundance among samples (Table 6.13 and 6.14; Figures 6.8 and 6.9). When year of sampling was also a significant factor for differences among plankton samples (Table 6.14), however, year is confounded by site, since only San Francisco Bay was sampled in multiple years (Figure 6.10). San Francisco Bay was sharply different in 2015 and 2016.

**Table 6.13. PERMANOVA testing differences in NIS composition and abundance among all plankton samples across years with reads per sample rarified to 1,000.**

| Factor | df | SS | MS | Pseudo-F | P(perm) |
|---|---|---|---|---|---|
| Plankton sample | 10 | 189870 | 18987 | 19.739 | 0.001 |
| Residues | 216 | 207780 | 961.94 | | |
| Total | 226 | 397650 | | | |

**Table 6.14. PERMANOVA testing differences in NIS composition and abundance among all plankton samples across years with reads per sample rarified to 10,000.**

| Factor | df | SS | MS | Pseudo-F | P(perm) |
|---|---|---|---|---|---|
| Plankton Sample | 4 | 23765 | 5941.3 | 7.2837 | 0.001 |
| Residues | 45 | 36706 | 815.7 | | |
| Total | 49 | 60471 | | | |

**Table 6.15. PERMANOVA testing differences in NIS composition and abundance among plankton samples and years with reads per sample rarified to 1,000.** Only San Francisco Bay was sampled in multiple years therefore the interaction of Bay and Year was not included.

| Factor | df | SS | MS | Pseudo-F | P(perm) |
|---|---|---|---|---|---|
| Bay | 7 | 102980 | 14711 | 15.293 | 0.001 |
| Year | 3 | 21400 | 7133.4 | 7.4157 | 0.001 |
| Residues | 216 | 207780 | 961.94 | | |
| Total | 226 | 397650 | | | |

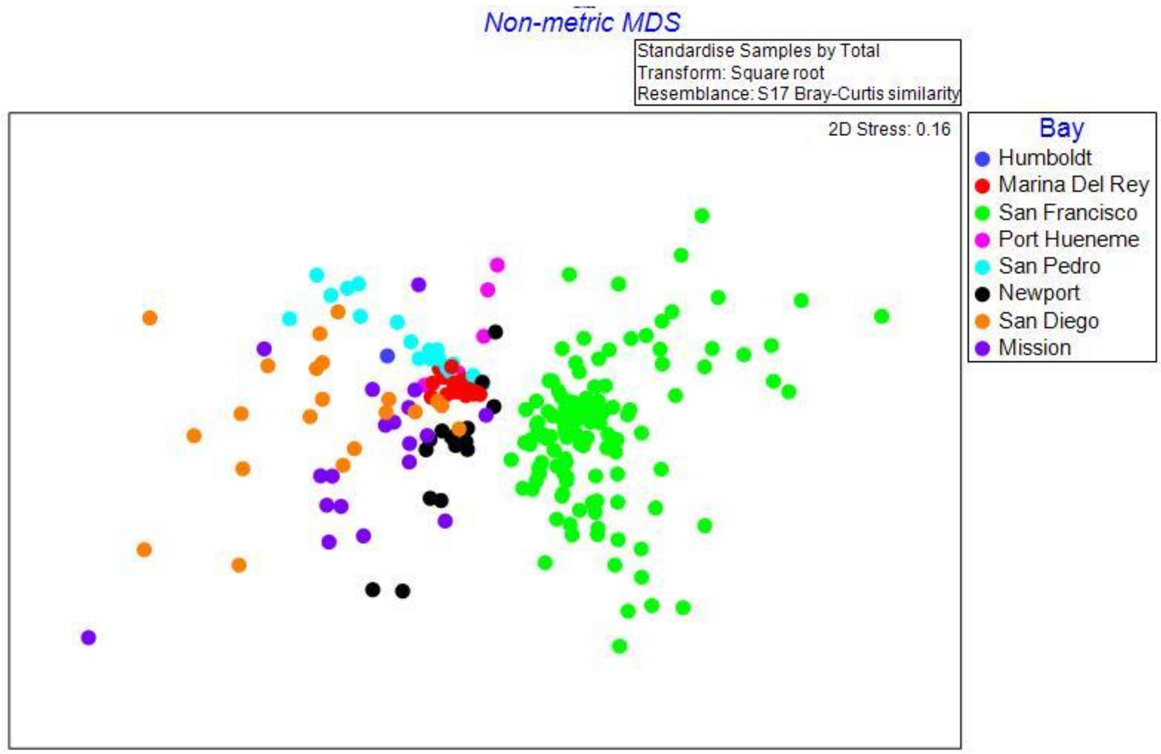


**Figure 6.8**. **nMDS of NIS assemblages in California bays using 1000 rarefied reads**.

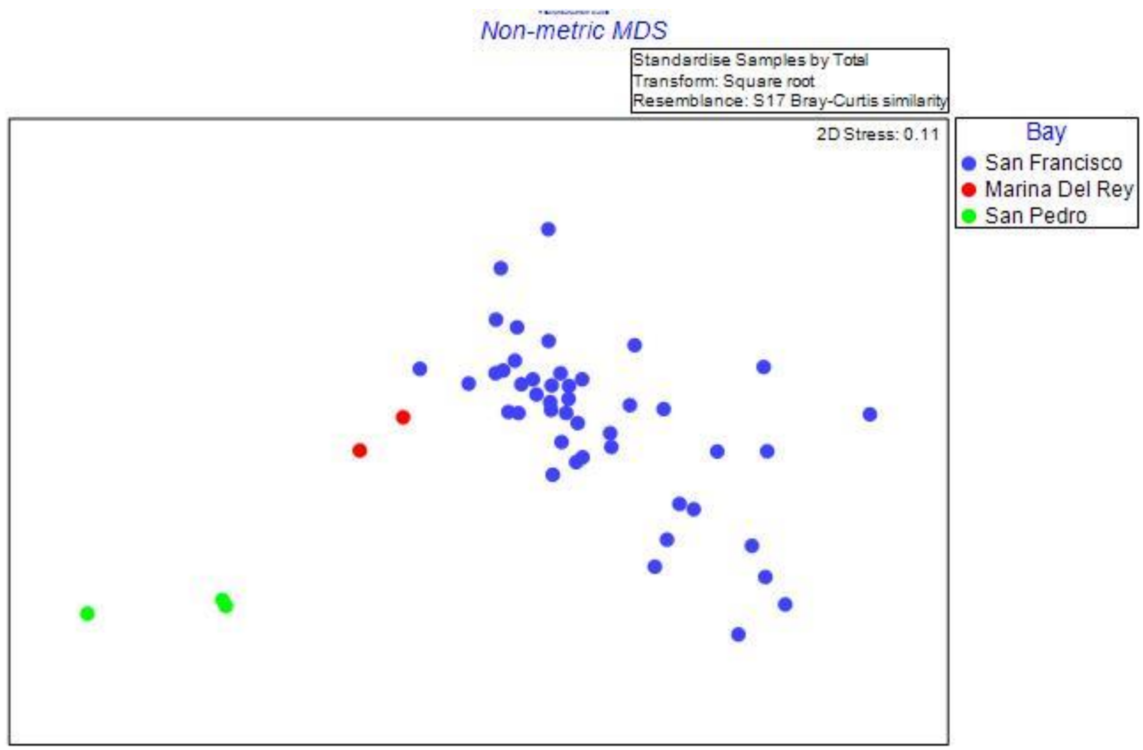


**Figure 6.9. nMDS of NIS assemblages in California bays using 10,000 rarefied reads.** Fewer bays are represented than in Figure 6.8 due to insufficient number of reads outside of the three bays shown.

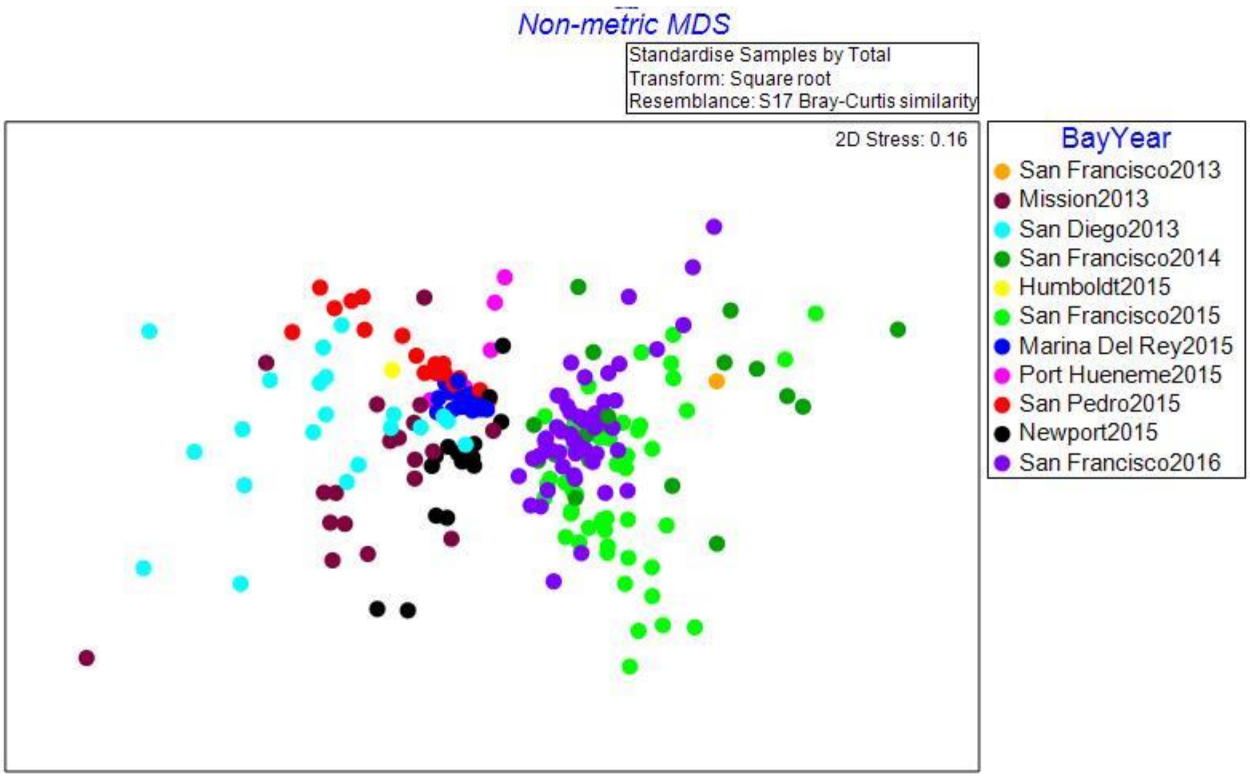


**Figure 6.10. nMDS of NIS assemblages in California bays separated by year and using 1,000 rarefied reads.** Only San Francisco Bay was repeatedly sampled and shows variation by years (c.f., 2015 v. 2016).

