SAMPLING AND TAXONOMIC ANALYSES FOR MARINE INVASIVE SPECIES IN CALIFORNIA ESTUARIES

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Executive Summary

Introduction

The California Department of Fish and Wildlife's Marine Invasive Species Program (CDFW MISP) has implemented a program (hereafter "Program") of intensive, long-term sampling efforts to detect non-indigenous species (NIS) in California's coastal marine waters. The Program aims to detect and report NIS occurrences to assess the effectiveness of measures such as ballast water management in reducing NIS introductions and spread, and to establish baseline measures of species distributions against which future efforts can be measured and new NIS arrivals can be detected. To do this, the Program has advanced a series of biological surveys covering a range of habitats and diverse taxonomic groups with the Smithsonian Environmental Research Center (SERC) and Moss Landing Marine Laboratories (MLML).

Following an initial pilot effort (2009-2011) to review current NIS status and trends in California and to build up a curated barcode library of reference sequences for NIS from San Francisco Bay, the Program commenced a series of surveys of 10 focal bays in California beginning in 2012. An initial round of field surveys using a combination of morphological taxonomy coupled with barcoding of individual voucher specimens to generate identifications was completed across the 10 bays, along with surveys of selected outer coast habitats, by 2017 (Ruiz and Geller 2015, 2018, 2021). BioBlitz efforts were also undertaken to build up the MLML barcode library for poorly covered taxonomic groups. In 2017, we introduced the broader-scale use of metagenetic techniques following initial trials during the 2012-2016 period. A second cycle of surveys began in 2018.

Intended as a more cost-effective means of sampling a broad range of taxa, the metagenetic methods employed by SERC and MLML revolve around standardized sample collection and a survey design similar to our full-scale morphogenetic surveys. Simultaneous barcoding of whole community samples is used rather than morphological identification and sequencing of individual voucher specimens. Several comparisons are underway to assess the best means of acquiring DNA from whole community samples, including homogenization of the biota followed by extraction and sequencing, or soaking the biota in filtered seawater, then filtering eDNA from the soak water and sequencing. In either case, the metagenetic approach requires accurate and comprehensive barcode libraries to generate reliable identifications. The curated MLML barcode library, along with improvements in taxonomic coverage in GenBank and other libraries over recent years makes this an increasingly viable means of supplementing traditional voucher-focused morphological and genetic surveys.

In recent years, we have also moved to a sentinel-site focused approach in which San Francisco Bay is surveyed repeatedly to improve statistical comparisons across time, while continuing to survey the others of the original ten focal bays in 3-5 year cycles using metagenetic methods. As we accumulate additional timepoints, we are adding Los Angeles / Long Beach Harbor and San Diego Bay as sentinel sites going forward. The detailed morphogenetic, voucher-focused survey approach continues to be a *sine qua non* for reliable detection of NIS and augmentation of our barcode library. But given increasingly constrained funding, the barcode library, BioBlitzes, and comparisons of metagenetic approaches so far will together also allow us to continue to

achieve broader geographical coverage of the state's bays while ensuring similar data quality and enhancing our overall ability to detect new invasions.

Summary

Here, we report on progress and results for a portion of the CDFW Program carried out by SERC in collaboration with MLML from 2020-2022.

This report includes the work and deliverables for surveys to detect marine non-indigenous invertebrate species (NIS) in California by the Smithsonian Environmental Research Center (SERC) conducted under Agreement No. P2075005 and a separate agreement with Moss Landing Marine Laboratories (MLML), with the following elements:

The first chapter reports results of standardized hard substrate surveys carried out in Los Angeles / Long Beach Harbor (2021), San Francisco Bay (2021, 2022), and Santa Catalina Island (2022), for which morphological taxonomic and genetic analyses were completed. The locations are also given for metagenetic-only sampling in Mission and San Diego Bays (2021), Humboldt Bay, Bodega Harbor, and Tomales Bay (2022). Statistical analyses indicate relatively complete sampling of NIS in each location, indicating that the surveys performed well in detecting NIS. In total, 39 NIS and 44 NIS were detected in the 2021 hard substrate surveys in Los Angeles / Long Beach Harbor and San Francisco Bay, respectively. In 2022, a total of 52 NIS and 21 NIS were detected, respectively, in the hard substrate surveys in San Francisco Bay and Santa Catalina Island. No new NIS records are reported from the 2021 hard substrate surveys in Los Angeles / Long Beach Harbor and San Francisco Bay. One new NIS was detected morphologically in the 2022 hard substrate survey of San Francisco Bay. Nine new NIS records are reported for Santa Catalina Island from 2022, all of which had previously been found elsewhere in California.

The second chapter reports results of standardized infaunal (soft sediment) surveys carried out in San Francisco Bay in 2022. As with the hard substrate surveys, statistical analyses indicate strong performance of the soft sediment survey in detecting NIS presence. Overall, 51 morphospecies were detected, including 15 NIS. No previously undetected NIS were found.

The third chapter reports standardized sampling efforts for zooplankton surveys, for which samples were taken for metagenetic processing. These surveys included Humboldt Bay, Bodega Harbor and Tomales Bay, San Francisco Bay, Los Angeles / Long Beach Harbor, Santa Catalina Island, Mission Bay, and San Diego Bay. Site maps and locations are provided.

The fourth chapter reports results of BioBlitzes to enhance our library of morphological taxonomic and genetic barcode data for these groups in California. In May 2022, we found 47 polychaete taxa in a BioBlitz effort focused on Bodega Harbor, with additional visits to Tomales Bay and San Francisco Bay. In October 2022, we found 18 hydrozoan taxa in a BioBlitz effort focused on San Francisco Bay. A third BioBlitz effort in Coos Bay collected 20 additional taxa across a range of different groups for barcoding.

The fifth chapter provides a brief overview of Cal-NEMO, an online database of marine and estuarine NIS in California. Cal-NEMO is a state-specific portal of SERC's National Exotic Marine and Estuarine Species Information System (NEMESIS) database. The NIS records detected in the

above surveys are being made public via Cal-NEMO. The taxonomic identifications and invasion status designations used in this report are current as of April 2023.

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Chapter 1: Hard Substrate Communities

1.1: Introduction and Methods

To detect the presence of non-native invertebrate taxa in sentinel site hard substrate communities, we sampled Los Angeles / Long Beach Harbor in 2021, San Francisco Bay in 2021 and 2022, and Santa Catalina Island in 2022, for which morphological taxonomic and genetic analyses were carried out. While the original contract called for two soft sediment surveys in San Francisco Bay in 2020 and 2021, we were not able to conduct soft sediment survey work in either year due to the COVID-19 pandemic. Following discussion with CDFW, we revised our sampling schedule and substituted a hard substrate survey of San Francisco Bay in 2022 for one of the soft sediment surveys. We also sampled hard substrate communities in Mission and San Diego Bays (2021), Humboldt (2022), and Bodega Harbor / Tomales Bay (2022) for metagenetic analyses only. For each estuary, we selected 10 sites in high salinity (> 20 ppt) waters in a given year. Specific locations are indicated in Figures A1.1.1 through A1.1.7, and in Tables A1.1.1 through A1.1.7.

All surveys were conducted in summer through mid-fall to control for possible seasonal differences. This time of year was selected to encompass the season of maximum plankton abundance and larval recruitment in order to maximize species detection.

For each site, we deployed PVC plates (14 x 14 cm) facing downward and 1 m below the surface, for a minimum of 3 months. Settlement plates are an efficient and effective method for detecting non-indigenous species (NIS), serving as passive collectors for marine invertebrate recruitment (Marraffini et al. 2017). Up to 10 plates were deployed at each site (to allow for potential loss), with the goal of obtaining 5 intact plates for morphological analysis per site per estuary. Plates were deployed using a stratified, randomized sampling design within each site. Upon retrieval, we randomly selected at least 5 plates per site for analysis of biota, for a total of 200 plates across all four morphological sampling events (Los Angeles / Long Beach Harbor in 2021, San Francisco Bay in 2021 and 2022, and Santa Catalina Island in 2022 (4 events x 10 sites x 5 plates)). For metagenetic-only sampling events, we deployed at least 7 plates per site, again with the goal of retrieving 5 intact plates for metagenetic analysis per site per estuary. This resulted in a total of 200 plates across four metagenetic sampling events (Mission and San Diego Bays in 2021 and Bodega Harbor / Tomales Bay and Humboldt Bay in 2022). In addition, for each site surveyed per estuary, we recorded GPS location (latitude (N) / longitude (W)), salinity, temperature, dissolved oxygen, sample date, and weather conditions.

For metagenetic-only retrievals, plates were retrieved and soaked in filtered seawater from the site for 4 hours. The resulting soak water was then filtered through 0.2 µm polyethersulfone filters attached to a vacuum pump and frozen at -20°C for delivery to MLML for metagenetic processing.

Upon retrieval, all sessile and mobile macroinvertebrates were collected and processed live to generate morphological vouchers for species-level identification on each plate. These “field vouchers” were later identified to species (or lowest taxonomic unit) based upon morphological

characteristics by SERC staff using published taxonomic literature. A subset of these identifications was verified through additional consultation with outside taxonomic experts (Appendix 1.2). Molecular vouchers were also collected for each species (at least n=5 per bay, when available), and the molecular vouchers were sent to the Geller Lab at Moss Landing Marine Laboratories (MLML) for DNA barcoding.