***Role of environmental factors for NIS composition and abundance.***

Salinity had a strong impact on NIS plankton communities (Table 6.16) and had significant interactions with year and surface temperature (Figures 6.11 and 6.12). Rainfall increased significantly in 2016, which probably explains the interaction with year. Loss of samples due to rarefaction to 10,000 reads per sample reduced statistical power but the same pattern was evident (Table 6.17).

**Table 6.16. PERMANOVA including environmental factors for composition of non-indigenous invertebrate species (NIS) in all bays across years after rarefaction to 1000 reads per sample.**

| Factor | df | SS | MS | Pseudo-F | P(perm) |
|---|---|---|---|---|---|
| BayYear | 7 | 68790 | 9827.1 | 15.894 | 0.001 |
| Surface Temperature | 2 | 1493.8 | 746.91 | 1.208 | 0.271 |
| Surface Salinity | 1 | 2161.9 | 2161.9 | 3.4967 | 0.003 |
| BayYear x Surface Temperature* | 8 | 12258 | 1532.2 | 2.4782 | 0.001 |
| BayYear x Surface Salinity* | 4 | 7042.2 | 1760.5 | 2.8475 | 0.001 |
| Surface Temperature x Surface Salinity* | 2 | 1230 | 615.02 | 0.99471 | 0.444 |
| BayYear x Surface Temperature x Surface Salinity** | 2 | 2122.2 | 1061.1 | 1.7162 | 0.069 |
| Residues | 188 | 116240 | 618.29 | | |
| Total | 226 | 397650 | | | |

*indicates uneven sample sizes

**Table 6.17. PERMANOVA including environmental factors for composition of non-indigenous invertebrate species (NIS) in all bays across years after rarefaction to 10,000 reads per sample.**

| Factor | df | SS | MS | Pseudo-F | P(perm) |
|---|---|---|---|---|---|
| BayYear | 2 | 8021.8 | 4010.9 | 9.4445 | 0.001 |
| Surface Temperature | 2 | 936.6 | 468.3 | 1.1027 | 0.333 |
| Surface Salinity | 1 | 877.37 | 877.37 | 2.0659 | 0.086 |
| BayYear x Surface Salinity* | 4 | 3487.3 | 871.83 | 2.0529 | 0.008 |
| Surface Temperature x Surface Salinity* | 1 | 339.75 | 339.75 | 0.8 | 0.499 |
| Residues | 32 | 13590 | 424.68 | | |
| Total | 49 | 60471 | | | |

*indicates uneven sample sizes

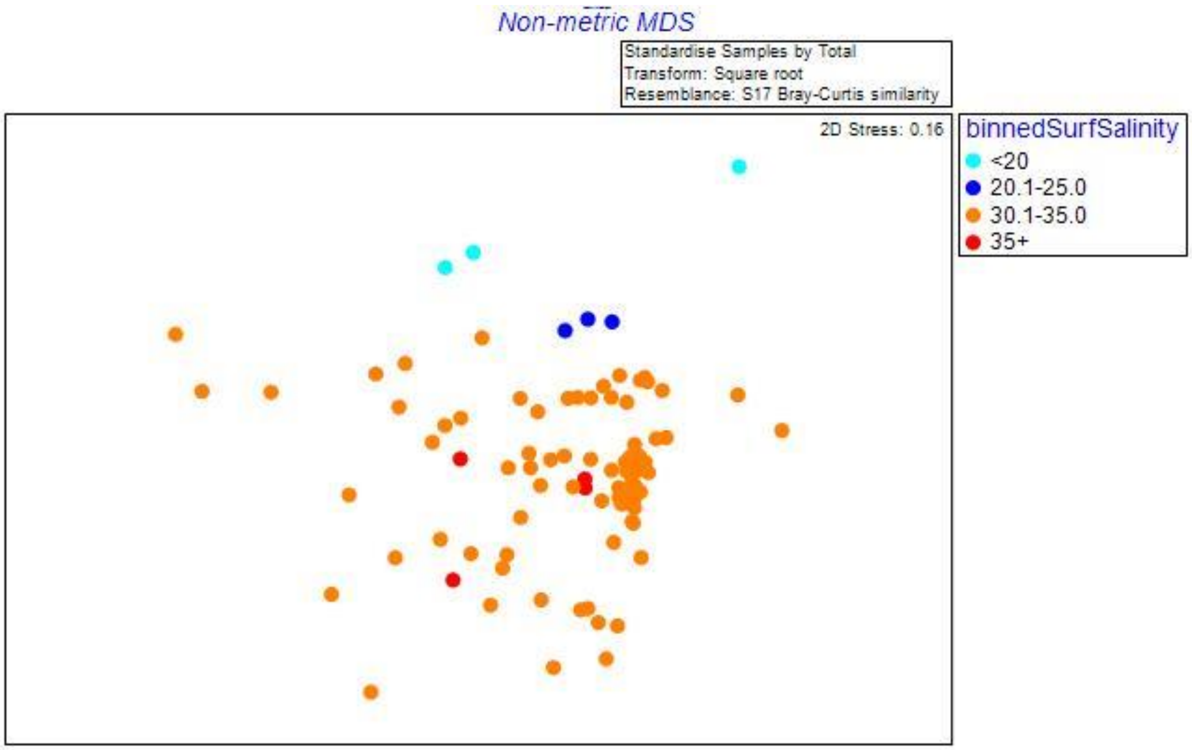


**Figure 6.11. nMDS of NIS assemblages in California bays binned into surface salinity groups, using 1000 rarefied reads**.

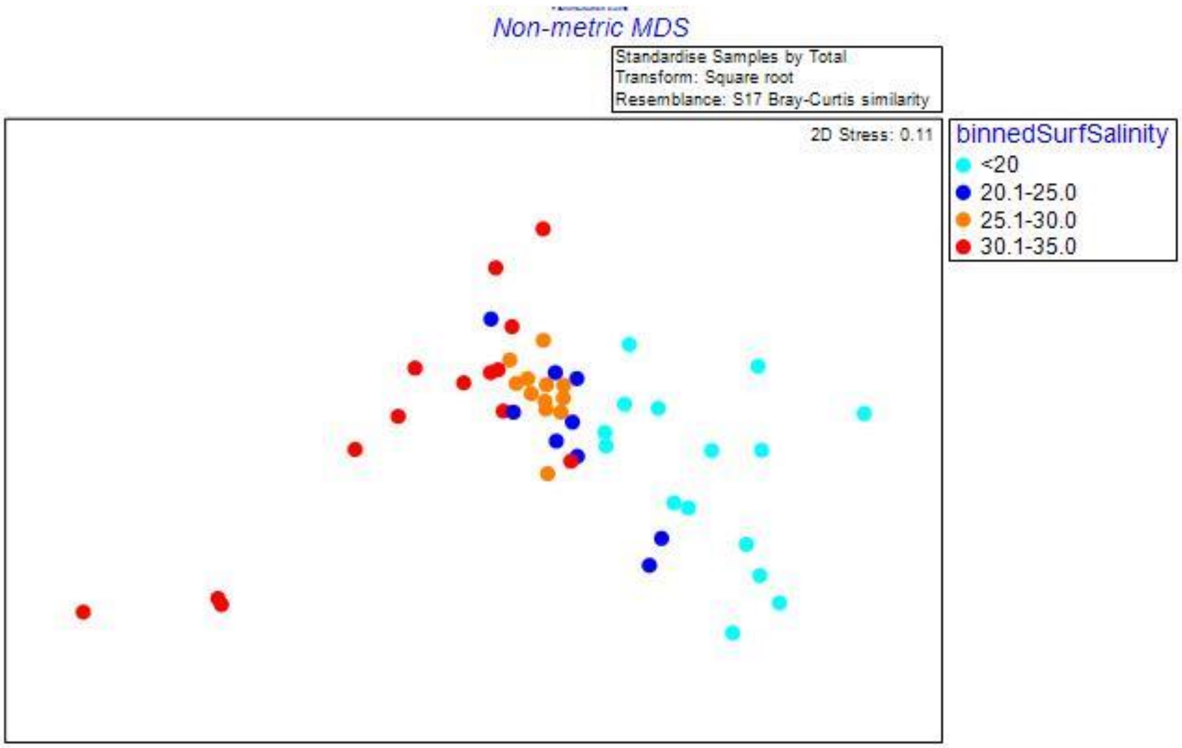


**Figure 6.12. nMDS of NIS assemblages in California bays binned into surface salinity groups, using 10,000 rarefied reads**

***Differences in NIS composition within San Francisco Bay.***

Data restricted to San Francisco Bay allows a better focus on sources of variation in NIS plankton composition and abundance (Figures 6.13 to 6.16). As for all sites, NIS varied across years in San Francisco Bay and interacted significantly with surface salinity (Table 6.18 and 6.19).

Temperature was marginally not significant as a driver of NIS assemblages at the 1000 read rarefaction level, and too few samples had enough reads to test that effect more robustly at the 10,000 read level.

**Table 6.18. PERMANOVA results of community composition of non-indigenous invertebrate species (NIS) for San Francisco samples when reads were rarified to 1000.**

| Factor | df | SS | MS | Pseudo-F | P(perm) |
|---|---|---|---|---|---|
| Year | 1 | 3129.7 | 3129.7 | 5.3883 | 0.001 |
| Surface Temperature | 1 | 1041.1 | 1041.1 | 1.7924 | 0.123 |
| Surface Salinity | 1 | 2001 | 2001 | 3.445 | 0.006 |
| Year x Surface Temperature * | 3 | 2822.1 | 940.69 | 1.6196 | 0.055 |
| Year x Surface Salinity * | 4 | 7042.2 | 1760.5 | 3.0311 | 0.001 |
| Surface Temperature x Surface Salinity* | 1 | 269.24 | 269.24 | 0.46354 | 0.832 |
| Year x Surface Temperature x Surface Salinity* | 2 | 2122.2 | 1061.1 | 1.8269 | 0.058 |
| Residues | 101 | 58664 | 580.83 | | |
| Total | 121 | 146430 | | | |

*indicates that sample size was not equal across factors.

**Table 6.19. PERMANOVA results of community composition of non-indigenous invertebrate species (NIS) for San Francisco samples when reads were rarified to 10,000.** Insufficient data were available to test the interaction of Year and Surface Temperature.

| Factor | df | SS | MS | Pseudo-F | P(perm) |
|---|---|---|---|---|---|
| Year | 1 | 2454.5 | 2454.5 | 5.5878 | 0.001 |
| Surface Temperature | 1 | 755.69 | 755.69 | 1.7204 | 0.146 |
| Surface Salinity | 1 | 877.37 | 877.37 | 1.9974 | 0.091 |
| Year x Surface Salinity * | 4 | 3487.3 | 871.83 | 1.9848 | 0.02 |
| Surface Temperature x Surface Salinity* | 1 | 339.75 | 339.75 | 0.77345 | 0.512 |
| Residues | 30 | 13178 | 439.26 | | |
| Total | 44 | 41611 | | | |

*indicates that sample size was not equal across factors.

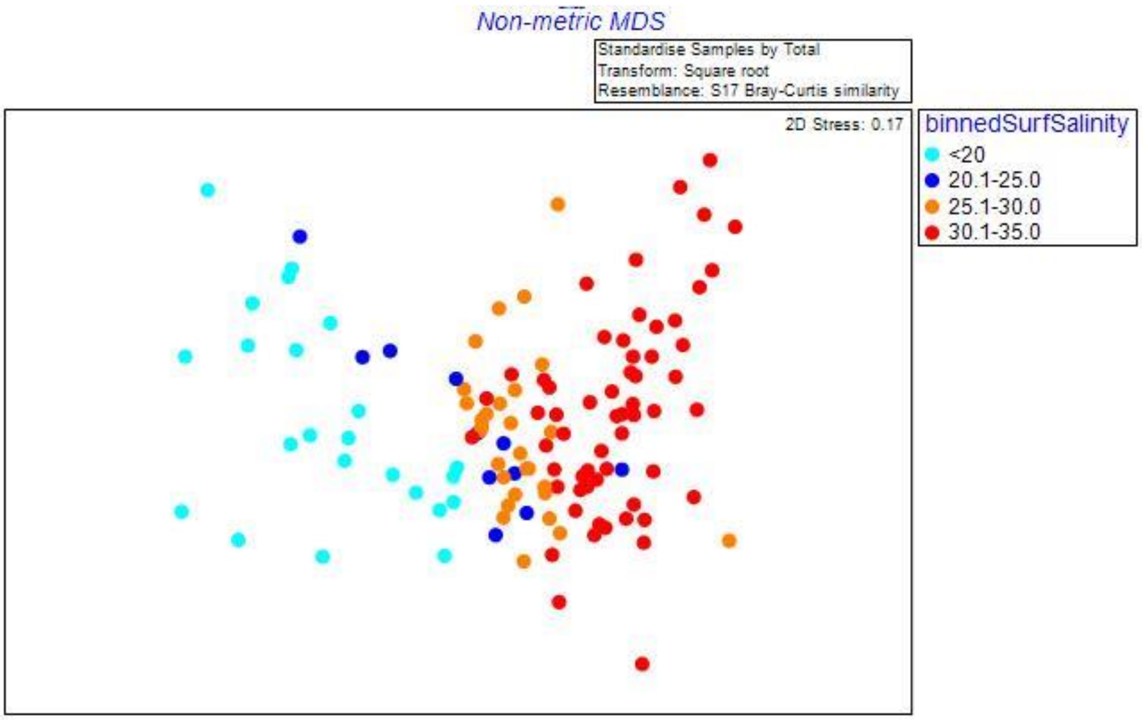


**Figure 6.13 nMDS of NIS assemblages in San Francisco bay binned into surface salinity groups, using 1000 rarefied reads per sample.**

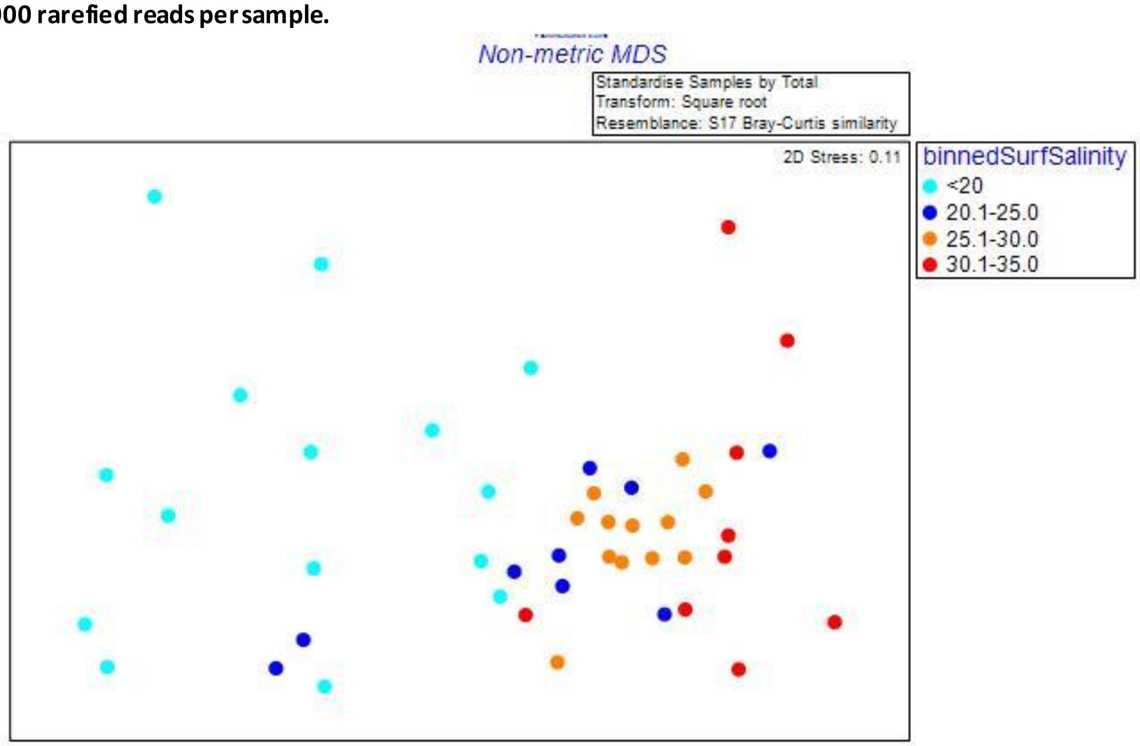


**Figure 6.14 nMDS of NIS assemblages in San Francisco bay binned into surface salinity groups, using 10,000 rarefied reads per sample.**

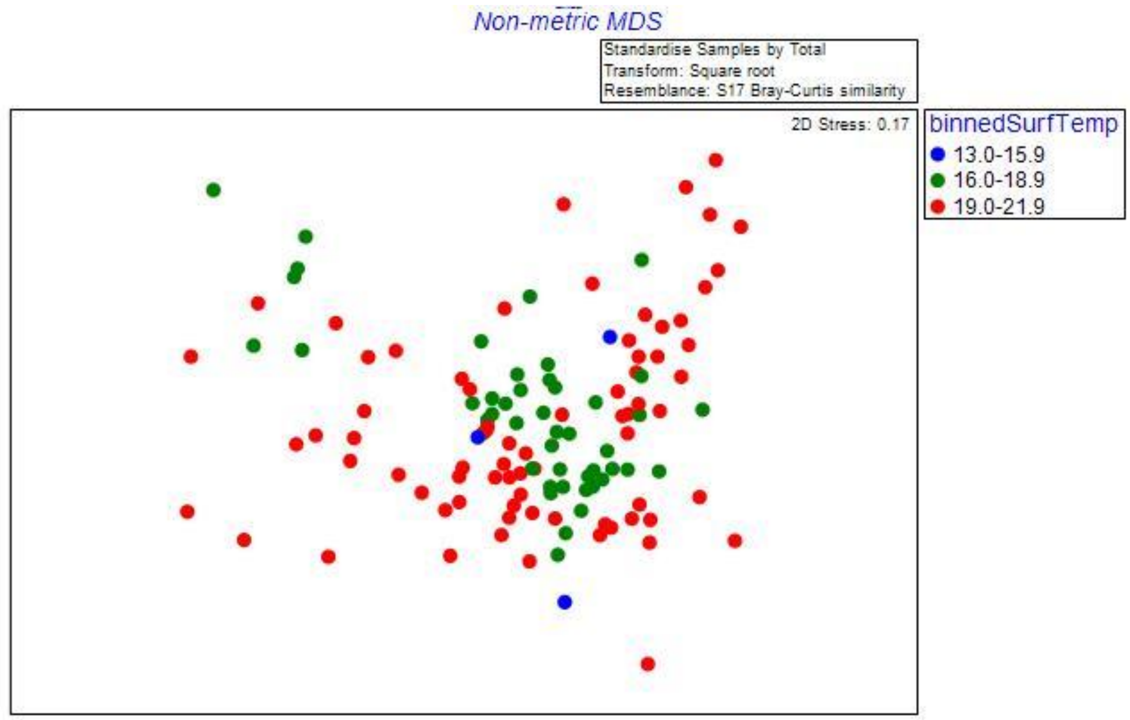


**Figure 6.15 nMDS of NIS assemblages in San Francisco bay binned into temperature groups, using 1000 rarefied reads per sample.**