The morphological identifications of specimens produced a list of taxa identified to the lowest possible taxonomic level for each sample. For each taxon, we classified the invasion status in the bay where it was found as of the year of sampling, based upon previous analyses, the literature, and using a synthesis of information in the SERC NEMESIS database (Fofonoff et al. 2018). Four categories were used for this classification: NIS, native, cryptogenic (of uncertain status, *sensu* Carlton 1996), and unresolved (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, native, cryptogenic, and unresolved taxa detected at each site and for the entire bay. We then constructed accumulation curves and calculated species richness estimators.

We conducted a standard series of statistical analyses to assess the completeness of our sampling efforts and estimate the number of NIS present. We used rarefaction to estimate the completeness of sampling for our level of sampling effort. This approach is combined with richness estimators calculated from our observations, to estimate the true (asymptotic) NIS richness detected using each method in each habitat, and to generate confidence intervals for detection.

To estimate the number of NIS captured by our sampling methods, we used a relatively recently developed approach to species richness estimation that builds on traditional methods of rarefaction by combining rarefaction and extrapolation to make asymptotic estimates of richness along with quantifiable measures of sample completeness (Colwell et al. 2012; Chao et al. 2020).

Sample completeness, or sample coverage, is a key determinant of how close the estimated number of species is to the true number of species present (observed + undetected) in a sampled assemblage. The more complete a set of samples is estimated to be, the more likely it is that all species actually present have been detected (Chao et al. 2014, 2020, 2021).

Statistical analyses were carried out using R 4.2.3 (R Core Team 2023) and the R packages vegan 2.6-4 (Oksanen et al. 2022), and iNEXT.3D 1.0.1 (Hu and Chao 2023).

1.2: Results

1.2.1 Detection of NIS in Hard Substrate Communities

Our analyses indicate that our sampling program performed well in detecting and characterizing identifiable NIS in hard substrate communities in Los Angeles / Long Beach Harbor, San Francisco Bay, and Santa Catalina Island. Below, we present a series of figures

depicting the detection of NIS using species accumulation curves and richness estimators (Appendix 1.4).

In 2021, we detected 39 and 44 NIS in hard substrate surveys in Los Angeles / Long Beach Harbor and San Francisco Bay, respectively. In our 2022 hard substrate surveys, we detected 52 NIS in San Francisco Bay and 21 NIS from Santa Catalina Island. The variation in NIS detected across sites in these four survey events is shown in Appendix 1.3.

Sample coverage estimators show that NIS were sampled nearly completely in all four sampling events, with sample coverage ranging from 96.16% to 99.32%.

More detailed results showing the number of taxa detected across different invasion status categories are presented in Appendix 1.4.

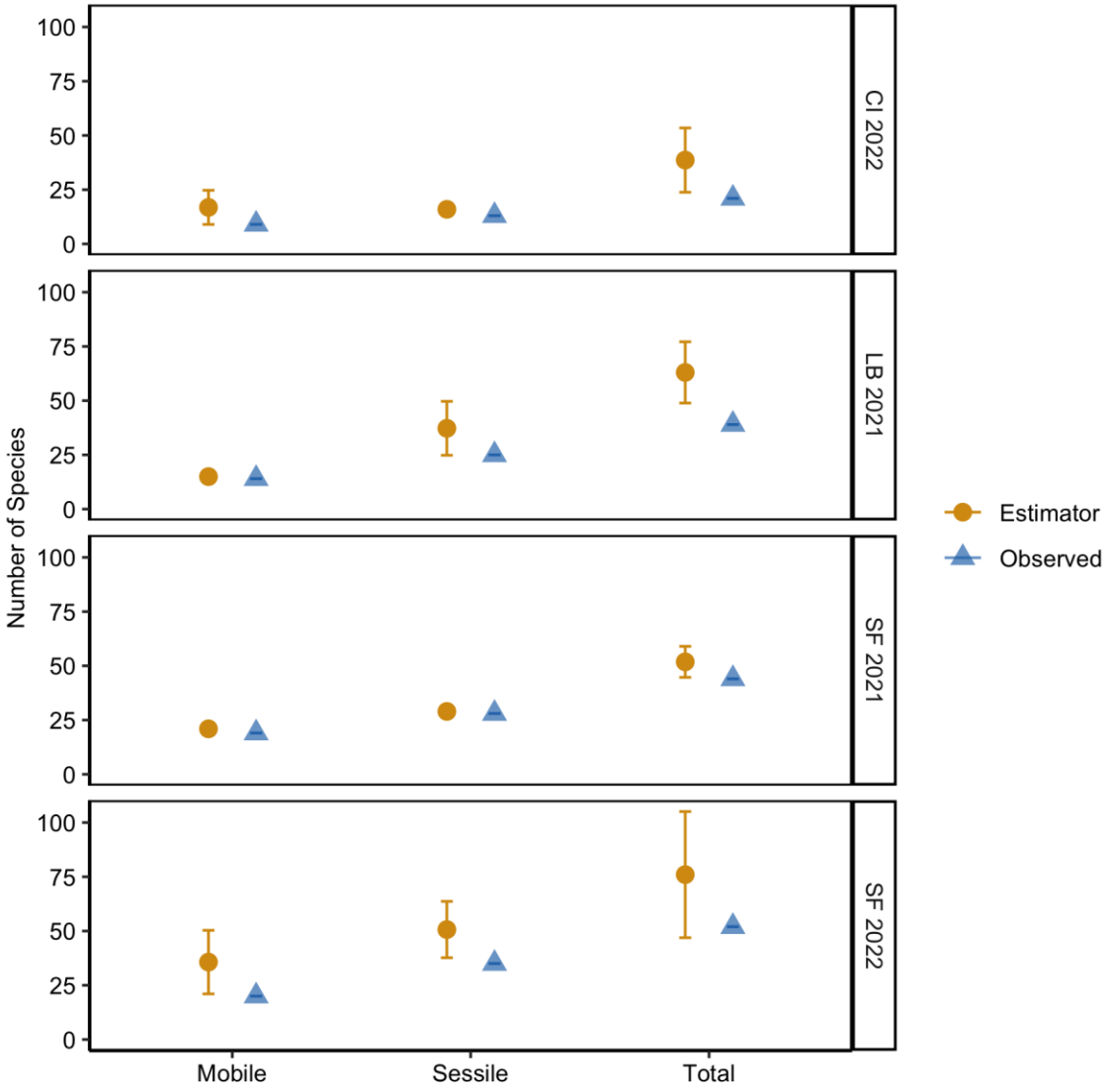

Figure 1.1: *Number of unique NIS detected for each sampling event ("Observed") and asymptotic estimate of NIS richness ± standard error ("Estimator"). Sampling events included hard substrate*

panel surveys of Los Angeles / Long Beach Harbor (LB) in 2021, San Francisco Bay (SF) in 2021 and 2022, and Santa Catalina Island (CI) in 2022. NIS status was assigned based on literature and SERC NEMESIS database (Fofonoff et al. 2018).

1.2.2 Newly-Detected NIS for Hard Substrate Communities

From our 2021 and 2022 San Francisco Bay hard substrate surveys, we report one NIS that was previously undetected morphologically: the polychaete *Lumbrineris perkinsi* (Carrera-Parra 2001), which we collected from San Francisco Marina in 2022. We previously detected *L. perkinsi* via new metabarcoding analyses of previously collected, homogenized samples of communities scraped off panels from our 2013 hard substrate surveys of San Francisco Bay (Ruiz and Geller 2021).

While *Lumbrineris* sp. has been observed in San Francisco Bay in previous surveys (at Sausalito Marine Harbor and Oakland Yacht Club in 2016, and from Oakland Yacht Club in 2020-2021), we were not able to resolve the identity beyond genus level.

Lumbrineris perkinsi was described from material obtained from the Gulf of Mexico and the Caribbean basin by L. Carrera-Parra in 2001 and has been reported throughout the Mediterranean as a Lessepsian invader (Çinar 2009; Zenetos et al. 2011), and more recently in the Mexican Pacific (Ardura et al. 2021).

Previous records of *L. perkinsi* in our California surveys (covering 2000 to the present) are limited to collections from four sites in San Diego Bay (2013) that were identified both morphologically and genetically (Ruiz and Geller 2015, 2018).

Across annual surveys of San Francisco Bay for CDFW since 2009, *L. perkinsi* marks the 11th new NIS detected, joining 6 other polychaetes and 4 sessile taxa (Table 1.1). Two species were previously reported in San Francisco Bay (but not on panel surveys), and others were new records for San Francisco Bay. Like *L. perkinsi*, all of these species were reported previously elsewhere in California (Tracy et al. 2017; Fofonoff et al. 2018). Interestingly, these previous records all occurred further south, suggesting northward movement over time, as our long-term systematic monitoring of San Francisco Bay would likely have detected earlier incursions of these taxa, morphologically and/or genetically.

Northward movement may be due to continued vector operation transporting potential invaders to more northerly locations. This continued activity may lead to greater opportunity for invasion and establishment when it coincides with more consistently hospitable recipient environments due to warming temperatures, or at least increases in the frequency of episodic warming events such as the 2014-16 marine heat wave (e.g. Di Lorenzo and Mantua 2016).