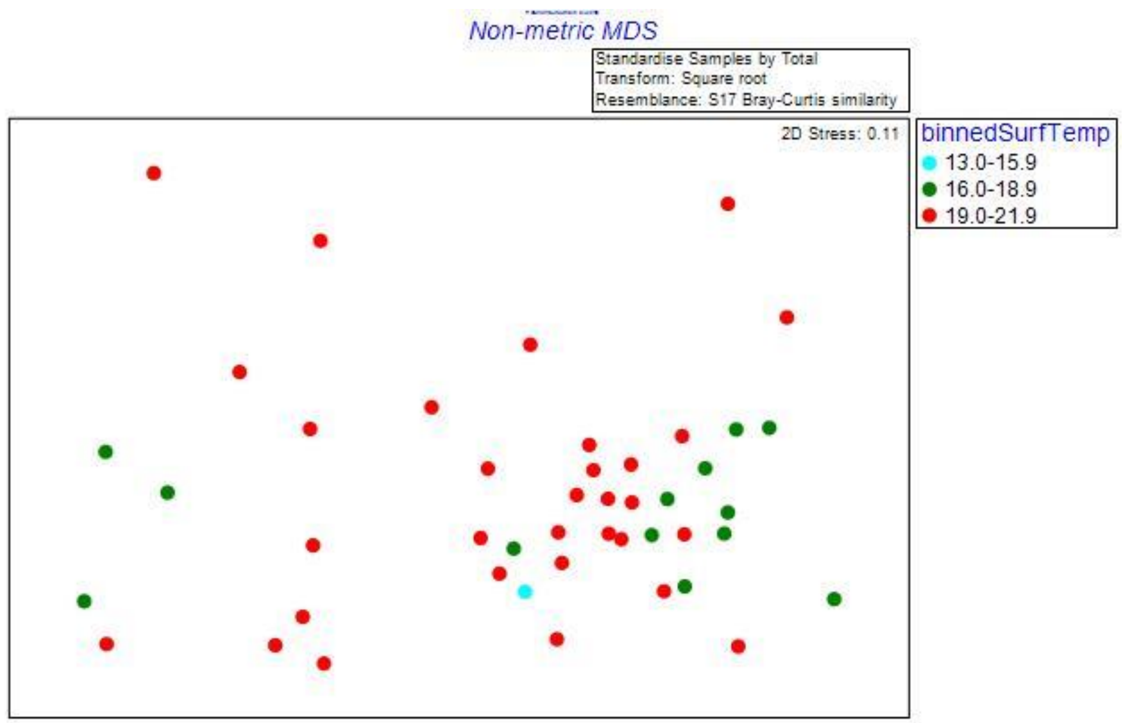


**Figure 6.16. nMDS of NIS assemblages in San Francisco bay binned into temperature groups, using 10,000 rarefied reads per sample.**

***Additional NIS that potentially are contained in plankton samples***

Table 6.11 includes all known marine NIS in California, according to Appendix 6.1, that were detected in plankton samples through metagenetic analysis. To find NIS not presently known in California, we reviewed all BLAST hits >94.5% for OTU representative sequences, including hits not top-ranked. We found 666 species by this criterion. Of these, 70 were on the SERC California NIS list, leaving 596 additional species. Most of these species are native. S. Foss (pers. com.) identified 21 species that are potential new NIS based on biogeographical information, after excluding synonyms and freshwater species (Table 6.20). This list undoubtedly contains false positives because each OTU is likely a single species even though its sequence may hit more than one database record. However, this list will contain fewer false negatives than if we used only the single top hit, as lower ranked hits may be the correct species.

**Table 6.20**. **Potential NIS not present in Appendix 6.1.** These species have COI sequences in Genbank that are >94.5% identical to OTU in California plankton samples. This is not considered unequivocal evidence of presence, but these species may be put on a watch list.

| Binomial | Phylum | Class | Taxon | Status* |
|---|---|---|---|---|
| *Acantholobulus bermudensis* | Arthropoda | Malacostraca | Crab | Y |
| *Agalma elegans* | Cnidaria | Hydrozoa | Siphonophora | C |
| *Alderia modesta* | Mollusca | Gastropoda | Saccoglossa | C |
| *Alexandrium fundyense* | Myzozoa | Dinophyceae | Dinoflagellate | Y |
| *Amathia gracilis* | Bryozoa | Gymnolaemata | Bryozoan | Y |
| *Amathia vidovici* | Bryozoa | Gymnolaemata | Bryozoan | Y |
| *Ameritella versicolor* | Mollusca | Bivalvia | Clam | Y |
| *Amphibalanus reticulatus* | Arthropoda | Hexanauplia | Barnacle | Y |
| *Amphipholis squamata* | Echinodermata | Ophiuroidea | Brittle star | C |
| *Ascidia virginea* | Chordata | Ascidiacea | Tunicate | Y |
| *Aurelia labiata* | Cnidaria | Scyphozoa | Jellyfish | C |
| *Botrylloides pizoni* | Chordata | Ascidiacea | Tunicate | Y |
| *Crassostrea virginica* | Mollusca | Bivalvia | Oyster | Y |
| *Halichondria panicea* | Porifera | Demospongiae | Sponge | C |
| *Megabalanus rosa* | Arthropoda | Hexanauplia | Barnacle | Y |
| *Membranipora membranacea* | Bryozoa | Gymnolaemata | Bryozoan | C |
| *Menippe adina* | Arthropoda | Malacostraca | Crab | Y |
| *Menippe mercenaria* | Arthropoda | Malacostraca | Crab | Y |
| *Onchidoris bilamellata* | Mollusca | Gastropoda | Nudibranch | C |
| *Perna viridis* | Mollusca | Bivalvia | Bivalve | Y |
| *Pfiesteria piscicida* | Myzozoa | Dinophyceae | Algae | Y |

*Y=potential novel NIS; C=cosmopolitan or potential cryptic species complex.

**Discussion and Conclusions.**

Over 14,000 COI haplotypes clustered into over 3700 OTU were found in plankton samples drawn from California bays by metagenetic analysis of the barcoding fragment of the mitochondrial COI gene. This is much more diversity than would be expected from morphological analysis. Extremely high OTU diversity in marine metagenetic studies is a common feature in such studies, and the meaning of this diversity is still a question of active investigation. Direct comparison of our diversity estimates to morphological studies of bay or other coastal plankton is difficult because most studies have not identified samples to the species level.

Community analyses of plankton communities revealed striking geographic differences among bays, and the pattern was not simply latitudinal. Where environmental metadata were complete, we detected a strong effect of surface water salinity; it is not surprising that salinity should have a strong effect on plankton composition. We also detected inter-annual differences in plankton assemblages, especially in San Francisco Bay where sampling was annually repeated. A long drought broke in 2016, and differences between years might be cross-correlated with salinity. Indeed, we observed a significant interaction between year of sampling and salinity in statistical analyses. We note a caveat that these ecological analyses treat reads as numerical abundance and OTU as species. The relationship between read number and numerical abundance is likely not straightforward. Furthermore, OTU bins based on thresholds have the potential to split some species into haplotype groups and lump some species as one OTU if their sequences are quite similar. A particularly genetically diverse species might contain many haplotype groups, and haplotypes might be distributed differently among bays reflecting population genetic processes. In that scenario, differences in species composition among bays could be overestimated.

Sixty nine invertebrates and two algae of 252 known marine NIS were detected in our samples, though many were in low abundance and present in few bays. An important caveat to this study is that the relationship between read number and numerical abundance of any species is not yet understood, as mentioned in the preceding paragraph, therefore it may be more pragmatic to consider Table 6.11 as a list of species present. By this reasoning, however, we should be cautious in saying that a species is absent if it is not detected. Quantitative PCR (qPCR) studies may be useful to investigate actual numerical abundance in Illumina libraries and, by extension, in plankton samples. Similarly, species not detected may be probed for in DNA extractions using qPCR or end-point PCR with species-specific primers as a secondary assay for presence.

A comparison of species lists for bays based on plankton metagenetics and settling plate morphological analysis is not yet complete. In comparing benthic species, we should expect plankton samples to be less diverse, as only species with plankton larvae are likely to be well represented. (Some species lacking planktonic larvae may occur in plankton samples, nonetheless, as broken fragments, shed mucus or tissues, or eDNA). Further, plankton samples are less time-averaged than settling plates. Meroplankton reflect recent reproductive activity of benthic adults and transport processes. Species composition in plankton is therefore likely to be more episodic than on settling plates and may explain why some samples had no NIS.

By relaxing criteria for annotating OTU, we found 27 additional species that could be NIS if they were confirmed in California estuaries. Many of these would be of great concern: oysters and other bivalves, predatory crabs, fouling bryozoans and sea squirts, and fish-killing protists. Uncertainty over actual ecological impact should any of these species become established highlights the challenges of such prediction.

**References**

Edgar R.C. 2010. Search and clustering orders of magnitude faster than BLAST. Bioinformatics 26(19), 2460-2461.

Edgar R.C. 2016. UNOISE2: Improved error-correction for Illumina 16S and ITS amplicon reads. Preprint (doi: https://doi.org/10.1101/081257)

Fofonoff P.W., Ruiz G.M., Steves B.,'Simkanin C., & Carlton J.T. 2017. California Non-native Estuarine and Marine Organisms (Cal-NEMO) System. http://invasions.si.edu/nemesis/

Heller et al. (in review)

Katoh M., & Kuma M. 2002 MAFFT: A novel method for rapid multiple sequence alignment based on fast Fourier transform. Nucleic Acids Res. 30:3059-3066

**Appendix 6.1**

## List of Marine NIS in California (Fofonoff *et al*. 2017)

| TXA_Group | TXA_Binomial |
|---|---|
| Algae | *Acrochaetium secundatum* |
| Algae | *Aglaothamnion tenuissimum* |
| Algae | *Attheya armata* |
| Algae | *Bryopsis* sp. 1 |
| Algae | *Caulacanthus okamurae* |
| Algae | *Ceramium kondoi* |
| Algae | *Ceramium sungminbooi* |
| Algae | *Codium fragile* |
| Algae | *Colpomenia claytoniae* |
| Algae | *Dasya sessilis* |
| Algae | *Elachista nigra* |
| Algae | *Fucus spiralis* |
| Algae | *Gelidium vagum* |
| Algae | *Gracilaria vermiculophylla* |
| Algae | *Gracilariopsis chorda* |
| Algae | *Grateloupia turuturu* |
| Algae | *Lomentaria hakodatensis* |
| Algae | *Mutimo cylindricus* |
| Algae | *Neosiphonia japonica* |
| Algae | *Pachymeniopsis lanceolata* |
| Algae | *Polysiphonia denudata* |
| Algae | *Pterosiphonia tanakae* |
| Algae | *Pyropia suborbiculata* |
| Algae | *Sargassum horneri* |
| Algae | *Sargassum muticum* |
| Algae | *Schizymenia dubyi* |
| Algae | *Ulva australis* |
| Algae | *Ulva clathratioides* |
| Algae | *Undaria pinnatifida* |
| Amphibians-Frogs | *Lithobates catesbeiana* |
| Amphibians-Frogs | *Xenopus laevis* |
| Annelids-Leeches | *Myzobdella lugubris* |
| Annelids-Oligochaetes | *Branchiura sowerbyi* |
| Annelids-Oligochaetes | *Cambarincola pamelae* |
| Annelids-Oligochaetes | *Chaetogaster diaphanus* |
| Annelids-Oligochaetes | *Eukerria saltensis* |
| Annelids-Oligochaetes | *Limnodriloides monothecus* |
| Annelids-Oligochaetes | *Potamothrix bavaricus* |
| Annelids-Oligochaetes | *Tubificoides apectinatus* |
| Annelids-Oligochaetes | *Tubificoides brownae* |
| Annelids-Oligochaetes | *Tubificoides diazi* |
| Annelids-Oligochaetes | *Tubificoides wasselli* |
| Annelids-Oligochaetes | *Varichaetadrilus angustipenis* |
| Annelids-Polychaetes | *Alitta succinea* |
| Annelids-Polychaetes | *Amblyosyllis speciosa form 4* |
| Annelids-Polychaetes | *Boccardiella ligerica* |
| Annelids-Polychaetes | *Crucigera websteri* |
| Annelids-Polychaetes | *Diplocirrus SD1* |

| | |
|---|---|
| Annelids-Polychaetes | *Epigamia noroi* |
| Annelids-Polychaetes | *Ficopomatus enigmaticus* |
| Annelids-Polychaetes | *Hediste diadroma* |
| Annelids-Polychaetes | *Heteromastus filiformis species* complex |
| Annelids-Polychaetes | *Hobsonia florida* |
| Annelids-Polychaetes | *Hydroides dirampha* |
| Annelids-Polychaetes | *Hydroides elegans* |
| Annelids-Polychaetes | *Laonome* cf. *calida* |
| Annelids-Polychaetes | *Marenzelleria neglecta* |
| Annelids-Polychaetes | *Megasyllis nipponica* |
| Annelids-Polychaetes | *Myrianida convoluta* |
| Annelids-Polychaetes | *Myrianida pachycera* |
| Annelids-Polychaetes | *Myrianida pentadentata* |
| Annelids-Polychaetes | *Neodexiospira brasiliensis* |
| Annelids-Polychaetes | *Polydora cornuta* |
| Annelids-Polychaetes | *Polydora hoplura* |
| Annelids-Polychaetes | *Proceraea okadai* |
| Annelids-Polychaetes | *Pseudopolydora paucibranchiata* |
| Annelids-Polychaetes | *Pseudopolydora* cf. *kempi* |
| Annelids-Polychaetes | *Sabaco elongatus* |
| Annelids-Polychaetes | *Streblospio benedicti* |
| Arthropoda-Insects | *Anisolabis maritima* |
| Arthropoda-Insects | *Neochetina bruchi* |
| Arthropoda-Insects | *Neochetina eichhorniae* |
| Arthropoda-Insects | *Prokelisia marginata* |
| Arthropoda-Insects | *Pselactus spadix* |
| Arthropoda-Insects | *Thambemyia borealis* |
| Arthropoda-Insects | *Trigonotylus uhleri* |
| Bacteria | *Teredinibacter turnerae* |
| Bacteria | *Xenohaliotis californiensis* |
| Bryozoans | *Aeverrillia armata* |
| Bryozoans | *Amathia verticillata* |
| Bryozoans | *Anguinella palmata* |
| Bryozoans | *Aspidelectra melolontha* |
| Bryozoans | *Bugula neritina* |
| Bryozoans | *Bugulina fulva* |
| Bryozoans | *Bugulina stolonifera* |
| Bryozoans | *Conopeum chesapeakensis* |
| Bryozoans | *Conopeum tenuissimum* |
| Bryozoans | *Cryptosula pallasiana* |
| Bryozoans | *Pectinatella magnifica* |
| Bryozoans | *Schizoporella errata* |
| Bryozoans | *Schizoporella japonica* |
| Bryozoans | *Victorella pavida* |
| Bryozoans | *Watersipora arcuata* |
| Bryozoans | *Watersipora* n. sp. |
| Bryozoans | *Watersipora subtorquata* complex |
| Cnidarians-Anthozoans | *Bunodeopsis* sp. A |
| Cnidarians-Anthozoans | *Diadumene franciscana* |
| Cnidarians-Anthozoans | *Diadumene leucolena* |
| Cnidarians-Anthozoans | *Diadumene lineata* |

| | |
|---|---|
| Cnidarians-Anthozoans | *Diadumene* sp. 1 |
| Cnidarians-Anthozoans | *Nematostella vectensis* |
| Cnidarians-Hydrozoans | *Bimeria vestita* |
| Cnidarians-Hydrozoans | *Blackfordia virginica* |
| Cnidarians-Hydrozoans | *Cladonema pacificum* |
| Cnidarians-Hydrozoans | *Clava multicornis* |
| Cnidarians-Hydrozoans | *Climacocodon ikarii* |
| Cnidarians-Hydrozoans | *Cordylophora caspia* |
| Cnidarians-Hydrozoans | *Corymorpha* sp. A |
| Cnidarians-Hydrozoans | *Craspedacusta sowerbii* |
| Cnidarians-Hydrozoans | *Ectopleura crocea* |
| Cnidarians-Hydrozoans | *Garveia franciscana* |
| Cnidarians-Hydrozoans | *Gonionemus vertens* |
| Cnidarians-Hydrozoans | *Laomedea calceolifera* |
| Cnidarians-Hydrozoans | *Maeotias marginata* |
| Cnidarians-Hydrozoans | *Moerisia lyonsi* |
| Cnidarians-Scyphozoans | *Aurelia coerulea* |
| Cnidarians-Scyphozoans | *Phyllorhiza punctata* |
| Crustaceans-Amphipods | *Ampelisca abdita* |
| Crustaceans-Amphipods | *Ampithoe valida* |
| Crustaceans-Amphipods | *Aoroides secunda* |
| Crustaceans-Amphipods | *Caprella drepanochir* |
| Crustaceans-Amphipods | *Caprella mutica* |
| Crustaceans-Amphipods | *Caprella scaura* |
| Crustaceans-Amphipods | *Caprella simia* |
| Crustaceans-Amphipods | *Chelura terebrans* |
| Crustaceans-Amphipods | *Corophium alienense* |
| Crustaceans-Amphipods | *Corophium heteroceratum* |
| Crustaceans-Amphipods | *Crangonyx floridanus* |
| Crustaceans-Amphipods | *Eochelidium* sp. A |
| Crustaceans-Amphipods | *Gammarus daiberi* |
| Crustaceans-Amphipods | *Grandidierella japonica* |
| Crustaceans-Amphipods | *Incisocalliope derzhavini* |
| Crustaceans-Amphipods | *Jassa marmorata* |
| Crustaceans-Amphipods | *Leucothoe nagatai* |
| Crustaceans-Amphipods | *Melita nitida* |
| Crustaceans-Amphipods | *Melita rylovae* |
| Crustaceans-Amphipods | *Microdeutopus gryllotalpa* |
| Crustaceans-Amphipods | *Monocorophium acherusicum* |
| Crustaceans-Amphipods | *Monocorophium insidiosum* |
| Crustaceans-Amphipods | *Monocorophium uenoi* |
| Crustaceans-Amphipods | *Paracorophium* sp. |
| Crustaceans-Amphipods | *Paradexamine* sp. SD1 |
| Crustaceans-Amphipods | *Stenothoe valida* |
| Crustaceans-Amphipods | *Transorchestia enigmatica* |
| Crustaceans-Barnacles | *Amphibalanus amphitrite* |
| Crustaceans-Barnacles | *Amphibalanus eburneus* |
| Crustaceans-Barnacles | *Amphibalanus improvisus* |
| Crustaceans-Cladocerans | *Daphnia lumholtzi* |
| Crustaceans-Copepods | *Acartiella sinensis* |
| Crustaceans-Copepods | *Eurytemora carolleeae* |