Table 1.1: *Year of first detection in panel surveys for new NIS in San Francisco Bay. Asterisks indicate species previously reported for San Francisco Bay, and all species were reported previously elsewhere in California.*

Species	**Year**
Amblyosyllis speciosa D	2014
Branchiomma sp. 2	2014
Myrianida pentadentata	2014
Neoamphitrite sp. A	2014
Perophora japonica	2014
Microcosmus squamiger	2015
Molgula ficus *	2015
Myrianida pachycera	2015
Styela canopus	2015
Pseudopolydora paucibranchiata *	2016
Lumbrineris perkinsi	2022

Our survey of Santa Catalina Island detected 9 NIS not previously known from the island, although all had previously been found elsewhere in California, on the mainland. All except the amphipod *Shoemakerella* cf. *cubensis* had previously been observed in Los Angeles / Long Beach Harbor surveys. Since systematic surveys specifically targeting marine invertebrate NIS had not previously been conducted on the island, it is unsurprising that there are a number of new records. These records do not necessarily indicate recent invasions, but more likely reflect the lack of previous surveys and baseline data against which to measure change.

Table 1.2: *Newly detected NIS from 2022 panel survey of Santa Catalina Island. All species were reported previously elsewhere in California.*

Group	Species
Arthropoda: Amphipoda	*Aoroides secunda*
Arthropoda: Amphipoda	*Shoemakerella* cf. *cubensis*
Arthropoda: Amphipoda	*Stenothoe valida*
Arthropoda: Isopoda	*Paranthura japonica*
Cnidaria: Anthozoa	*Diadumene lineata*
Bryozoa	*Amathia dichotoma*
Bryozoa	*Watersipora arcuata*
Tunicata	*Botrylloides giganteus*
Tunicata	*Polyandrocarpa* cf. *zorritensis*

The crustaceans *Aoroides secunda*, *Paranthura japonica*, and *Stenothoe valida*, and the anthozoan *Diadumene lineata* have relatively broad distributions throughout the state.

Notably, the tunicates *Botrylloides giganteus* and *Polyandrocarpa* cf. *zorritensis* were historically more southerly species that appear to be spreading northward and are becoming more abundant over time (Nichols et al. 2023).

The bryozoan *Watersipora arcuata* is also a more southern species that is rarely found north of Point Conception.

Additional Results Presented in Appendices

Additional results are presented in the appendices, including the contribution of NIS to total richness in each Bay (Appendix 1.5), contribution of NIS to richness per panel at each site (Appendix 1.6), the relative abundance of NIS across sites (Appendix 1.7), and a per-site listing of species detected and their associated invasion statuses (Appendix 1.8).

1.3: References

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Appendix 1.1: Survey Locations by Estuary

A1.1.1: Los Angeles / Long Beach Harbor (2021)

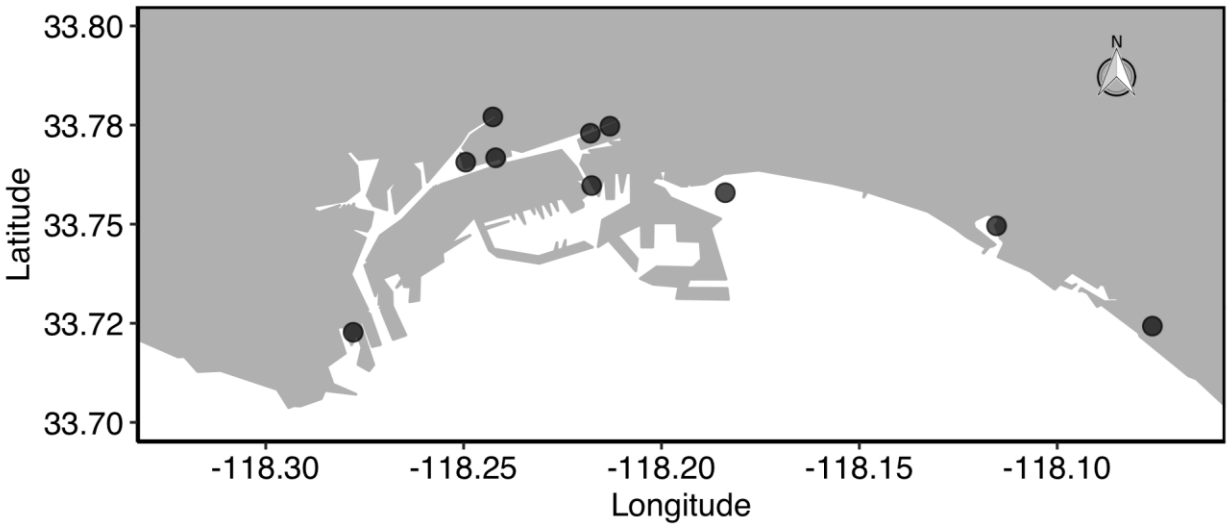

Figure A1.1.1: *Map of hard substrate community sampling locations in Los Angeles / Long Beach Harbor (2021).*

Table A1.1.1: *Hard substrate community sampling locations in Los Angeles / Long Beach Harbor (2021).*

Site Name	Latitude (N)	Longitude (W)
Alamitos Bay Marina	33.750	-118.115
Cabrillo Marina	33.723	-118.278
Island Yacht Anchorage	33.767	-118.242
Leeward Island Marina	33.777	-118.243
Pacific Yacht Landing	33.766	-118.249
Peter's Landing Marina	33.724	-118.076
Port of LB Matson	33.773	-118.218
Port of LB Pier D	33.760	-118.218
Port of LB Pier F	33.775	-118.213
Shoreline Public Marina	33.758	-118.184

A1.1.2: San Francisco Bay (2021 and 2022)

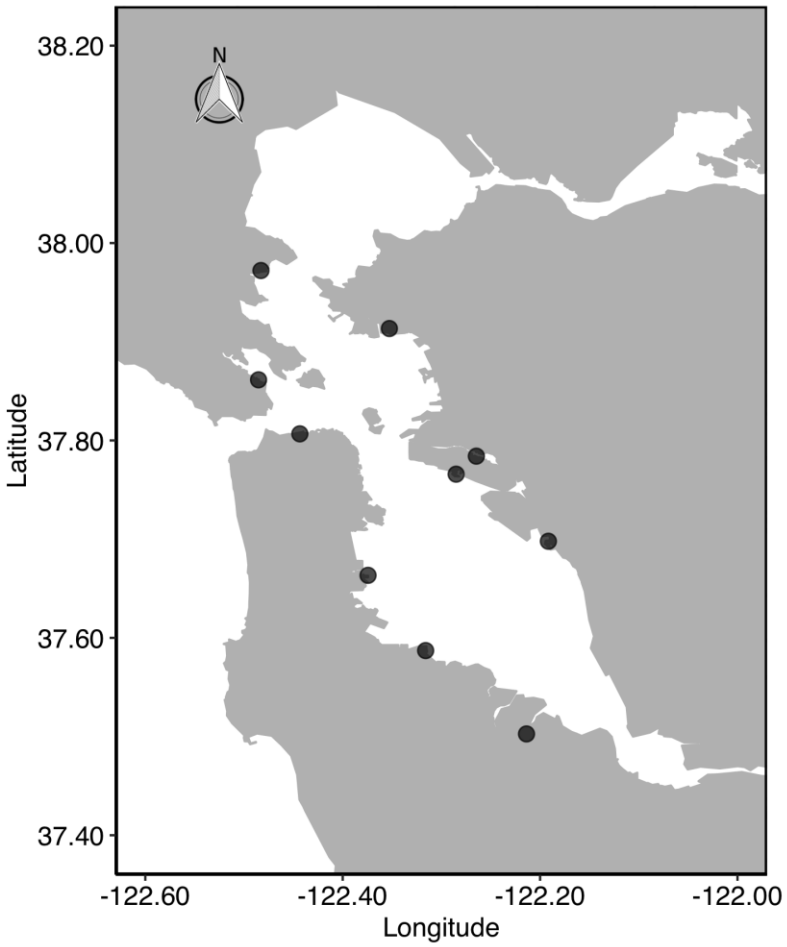

Figure A1.1.2: *Map of hard substrate community sampling locations in San Francisco Bay (2021 and 2022).*

Table A1.1.2: Hard substrate community sampling locations in San Francisco Bay (2021 and 2022).