| | |
|---|---|
| Crustaceans-Copepods | *Harpacticella paradoxa* |
| Crustaceans-Copepods | *Lernaea cyprinacea* |
| Crustaceans-Copepods | *Limnoithona sinensis* |
| Crustaceans-Copepods | *Limnoithona tetraspina* |
| Crustaceans-Copepods | *Mytilicola orientalis* |
| Crustaceans-Copepods | *Oithona davisae* |
| Crustaceans-Copepods | *Pseudodiaptomus forbesi* |
| Crustaceans-Copepods | *Pseudodiaptomus inopinus* |
| Crustaceans-Copepods | *Pseudodiaptomus marinus* |
| Crustaceans-Copepods | *Sinocalanus doerrii* |
| Crustaceans-Copepods | *Tortanus dextrilobatus* |
| Crustaceans-Crabs | *Carcinus maenas* |
| Crustaceans-Crabs | *Eriocheir sinensis* |
| Crustaceans-Crabs | *Rhithropanopeus harrisii* |
| Crustaceans-Crayfish | *Orconectes virilis* |
| Crustaceans-Crayfish | *Pacifastacus leniusculus* |
| Crustaceans-Crayfish | *Procambarus clarkii* |
| Crustaceans-Cumaceans | *Nippoleucon hinumensis* |
| Crustaceans-Isopods | *Asellus hilgendorfii* |
| Crustaceans-Isopods | *Caecidotea racovitzai* |
| Crustaceans-Isopods | *Caecijaera horvathi* |
| Crustaceans-Isopods | *Dynoides dentisinus* |
| Crustaceans-Isopods | *Eurylana arcuata* |
| Crustaceans-Isopods | *Gnorimosphaeroma rayi* |
| Crustaceans-Isopods | *Iais californica* |
| Crustaceans-Isopods | *Ianiropsis serricaudis* |
| Crustaceans-Isopods | *Limnoria quadripunctata* |
| Crustaceans-Isopods | *Limnoria tripunctata* |
| Crustaceans-Isopods | *Orthione griffenis* |
| Crustaceans-Isopods | *Paranthura japonica* |
| Crustaceans-Isopods | *Pseudosphaeroma* sp. A |
| Crustaceans-Isopods | *Sphaeroma quoianum* |
| Crustaceans-Isopods | *Sphaeroma walkeri* |
| Crustaceans-Isopods | *Synidotea laticauda* |
| Crustaceans-Isopods | *Uromunna* sp. A |
| Crustaceans-Leptostacans | *Nebalia* sp A. |
| Crustaceans-Mysids | *Deltamysis holmquistae* |
| Crustaceans-Mysids | *Hyperacanthomysis longirostris* |
| Crustaceans-Mysids | *Neomysis japonica* |
| Crustaceans-Mysids | *Orientomysis aspera* |
| Crustaceans-Mysids | *Orientomysis hwanhaiensis* |
| Crustaceans-Ostracods | *Aspidoconcha limnoriae* |
| Crustaceans-Ostracods | *Eusarsiella zostericola* |
| Crustaceans-Ostracods | *Redekea californica* |
| Crustaceans-Ostracods | *Spinileberis quadriaculeata* |
| Crustaceans-Shrimp | *Palaemon kadiakensis* |
| Crustaceans-Shrimp | *Palaemon macrodactylus* |
| Crustaceans-Shrimp | *Palaemon modestus* |
| Crustaceans-Tanaids | *Sinelobus* cf. *stanfordi* |
| Entoprocts | *Barentsia benedeni* |

| | |
|---|---|
| Entoprocts | *Urnatella gracilis* |
| Fishes | *Acanthogobius flavimanus* |
| Fishes | *Alosa sapidissima* |
| Fishes | *Ameiurus catus* |
| Fishes | *Ameiurus melas* |
| Fishes | *Ameiurus nebulosus* |
| Fishes | *Carassius auratus* |
| Fishes | *Cyprinella lutrensis* |
| Fishes | *Cyprinus carpio* |
| Fishes | *Dorosoma petenense* |
| Fishes | *Gambusia affinis* |
| Fishes | *Gila orcuttii* |
| Fishes | *Hypomesus nipponensis* |
| Fishes | *Ictalurus furcatus* |
| Fishes | *Ictalurus punctatus* |
| Fishes | *Lepomis cyanellus* |
| Fishes | *Lepomis gibbosus* |
| Fishes | *Lepomis gulosus* |
| Fishes | *Lepomis macrochirus* |
| Fishes | *Lepomis microlophus* |
| Fishes | *Lucania goodei* |
| Fishes | *Lucania parva* |
| Fishes | *Menidia audens* |
| Fishes | *Micropterus coosae* |
| Fishes | *Micropterus dolomieu* |
| Fishes | *Micropterus punctulatus* |
| Fishes | *Micropterus salmoides* |
| Fishes | *Morone saxatilis* |
| Fishes | *Notemigonus crysoleucas* |
| Fishes | *Oreochromis mossambicus* |
| Fishes | *Percina macrolepida* |
| Fishes | *Pimephales promelas* |
| Fishes | *Poecilia latipinna* |
| Fishes | *Pomoxis annularis* |
| Fishes | *Pomoxis nigromaculatus* |
| Fishes | *Ptychocheilus grandis* |
| Fishes | *Rhinogobius brunneus* |
| Fishes | *Tridentiger barbatus* |
| Fishes | *Tridentiger bifasciatus* |
| Fishes | *Tridentiger trigonocephalus* |
| Fungi | *Claviceps purpurea var. spartinae* |
| Mammals | *Ondatra zibethicus* |
| Mollusks-Bivalves | *Corbicula fluminea* |
| Mollusks-Bivalves | *Corbula amurensis* |
| Mollusks-Bivalves | *Crassostrea gigas* |
| Mollusks-Bivalves | *Gemma gemma* |
| Mollusks-Bivalves | *Geukensia demissa* |
| Mollusks-Bivalves | *Laternula gracilis* |
| Mollusks-Bivalves | *Lyrodus pedicellatus* |
| Mollusks-Bivalves | *Macoma petalum* |
| Mollusks-Bivalves | *Mercenaria mercenaria* |

| | |
|---|---|
| Mollusks-Bivalves | *Musculista senhousia* |
| Mollusks-Bivalves | *Mya arenaria* |
| Mollusks-Bivalves | *Mytilus galloprovincialis* |
| Mollusks-Bivalves | *Neotrapezium liratum* |
| Mollusks-Bivalves | *Nuttallia obscurata* |
| Mollusks-Bivalves | *Petricolaria pholadiformis* |
| Mollusks-Bivalves | *Teredo bartschi* |
| Mollusks-Bivalves | *Teredo navalis* |
| Mollusks-Bivalves | *Theora lubrica* |
| Mollusks-Bivalves | *Venerupis philippinarum* |
| Mollusks-Gastropods | *Assiminea parasitologica* |
| Mollusks-Gastropods | *Babakina festiva* |
| Mollusks-Gastropods | *Batillaria attramentaria* |
| Mollusks-Gastropods | *Bellamya chinensis* |
| Mollusks-Gastropods | *Boonea bisuturalis* |
| Mollusks-Gastropods | *Busycotypus canaliculatus* |
| Mollusks-Gastropods | *Catriona rickettsi* |
| Mollusks-Gastropods | *Cecina manchurica* |
| Mollusks-Gastropods | *Crepidula convexa* |
| Mollusks-Gastropods | *Crepidula fornicata* |
| Mollusks-Gastropods | *Crepidula plana* |
| Mollusks-Gastropods | *Cuthona perca* |
| Mollusks-Gastropods | *Haminoea japonica* |
| Mollusks-Gastropods | *Leostyletus misakiensis* |
| Mollusks-Gastropods | *Littoridinops monroensis* |
| Mollusks-Gastropods | *Littorina saxatilis* |
| Mollusks-Gastropods | *Melanochlamys ezoensis* |
| Mollusks-Gastropods | *Melanoides tuberculata* |
| Mollusks-Gastropods | *Myosotella myosotis* |
| Mollusks-Gastropods | *Ocenebra inornata* |
| Mollusks-Gastropods | *Okenia plana* |
| Mollusks-Gastropods | *Philine auriformis* |
| Mollusks-Gastropods | *Philine orientalis* |
| Mollusks-Gastropods | *Potamopyrgus antipodarum* |
| Mollusks-Gastropods | *Sakuraeolis enosimensis* |
| Mollusks-Gastropods | *Spurwinkia salsa* |
| Mollusks-Gastropods | *Tenellia adspersa* |
| Mollusks-Gastropods | *Tritia obsoleta* |
| Mollusks-Gastropods | *Urosalpinx cinerea* |
| Myxozoans | *Myxobolus koi* |
| Nematodes | *Capillaria catenata* |
| Nematodes | *Hysterothylacium brachyurum* |
| Nematodes | *Philometroides sanguineus* |
| Nemerteans | *Cephalothrix* cf. *simula* |
| Plants | *Agrostis gigantea* |
| Plants | *Alisma lanceolatum* |
| Plants | *Cakile edentula* |
| Plants | *Cakile maritima* |
| Plants | *Cotula coronopifolia* |
| Plants | *Egeria densa* |
| Plants | *Eichhornia crassipes* |

| | |
|---|---|
| Plants | *Iris pseudacorus* |
| Plants | *Juncus gerardii* |
| Plants | *Lepidium latifolium* |
| Plants | *Limosella australis* |
| Plants | *Lythrum salicaria* |
| Plants | *Myriophyllum aquaticum* |
| Plants | *Myriophyllum spicatum* |
| Plants | *Parapholis incurva* |
| Plants | *Polygonum patulum* |
| Plants | *Polypogon elongatus* |
| Plants | *Potamogeton crispus* |
| Plants | *Rorippa nasturtium-aquaticum* |
| Plants | *Salsola soda* |
| Plants | *Schinus terebinthifolius* |
| Plants | *Spartina alterniflora* |
| Plants | *Spartina anglica* |
| Plants | *Spartina densiflora* |
| Plants | *Spartina patens* |
| Plants | *Spergularia maritima* |
| Plants | *Typha angustifolia* |
| Plants | *Zostera japonica* |
| Platyhelminthes | *Alloglossidium corti* |
| Platyhelminthes | *Atractolytocestus huronensis* |
| Platyhelminthes | *Austrobilharzia variglandis* |
| Platyhelminthes | *Bothriocephalus cuspidatus* |
| Platyhelminthes | *Cercaria batillariae* |
| Platyhelminthes | *Corallobothrium fimbriatum* |
| Platyhelminthes | *Dactylogyrus extensus* |
| Platyhelminthes | *Gigantobilharzia* sp. |
| Platyhelminthes | *Himasthla quissetensis* |
| Platyhelminthes | *Khawia japonensis* |
| Platyhelminthes | *Lepocreadium setiferoides* |
| Platyhelminthes | *Leptoplana limnoriae* |
| Platyhelminthes | *Ligictaluridus pricei* |
| Platyhelminthes | *Maritrema arenaria* |
| Platyhelminthes | *Megathylacoides giganteum* |
| Platyhelminthes | *Microphallus similis* |
| Platyhelminthes | *Pisciamphistoma stunkardi* |
| Platyhelminthes | *Stephanostomum tenue* |
| Platyhelminthes | *Zoogonus lasius* |
| Protozoans | *Ancistrocoma pelseneeri* |
| Protozoans | *Ancistrum cyclidioides* |
| Protozoans | *Boveria teredinidi* |
| Protozoans | *Conidophrys pilisuctor* |
| Protozoans | *Cothurnia limnoriae* |
| Protozoans | *Lagenophrys cochinensis* |
| Protozoans | *Lankesteria ascidiae* |
| Protozoans | *Lobochona prorates* |
| Protozoans | *Mirofolliculina limnoriae* |
| Protozoans | *Rhizodomus tagatzi* |
| Protozoans | *Sphenophrya dosiniae* |

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|---|---|
| Protozoans | *Trochammina hadai* |
| Reptiles-Turtles | *Trachemys scripta* |
| Sponges | *Chalinula loosanoffi* |
| Sponges | *Clathria prolifera* |
| Sponges | *Cliona* sp. |
| Sponges | *Halichondria bowerbanki* |
| Sponges | *Hymeniacidon sinapium* |
| Sponges | *Prosuberites* sp. |
| Tunicates | *Ascidia zara* |
| Tunicates | *Botrylloides giganteum* |
| Tunicates | *Botrylloides violaceus* |
| Tunicates | *Botryllus schlosseri* |
| Tunicates | *Ciona robusta* |
| Tunicates | *Ciona savignyi* |
| Tunicates | *Corella inflata* |
| Tunicates | *Didemnum vexillum* |
| Tunicates | *Diplosoma listerianum* |
| Tunicates | *Microcosmus squamiger* |
| Tunicates | *Molgula citrina* |
| Tunicates | *Molgula ficus* |
| Tunicates | *Molgula manhattensis* |
| Tunicates | *Perophora japonica* |
| Tunicates | *Polyandrocarpa zorritensis* |
| Tunicates | *Styela canopus* |
| Tunicates | *Styela clava* |
| Tunicates | *Styela plicata* |
| Tunicates | *Symplegma reptans* |

# Section III: Synthesis

Gregory Ruiz, Jonathan Geller

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# Chapter 7: Current Status of the Marine NIS Detection in California and Future Directions

## Introduction

The CDFW Marine Invasive Species Program has implemented an intensive and long-term program to detect and evaluate NIS invasions in coastal marine waters throughout California, to assess the effectiveness of ballast water management (and other actions) in reducing the introduction and spread of NIS. To meet the goals of this Program, the CDFW has advanced biological surveys of marine communities for a diverse range of habitats and taxonomic groups, to both establish baseline measures of species distributions and detect new arrivals of NIS.

In 2012, CDFW launched a new, 3-part campaign of field-based surveys, representing a new initiative to evaluate the current status and trends of NIS in California. Led by SERC and MLML, this campaign focuses primarily on bays and estuaries, because these are hotspots for invasions in California and elsewhere around the globe and aims to significantly advance our current ability to detect new NIS and evaluate temporal changes in invasion dynamics in several ways. First, we use standardized (quantitative) measures of NIS distribution and abundance across multiple habitats, including benthic (hard substrate and soft-sediment) and planktonic assemblages, to allow formal (statistical) comparisons across space or time. Second, we have implemented repeated measures in San Francisco Bay, serving as a sentinel site to both provide a robust baseline and evaluate changes in species detection (*i.e.*, new invasions) across years. Third, we are combining both morphological and genetic analyses to cross-validate NIS identifications and improve methods for detection, increasing sensitivity and cost-efficiency.

This is the second report on progress and results for the current CDFW initiative. Here we summarize key findings presented in Chapters 1-6, combining information from the morphological and molecular analyses. We also highlight some initial comparisons across habitats and methods, discussing the expanded set of future comparisons planned for our next (third) report in this 3-part campaign. In addition, we provide conclusions and recommendations that stem for the results to date.

## State of NIS in California Coastal Waters: Morphological Analyses

Our surveys detected surprisingly few new NIS records across the four bays based on morphological analysis. For the hard substrate habitats, only one NIS, the bryozoan *Cradoscrupocellaria bertholletii* found in Humboldt Bay, was considered new to the state (see Chapter 2), and we are presently examining genetic data and the biogeography of this species to confirm this status. In addition, we detected 8 new NIS records for San Francisco Bay, representing probable coastwise spread from elsewhere in the state (where the species are known to occur). For three tunicate species, this spread was associated with unusually warm temperatures in 2015, possibly facilitating colonization from warmer waters in southern California, where the species occur. The other new records were polychaetes, which may either be recent arrivals or simply overlooked to date, since polychaete diversity has not received as much attention as other taxonomic groups.

For soft-sediment surveys, morphological analysis revealed two new NIS records for Humboldt Bay, including the Asian cephalaspidean gastropods *Philine auriformis* and *P. orientalis*, both of which were known previously from the U.S. Pacific coast (Chapter 3). No new NIS were detected by morphological analysis of soft-sediment invertebrates for San Francisco Bay (Chapter 3) or zooplankton across the four different bays (Chapter 4).

Species accumulation curves indicated that our surveys detected a high percentage (> 90%) of the total pool of NIS estimated to be present in each bay per year. Moreover, the repeated surveys for San Francisco Bay (a sentinel site), across multiple years with different environmental (thermal and salinity) conditions, serve to measure temporal change in NIS composition, providing a robust baseline to detect and evaluate new invasions. Thus, despite the performance of spatially extensive surveys (4 bays) and temporal replication (3 years in San Francisco Bay), across several habitats, it is noteworthy that only one new NIS was detected for California in the current study, using morphological analyses.

**Use of DNA Barcoding in California Surveys**

We used DNA barcoding to confirm the morphological identification of NIS and to build a barcode library for multiple applications. As described in Chapter 5, voucher specimens of putative species (morphospecies) were collected during morphological analysis and processed to obtain DNA sequences. In general, the DNA barcode confirmed the presence of the NIS. When morphological identification yielded a species-level identification, these were concordant with the genetic results 82% of the time. For the other 18% where the genetic and morphological data were discordant at the species level, this was due to multiple causes, including (a) morphological misidentification, (b) sequences from one or more non-target organisms associated with the voucher specimen, (c) laboratory contamination due to handling and workflow by SERC or MLML teams, or true environmental DNA (eDNA). Extra DNA sequences were commonly observed and indicate that non-target DNA molecules had entered into the workflow for each vial. We evaluated laboratory contamination with no-tissue and no-template controls in extraction and PCR stages and found contamination at these stages to be rare. Therefore, we believe that the majority of excess sequences result from DNA introduced prior to DNA extraction steps.

The cases of discordance between morphological and genetic results have helped improve our sample processing and workflow, and also underscore some of the current limitations with each morphological and genetic component. For some taxonomic groups (*e.g.*, tunicates and bryozoans), species assignment by morphological analysis performed well, when large and high quality specimens are available. However, some specimens in these groups are low quality, in that they are small or damaged and lack key characters needed for identification. Moreover, other taxonomic groups are notoriously difficult to identify with confidence, even for skilled and knowledgeable researchers, including sponges and hydroids, limiting the percentage of vouchers that are given species-level identifications. For these latter groups, even genus and higher-level identifications can be challenging. Our workflow now reflects these limitations, using morphological analyses to measure abundance and community composition at the species level for groups with high fidelity, and reviewing possible morphological traits to improve fidelity for additional groups. Where species-level identifications are currently not readily achieved (at the current time) by morphological analysis, occurrences are recorded at coarser taxonomic level, such as genus or family. In both cases, vouchers are collected for genetic analysis to obtain species-level identifications.

The MLML DNA barcode database version used herein contains 269 species and is continuing to grow, as we add additional voucher analyses. However, a fully genetic approach to voucher analysis is premature, at least by the next-generation sequencing approach used in this study. In our current study, genetic identification was hampered by the finding of multiple sequences for most specimens. Therefore, the prior knowledge of the type of organism was used to select the most plausible genetic result; without this prior knowledge, genetic identification by the methods used here would have been ineffective for specimens that yielded multiple sequences. Full morphological identification, however, would not be necessary in most cases, as the extra sequences are usually implausible for the type of organism. In other words, a crude identification would generally be sufficient to pinpoint a correct DNA sequence. With this approach, less expert technicians would be sufficient to process vouchers for sequencing.

Alternatively, vouchers could be sequenced solely with the Sanger method, for which multiple sequences per specimen are impossible: with that method, mixed templates produce unreadable results. The downside to Sanger sequencing, since mixed templates appear to be common, would be a higher rate of sequence failure, unless the lower sensitivity of Sanger negates superimposed sequences.

At the present time, we have maintained both morphological and genetic analysis of vouchers from field surveys to multiple ends. First, the paired samples are required to build a comprehensive NIS barcode library, to both confirm identifications and advance metagenetic approaches to detect species and evaluate community composition. Second, morphological analyses provide novel information on NIS species abundance and effects on community structure, which complement genetic data on species detection and occurrence. For this reason, the ongoing research (Part III of the current study) has established San Francisco Bay and Los Angeles/Long Beach as sentinel sites, to sustain both morphological and genetic measures to be repeated across years, combined with metagenetic analyses (see below) of additional bays throughout the state that focus on genetic detection of NIS.

**Use of Metagenetics in California Surveys**

We implemented metagenetic analyses in the current 3-part study to detect and evaluate the occurrence of NIS, focusing on both plankton and hard substrate communities. The current report includes analysis of plankton communities (Chapter 6), and the metagenetic analysis of hard substrate panel communities is a focus of the current work, to be included in the next (Part 3) report.

We collected 593 plankton samples by pump and net tow from 10 bays spanning the coast of California from 2013-2015. In total, we found 3,719 operational taxonomic units (OTU) by clustering sequences at the 95% level. OTUs are roughly equivalent to biological species, although variation in molecular evolutionary rates may cause some species to be lumped or split. Too, some nominal species may actually be two or more cryptic species that are separated at the 95% threshold yet bear the same name. Thus, there is not perfect correspondence between OTUs and biological species. Community analyses showed strong differences in plankton and NIS communities across sites, but not strictly corresponding to geographic separation. Surface temperature and salinity were important drivers of community composition. Sequences were identified by BLAST using private and public databases. BLAST searches may produce more than one match that exceeds a 95% similarity threshold due to variation in molecular evolutionary rate, as noted above, or database errors. Because specimens are not linked to sequences in metagenetic analyses, we included all matches exceeding 95% as possibly present in our samples

Using this approach for plankton metagenetics, NIS were detected in every bay, and we found 69 of 252 marine NIS (excluding vertebrates and vascular plants) recognized in California. We also found sequences matching additional NIS not presently verified in California. We suggest those additional species be considered possible but not verified new NIS in California and be targets for discovery in bioblitz and other benthic surveys, to confirm current status.