Site Name	Latitude (N)	Longitude (W)
Ballena Isle Marina	37.766	-122.285
Coyote Point Marina	37.587	-122.316
Loch Lomond Marina	37.972	-122.483
Oakland Yacht Club	37.784	-122.265
Oyster Point Marina	37.663	-122.374
Redwood City Marina	37.503	-122.214
Richmond Marina Bay	37.913	-122.353
San Francisco Marina	37.807	-122.443
San Leandro Marina	37.698	-122.192
Sausalito Marine Harbor	37.861	-122.485

A1.1.3: Santa Catalina Island

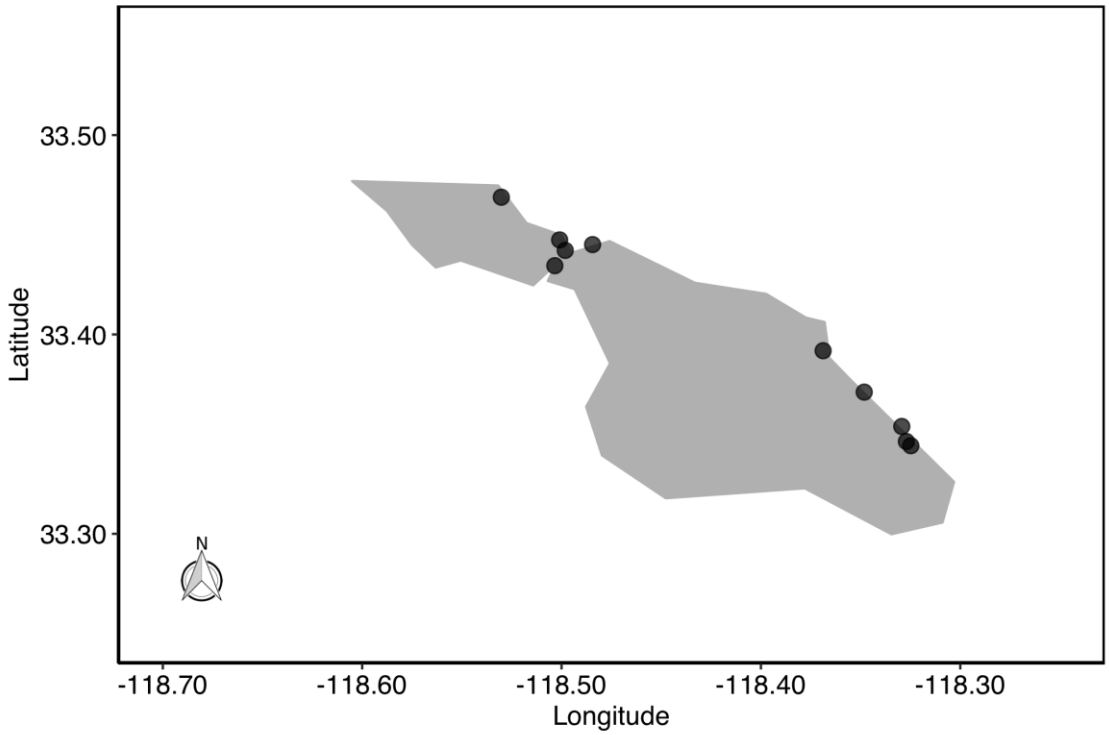

Figure A1.1.3: *Map of hard substrate community sampling locations in Santa Catalina Island (2022).*

Table A1.1.3: *Hard substrate community sampling locations in Santa Catalina Island (2022).*

Site Name	Latitude (N)	Longitude (W)
Cat Harbor	33.434	-118.503
Catalina Ave Dinghy Dock	33.344	-118.325
Emerald Bay	33.469	-118.530
Fourth of July Cove	33.447	-118.501
Gallaghers Cove	33.371	-118.348
Hamilton Cove	33.354	-118.329
Middle Dock	33.346	-118.327
Two Harbors	33.442	-118.498
Whites Cove	33.392	-118.369
Wrigley	33.445	-118.484

A1.1.4: Mission Bay

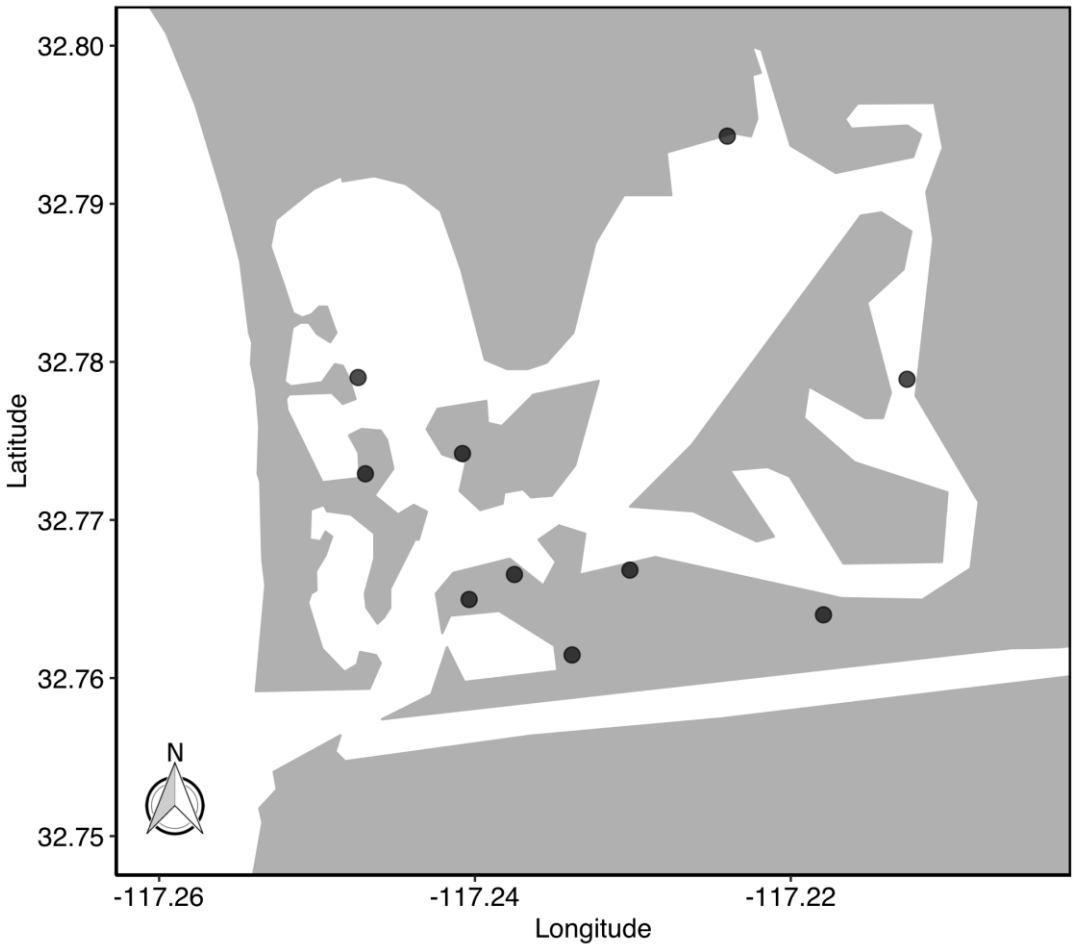

Figure A1.1.4: *Map of hard substrate community sampling locations in Mission Bay (2021).*

Table A1.1.4: *Hard substrate community sampling locations in Mission Bay (2021).*

Site Name	Latitude (N)	Longitude (W)
Bahia Resort Marina	32.773	-117.247
Campland on the Bay	32.794	-117.224
Hilton Resort Docks	32.779	-117.213
Hyatt Resort Marina	32.765	-117.240
Marina Village	32.761	-117.234
Mission Bay Yacht Club	32.779	-117.247
Paradise Point Resort	32.774	-117.241
SeaWorld Marina	32.767	-117.230
South Shores Park	32.764	-117.218
The Dana Marina	32.767	-117.237

A1.1.5: San Diego Bay

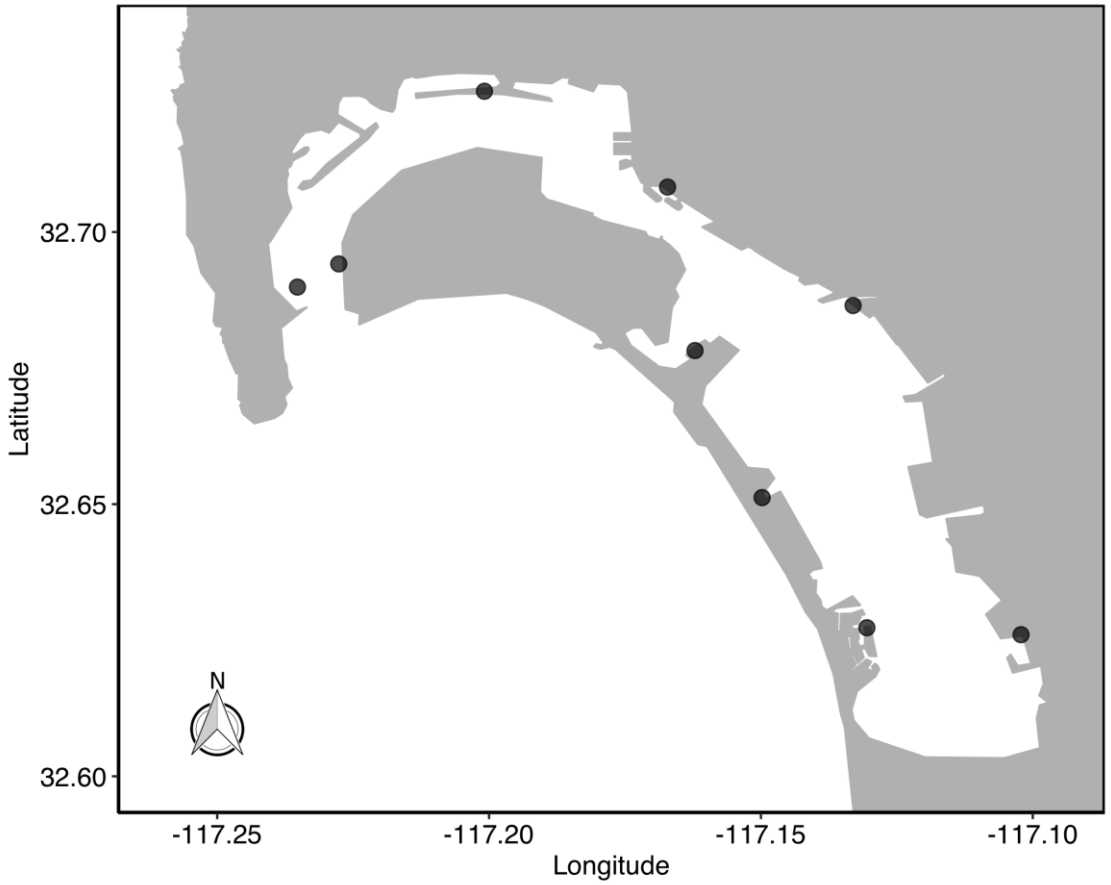

Figure A1.1.5: *Map of hard substrate community sampling locations in San Diego Bay (2021).*