It is also useful to recognize that this analysis provides a minimum estimate of NIS detection performance. More than 69 NIS may be detected eventually in these sequence data, since we still lack DNA barcodes for some known NIS. Thus, as our barcode library continues to grow, we predict additional NIS will be confirmed present in these samples.

**Cross-Method Comparison for California Survey Data**

We compared NIS found in plankton to those found on settlement plates in each bay (except San Pedro and Newport bays, for which panel data were not yet available). On average, we found 32.3 ±6.6 (standard deviation) NIS per bay in plankton, 32.4 ±7.7 from morphological analysis of settlement panels, and 14.4 ±4.3 NIS found in both sample types (Table 7.1).

The plankton samples provide an integrative approach to detect species across multiple habitat types, since these include both waterborne stages of benthic (hard substrate and soft-sediment) species and holoplankton. Among plankton samples were infaunal and planktonic NIS, whereas plate samples do not include most infaunal and plankton species.

Our data indicate that high throughput sequencing was effective at detecting many NIS and finding community variation in Californian estuarine waters. However, the general episodic nature of larval production suggests a need for higher frequency of plankton sampling or supplementation with benthic surveys to detect additional NIS present. We also expect that some taxa will not be detected in plankton assemblages, due to (a) reproductive mode (including direct development and lecithotrophic larvae, which spend little-to-no time in the water column), (b) frequency of reproduction, and (c) larval behavior.

**Next Steps**

We will expand this cross-method comparison in the current work and next report, Part 3 of the current initiative, providing a more synthetic view of detection performance and gaps across measures for the 10 focal bays studied. This analysis will specifically examine the frequency of detection of NIS by habitat (plankton, hard substrate, and soft-sediment) and method (morphological and metagenetic analysis). Such analysis is not yet possible, until the metagenetic analyses of panel samples (now underway) are completed in Part 3 of the study.

Using the expanded cross-system comparison and synthesis, we will provide a comprehensive evaluation of status and trends of NIS in California waters and make recommendations to further optimize the CDFW program for detection and management of NIS. Based on our results to date from this research program, some of these recommendations are already implemented in the current (Part 3) study, including:

- Reduced individual voucher sequencing and increased metagenetic analysis of settling panels.
- Focused sequencing on taxonomic groups that have proven most difficult for morphological analysis and groups needed to fill database gaps, using bioblitz activities to augment survey collections.
- Use of Sanger sequencing for a lower volume of vouchers that serves to (a) reduce the level of technical difficulty in sample preparation and (b) minimize sequences from non-target taxa.
- Use of Illumina sequencing to replace Ion Torrent sequencing for metagenetics, due to higher sequence yield, simpler sample preparation, and lower per run cost. In addition, Life Technologies have phased out the current Ion Torrent PGM instrument, reagent and software product development has ceased, and legacy support will expire.
- Use of paired head-to-head comparisons of plankton and settlement panel metagenetic, to those from morphological analyses in sentinel bays to evaluate the performance of detection methods for individual NIS, habitats, and traits. This information can further refine relative sampling effort for each method in ongoing surveys, to meet CDFW program objectives.

**Table 7.1. Number of NIS found in plankton and settlement panels in each bay where plankton was taken.** NIS in plankton were identified by analysis of DNA sequences from bulk samples as described in Chapter 6. NIS on panels were identified by morphological analysis as described in Chapter 2. Because plankton samples were not examined morphologically, and vouchers from panels were not necessarily sequenced, these data assume that taxonomic names are used similarly. Additionally, some species found by molecular analysis are unlikely to be seen on panels (*i.e.*, holoplankton and infaunal species), and some species found on plates are unlikely to be found in plankton (species lacking planktonic larvae). Lastly, unresolved names (order, family, or genus only) were included in morphological species lists but not in molecular analysis.

| | Found on Both | Found in Plankton Only | Found on Panels Only | Total in Plankton | Total on Panels | Total in Bay |
|---|---|---|---|---|---|---|
| San Francisco 2013 | 20 | 19 | 11 | 39 | 31 | 50 |
| San Francisco 2014 | 17 | 21 | 22 | 38 | 39 | 60 |
| San Francisco 2015 | 18 | 24 | 30 | 42 | 48 | 72 |
| Morro Bay 2013 | 10 | 13 | 12 | 23 | 22 | 35 |
| Mission Bay 2013 | 18 | 16 | 19 | 34 | 37 | 53 |
| San Diego Bay 2013 | 19 | 17 | 19 | 36 | 38 | 55 |
| Bodega-Tomales Bays 2014 | 12 | 9 | 19 | 21 | 31 | 40 |
| Humboldt Bay 2015 | 12 | 17 | 18 | 29 | 30 | 47 |
| Port Hueneme 2015 | 9 | 25 | 13 | 34 | 22 | 47 |
| Marina del Rey 2015 | 10 | 19 | 17 | 29 | 27 | 46 |
| Newport Bay 2015 | 10 | 20 | 21 | 30 | 31 | 51 |
| Average | 14.1 | 18.2 | 18.3 | 32.3 | 32.4 | 50.5 |
| Standard Deviation | 4.3 | 4.6 | 5.3 | 6.6 | 7.7 | 9.9 |

# Selected Glossary of Barcoding and Metabarcoding Terminology

**Amplicon** – a product of the polymerase chain reaction (PCR), which amplifies a targeted region from a DNA template (see template). Loosely synonymous with "PCR product" though "amplicon" may refer to a single molecule, while "PCR product" usually refers to pool of amplified DNA.

**Assembly** – the alignment of multiple reads of the same or overlapping DNA sequence to produce a single consensus sequence called a "contig" (contiguous sequence).

**Binning** – grouping DNA sequences based on some criterion, for example a threshold of similarity.

**BLAST** – Basic Local Alignment Search Tool; a method to find similar sequences (subjects) in a database to a submitted sequence (query).

**Chimera** – two sequences merged into one during the PCR process.

**Contig** – see Assembly

**Demultiplexing** – in the context of metabarcoding, sorting a list of DNA sequences into groups corresponding to the biological sample of origin (for example, a plankton tow, or a voucher specimen)

**Denoising** – removal of sequencing errors that are predicted by statistical inference to occur due to known artifacts in the NGS platform.

**Diversity** – in the context of biological diversity, usually refers to both the number of species (richness) and their relative abundances (evenness) in a given area

**E score** – "The Expect value (**E**) is a parameter that describes the number of hits one can "expect" to see by chance when searching a database of a particular size." (blast.ncbi.nlm.nih.gov). A barcode that matches a Genbank record will have an E score <<<0.01.

**End repair** – an enzymatic process to remove overhangs in DNA fragments, used to facilitate blunt-end ligation of DNA fragments.

**Evenness** – how evenly abundant (*i.e.*, relative abundance) species or OTUs are in a given area of interest

**FASTA** – a standardized file format for DNA sequences readable by many software packages.

**FASTQ** – a file format containing sequence and quality scores for each base pair.

**Library** – in the context of metabarcoding, a PCR product to which relevant DNA adaptors have been ligated.

**Locus** (plural, loci) –a physical region of the genome, sometime used synonymously with "gene" (a coding region), or gene fragment, but not necessarily a coding region.

**Ligation** – enzymatic joining of two DNA fragments.

**Non-metric multidimensional scaling (nMDS)** – a method of visualizing (dis)similarities between different sampling units. It is an ordination technique that attempts to represent the multi-dimensional nature of similarities between samples (in this case, the richness and relative abundance of species or OTUs on panels, grabs, or tows) in two dimensions. The result is a visual representation of a matrix of pairwise similarity scores for all samples of interest.

**Next generation sequencing (NGS)** – a variety of methods for DNA sequencing that typically allow massively parallel (*i.e.*, simultaneous) sequencing of single molecule DNA templates. The term is falling out of usage because sequencing technology continues to advance, therefore "next" becomes a somewhat meaningless term. Sequencing methods are now often referred to the instrument and chemistry involved (eg, Illumina MiSeq).

**OTU (operational taxonomic unit)** – a group of specimens or, in the context of molecular systematics, DNA sequences thought to comprise a evolutionary lineage such as a species. In the context of DNA barcoding, a criterion is used to identify such groups, such as threshold of sequence similarity.

**Phred score** – a measure of quality of a base call in DNA sequencing, expressed as a Q, where Q is a logarithmic value. For example, Q20 is 1/100 probability of incorrect base call (or 99% base call accuracy).

**Polymerase Chain Reaction (PCR)** – an *in vitro*, enzymatic reaction to make sufficient copies of a targeted region on a DNA template for DNA sequencing or other procedures.

**Primer** – a short single stranded DNA molecule used to initiate ("prime") the polymerase chain reaction. Primer DNA sequences are designed to bind to the DNA to be copied (see Template) at a specific nucleotide sequence; this allows specificity of DNA amplification.

**Rarefaction** (**rarefy**) – resampling of individual data points in a sample (in this case, DNA reads or species) to standardize the number of data points per sample. This is meant to account for differences in sampling effort (in this case, variation in sequencing depth, or different numbers of panels or samples per bay due to panel loss)

**Richness** – number of morphologically distinct species or OTUs found in a given sampling area

**Sanger sequencing** – *in vitro*, enzymatic reaction to determine the order of nucleotides on a single DNA template, in this case a pool of identical DNA molecules (see Template); Next-generation sequencing, in contrast, achieves this for many (millions) templates that are not necessarily similar by tracking. Sanger sequencing is name for Frederick Sanger, its inventor, and is more technically called dideoxynucleotide chain termination reaction.

**Species accumulation curve** – a graph of the cumulative number of species found in a given area of interest as a function of the number of samples (panels, grabs, tows) examined

**Template** – a DNA molecule or pool of molecules that is acted on by enzymes; in the context of PCR, the DNA to be copied; in the context of DNA sequencing, the DNA to be sequenced.