Table A1.1.5: *Hard substrate community sampling locations in San Diego Bay (2021).*

Site Name	Latitude (N)	Longitude (W)
Cabrillo Isle Marina	32.726	-117.201
Chula Vista Marina	32.626	-117.102
Coronado Cays Marina	32.627	-117.131
Marriott Marquis and Marina	32.708	-117.167
NAB ACU-1 Docks	32.678	-117.162
NAB Fiddlers Cove	32.651	-117.150
Naval Base Point Loma	32.690	-117.235
Naval Station San Diego	32.687	-117.133
Navy Ammo Dock, Pier Bravo	32.694	-117.228
Pier 32 Marina	32.653	-117.108

A1.1.6: Humboldt Bay

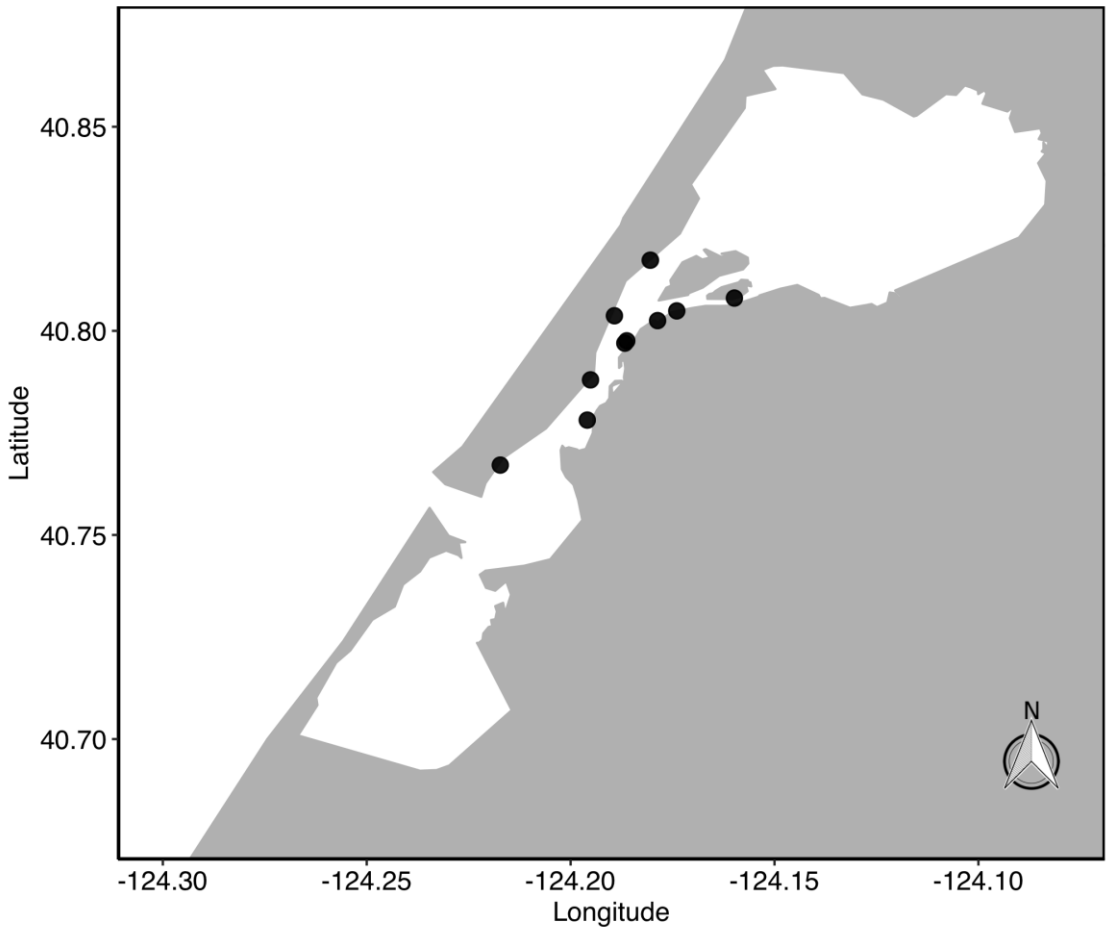

Figure A1.1.6: *Map of hard substrate community sampling locations in Humboldt Bay (2022).*

Table A1.1.6: *Hard substrate community sampling locations in Humboldt Bay (2022).*

Site Name	Latitude (N)	Longitude (W)
Chevron Station	40.778	-124.196
EZ Landing Marina	40.797	-124.187
Eureka Public Marina	40.803	-124.179
Fairhaven Terminal	40.788	-124.195
Pacific Seafood	40.805	-124.174
Redwood Terminal Berth 1	40.817	-124.181
Redwood Terminal Berth 2	40.804	-124.189
Schneider Dock (Industrial Park)	40.798	-124.186
US Coast Guard	40.767	-124.217
Woodley Island Marina	40.808	-124.160

A1.1.7: Bodega Harbor and Tomales Bay

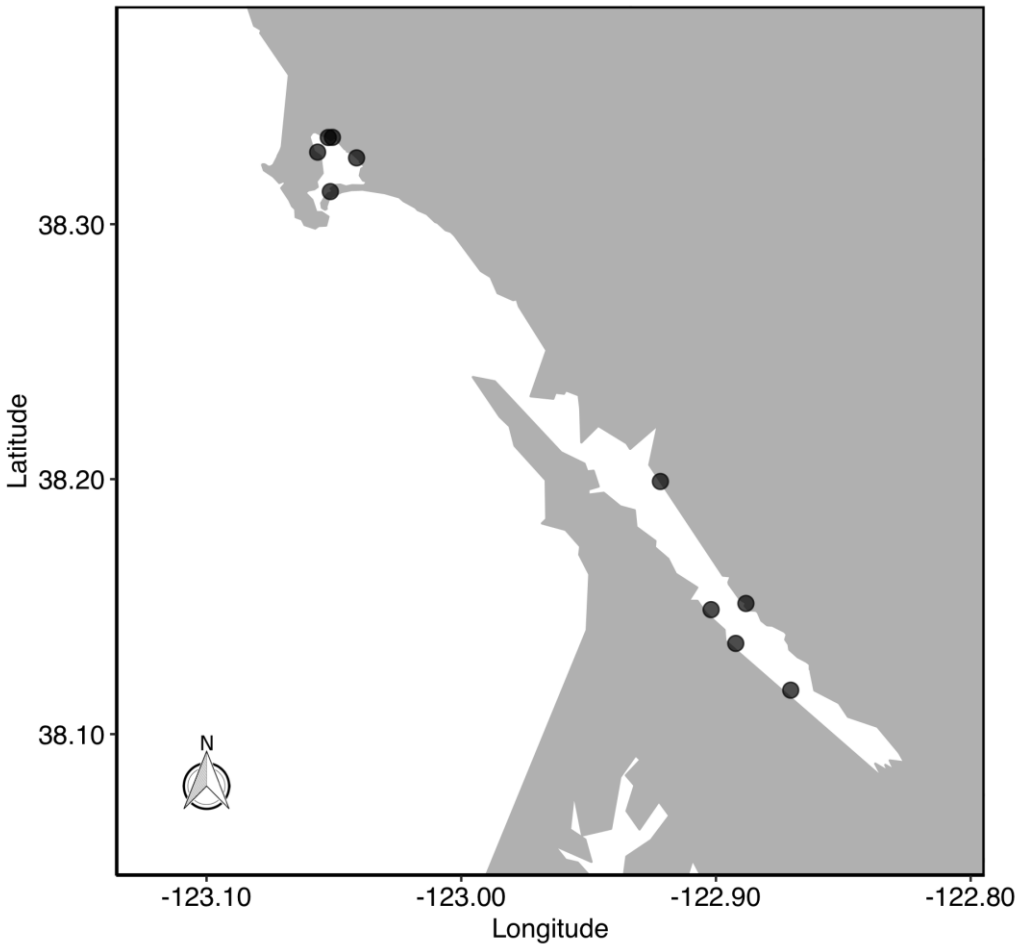

Figure A1.1.7: *Map of hard substrate community sampling locations in Bodega Harbor and Tomales Bay (2022).*

Table A1.1.7: *Hard substrate community sampling locations in Bodega Harbor and Tomales Bay (2022).*

Site Name	Latitude (N)	Longitude (W)
Coast Guard	38.313	-123.051
Lucas Wharf	38.326	-123.041
Porto Bodega - North Dock	38.334	-123.052
Porto Bodega - South Dock	38.334	-123.051
Spud Point	38.328	-123.056
Tomales - FisherSmith Boatworks	38.151	-122.888
Tomales- Duck Cove	38.149	-122.902
Tomales- Heart's Desire	38.136	-122.892
Tomales- Shell Beach	38.117	-122.871
Tomales-Nick's Cove	38.199	-122.922

Appendix 1.2: Taxonomists

This table lists taxonomists and their affiliations who assisted with morphological identifications of voucher specimens.

Table A1.2.1: *Taxonomists who assisted with morphological identifications of voucher specimens.*

Name	Affiliation	Group
Henry Choong	Royal British Columbia Museum	Hydrozoa
Erica Keppel	Smithsonian Environmental Research Center	Polychaeta
Gretchen Lambert	University of Washington	Tunicata
Megan McCuller	North Carolina Museum of Natural Sciences	Bryozoa
Marie Nydam	Soka University of America	Tunicata
Dean Pasko	Pasko Taxonomic Services	Peracarid Crustaceans
Tony Phillips	Dancing Coyote Environmental	Gastropoda
Judith Winston	Virginia Museum of Natural History	Bryozoa

Appendix 1.3: 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 was based on morphological characteristics.

A1.3.1: Los Angeles / Long Beach Harbor 2021

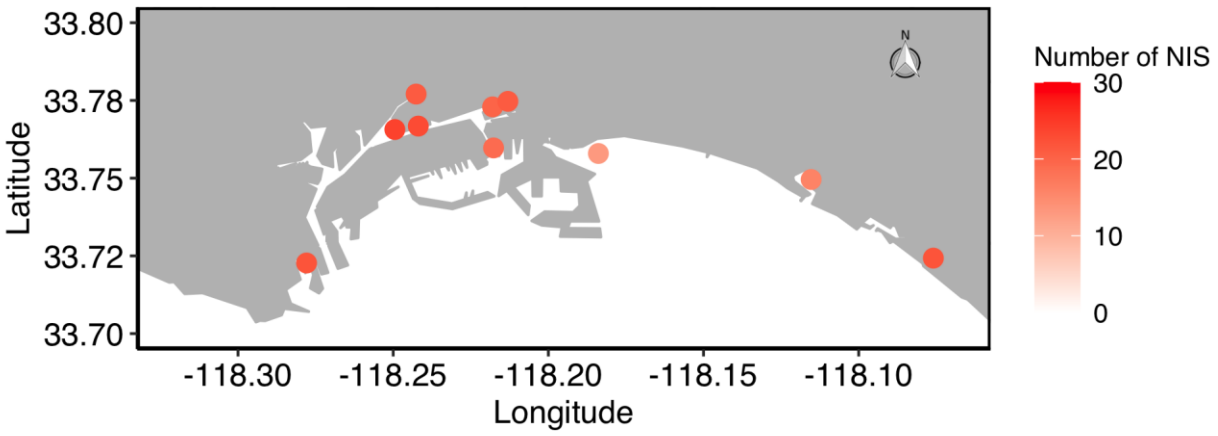

Figure A1.3.1: *Map of non-native invertebrate species richness detected in hard substrate samples from Los Angeles / Long Beach Harbor in 2021.*

A1.3.2: San Francisco Bay 2021

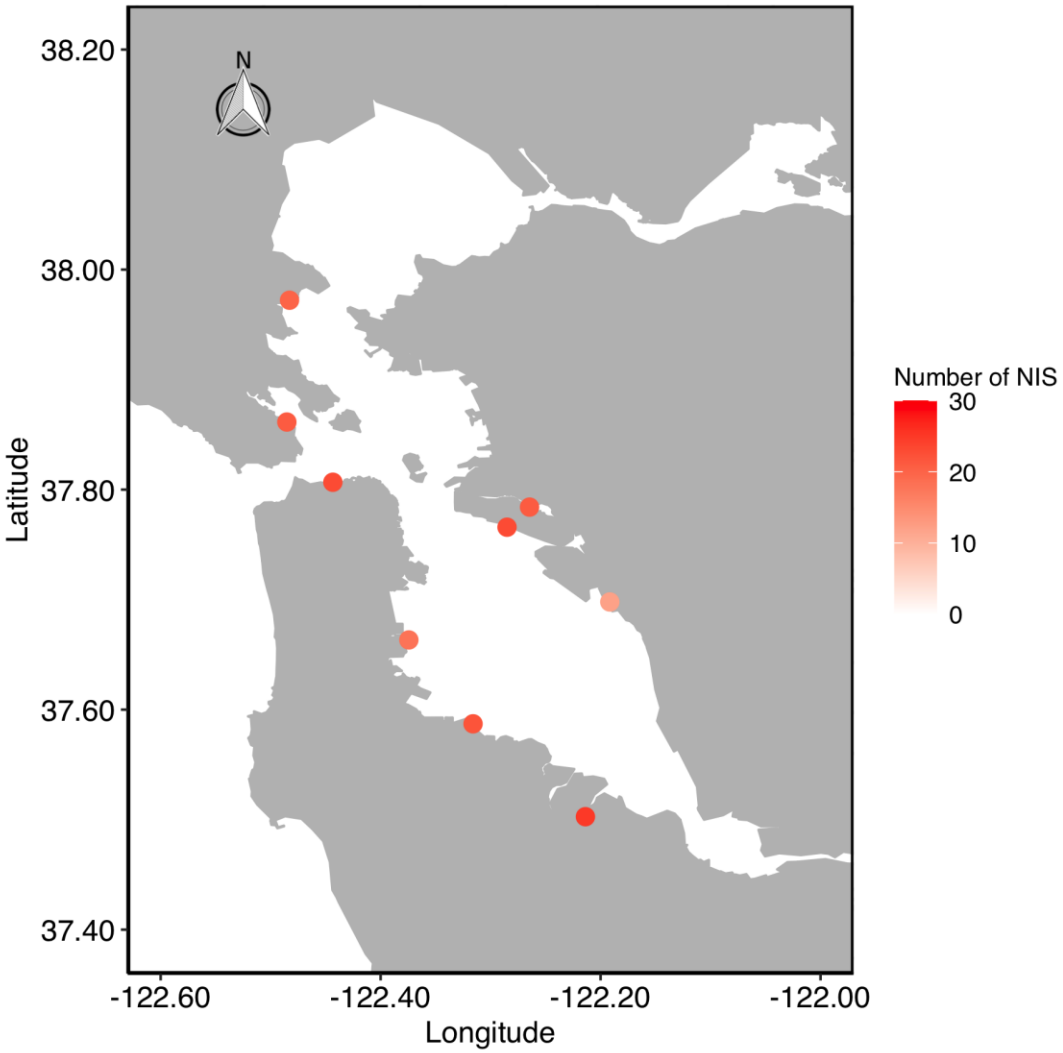

Figure A1.3.2: *Map of non-native invertebrate species richness detected in hard substrate samples from San Francisco Bay in 2021.*

A1.3.3: San Francisco Bay 2022

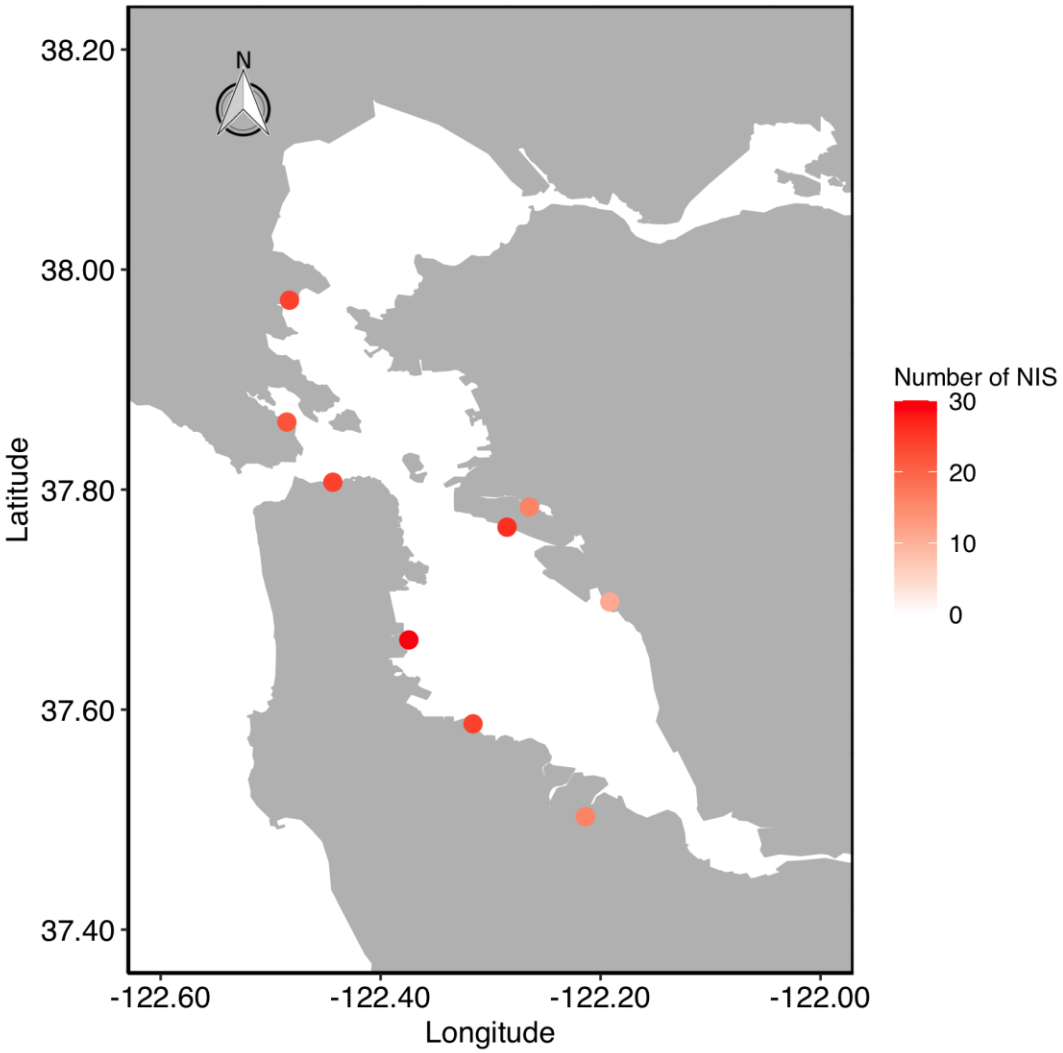

Figure A1.3.3: *Map of non-native invertebrate species richness detected in hard substrate samples from San Francisco Bay in 2022.*

A1.3.4: Santa Catalina Island 2022

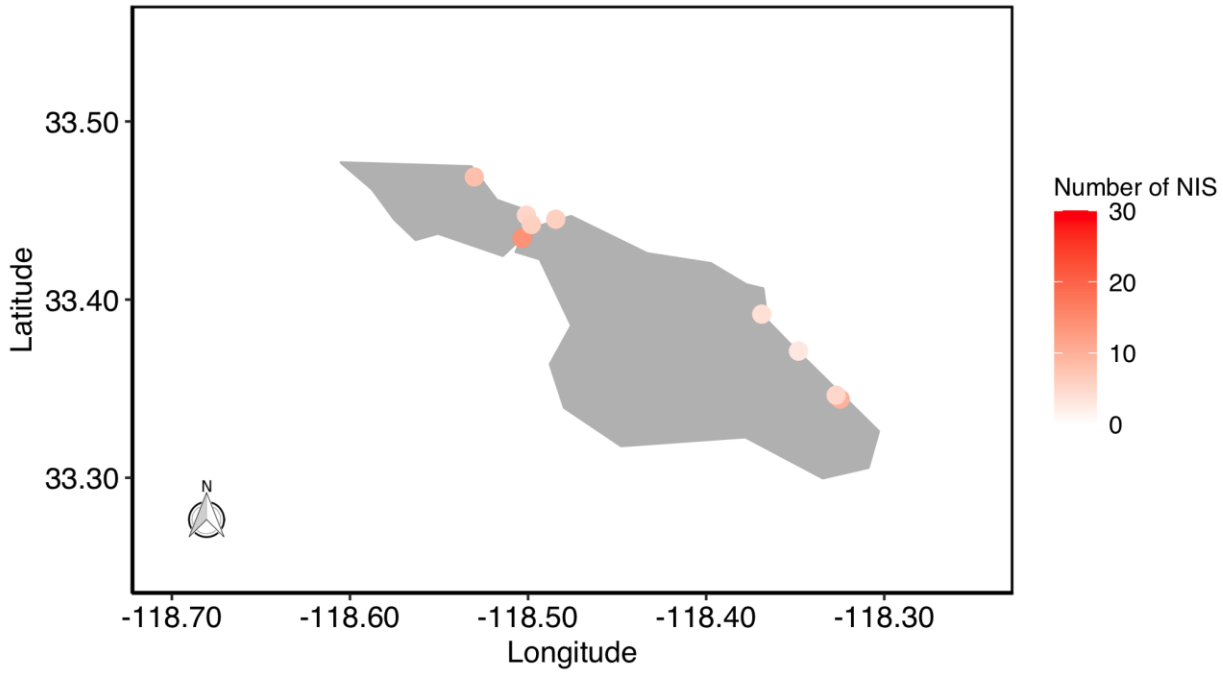

Figure A1.3.4: *Map of non-native invertebrate species richness detected in hard substrate samples from Santa Catalina Island in 2022.*

Appendix 1.4: Species Accumulation Curves and Richness Estimators by Invasion Status

Species accumulation curves (based on 1,000 random draws) show the rate at which new species are found in a given area with additional sampling and are used to assess the completeness of sampling.

A1.4.1 Los Angeles / Long Beach Harbor 2021

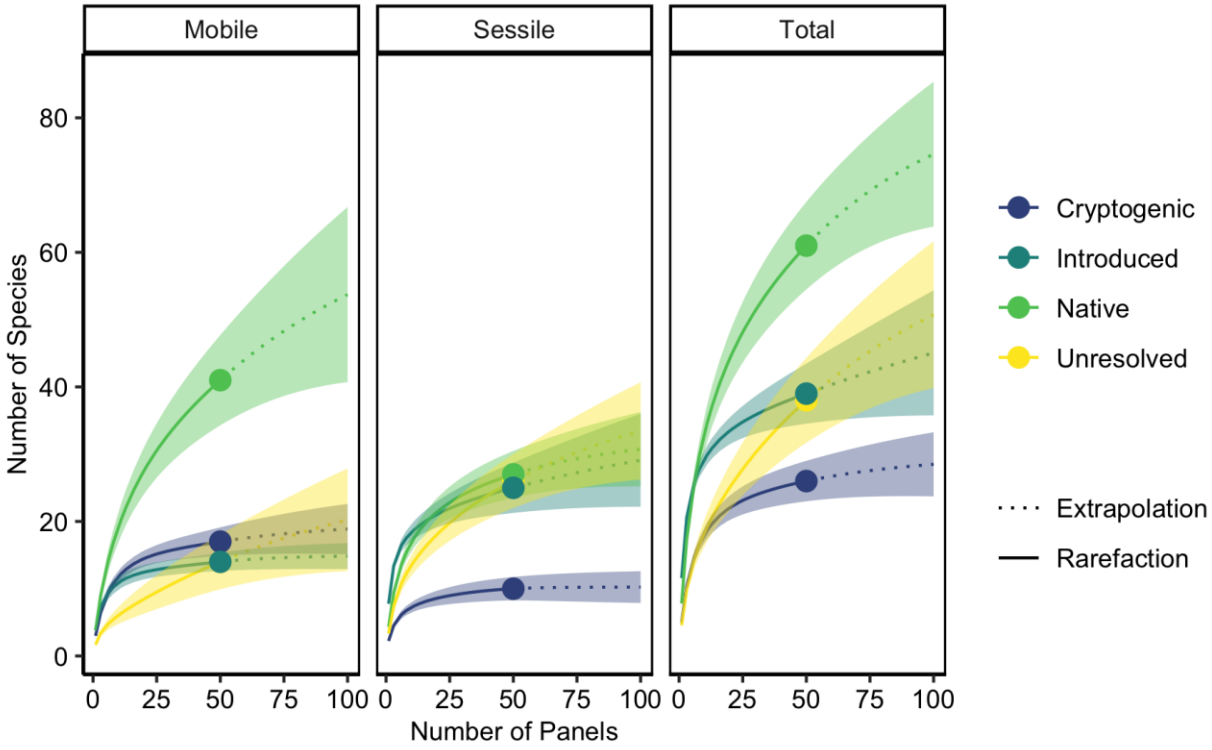

Figure A1.4.1: *Species accumulation curves (based on 1,000 random draws) by invasion status for marine macroinvertebrates in Los Angeles / Long Beach Harbor hard substrate communities in 2021. Number of species detected as a function of panels for each invasion status. Invasion status is assigned based on literature and SERC National Exotic Marine and Estuarine Species Information System (NEMESIS) database (Fofonoff et al. 2018). Here, a sample represents one settlement plate; 5 plates were analyzed from each of 10 sites in Los Angeles / Long Beach Harbor in 2021. Shading around each line represents ± 1 SE. Rarefied estimates (solid line) up to the number of observed samples (dot), beyond which estimates are extrapolated (dashed line) up to twice the size of the reference (observed) samples.*

Table A1.4.1: *Species richness estimators by invasion status for sessile, mobile, and total marine macroinvertebrates in Los Angeles / Long Beach Harbor hard substrate communities (2021). Invasion status is designated based on literature and SERC NEMESIS database (Fofonoff et al. 2018).*

Type	Status	Observed	Estimator	SE	LCL	UCL	SC
Mobile	Cryptogenic	17	19.94	3.76	17.00	27.31	98.04
Mobile	Introduced	14	14.98	1.57	14.00	18.05	98.99
Mobile	Native	41	69.32	17.93	41.00	104.46	91.25
Mobile	Unresolved	14	29.68	16.28	14.00	61.58	90.57
Mobile	Total	86	149.00	23.27	103.39	194.61	95.18
Sessile	Cryptogenic	10	10.24	1.88	10.00	13.92	99.17
Sessile	Introduced	25	37.25	12.43	25.00	61.60	98.72
Sessile	Native	27	32.88	8.51	27.00	49.57	97.29
Sessile	Unresolved	26	42.33	27.05	26.00	95.34	94.12
Sessile	Total	88	114.35	12.79	89.29	139.41	97.55
Total	Cryptogenic	26	29.92	5.63	26.00	40.95	98.42
Total	Introduced	39	63.01	14.13	39.00	90.71	98.80
Total	Native	61	85.50	18.17	61.00	121.11	94.95
Total	Unresolved	38	66.32	14.34	38.22	94.43	92.66
Total	Total	164	234.56	20.57	194.24	274.88	96.73

A1.4.2 San Francisco Bay 2021

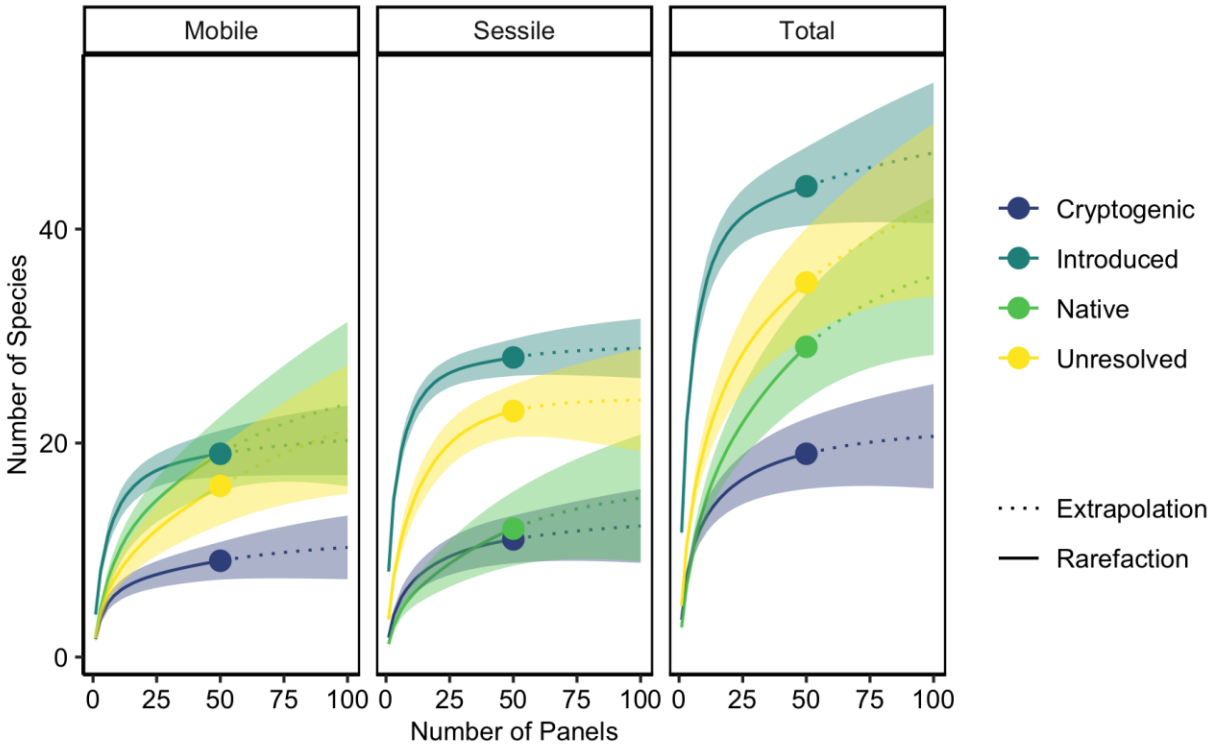

Figure A1.4.2: *Species accumulation curves (based on 1,000 random draws) by invasion status for marine macroinvertebrates in San Francisco Bay hard substrate communities in 2021. Number of species detected as a function of panels for each invasion status. Invasion status is assigned based on literature and SERC National Exotic Marine and Estuarine Species Information System (NEMESIS) database (Fofonoff et al. 2018). Here, a sample represents one settlement plate; 5 plates were analyzed from each of 10 sites in San Francisco Bay in 2021. Shading around each line represents ± 1 SE. Rarefied estimates (solid line) up to the number of observed samples (dot), beyond which estimates are extrapolated (dashed line) up to twice the size of the reference (observed) samples.*

Table A1.4.2: *Species richness estimators by invasion status for sessile, mobile, and total marine macroinvertebrates in San Francisco Bay hard substrate communities (2021). Invasion status is designated based on literature and SERC NEMESIS database (Fofonoff et al. 2018).*

Type	Status	Observed	Estimator	SE	LCL	UCL	SC
Mobile	Cryptogenic	9	10.96	2.29	9.00	15.45	97.67
Mobile	Introduced	19	20.96	2.62	19.00	26.10	99.02
Mobile	Native	19	27.00	14.17	19.00	54.77	92.68
Mobile	Unresolved	16	28.00	11.09	16.00	49.73	92.14
Mobile	Total	63	85.68	14.87	63.00	114.82	96.19
Sessile	Cryptogenic	11	12.96	2.71	11.00	18.27	97.85
Sessile	Introduced	28	28.98	1.52	28.00	31.95	99.52
Sessile	Native	12	16.08	6.97	12.00	29.74	92.00
Sessile	Unresolved	23	24.10	3.28	23.00	30.53	98.37
Sessile	Total	74	82.82	10.82	74.00	104.02	98.39
Total	Cryptogenic	19	21.20	7.01	19.00	34.95	98.32
Total	Introduced	44	51.84	7.15	44.00	65.86	99.32
Total	Native	29	38.88	9.61	29.00	57.72	92.26
Total	Unresolved	35	47.25	13.54	35.00	73.79	95.88
Total	Total	127	156.55	12.36	132.33	180.77	97.58

A1.4.3 San Francisco Bay 2022

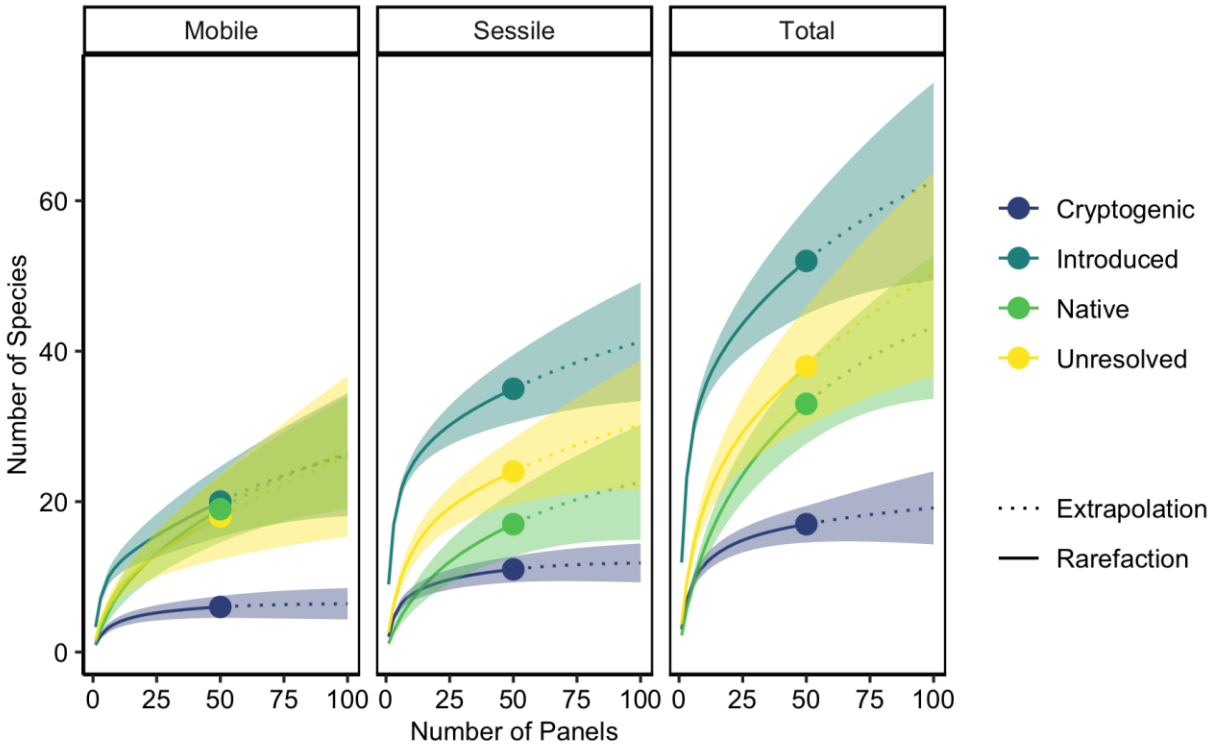

Figure A1.4.3: *Species accumulation curves (based on 1,000 random draws) by invasion status for marine macroinvertebrates in San Francisco Bay hard substrate communities in 2022. Number of species detected as a function of panels for each invasion status. Invasion status is assigned based on literature and SERC National Exotic Marine and Estuarine Species Information System (NEMESIS) database (Fofonoff et al. 2018). Here, a sample represents one settlement plate; 5 plates were analyzed from each of 10 sites in San Francisco Bay in 2022 . Shading around each line represents ± 1 SE. Rarefied estimates (solid line) up to the number of observed samples (dot), beyond which estimates are extrapolated (dashed line) up to twice the size of the reference (observed) samples.*

Table A1.4.3: *Species richness estimators by invasion status for sessile, mobile, and total marine macroinvertebrates in San Francisco Bay hard substrate communities (2022). Invasion status is designated based on literature and SERC NEMESIS database (Fofonoff et al. 2018).*

Type	Status	Observed	Estimator	SE	LCL	UCL	SC
Mobile	Cryptogenic	6	6.49	1.65	6.00	9.72	98.04
Mobile	Introduced	20	35.68	14.65	20.00	64.39	95.26
Mobile	Native	19	35.33	18.55	19.00	71.69	82.97
Mobile	Unresolved	18	57.69	17.99	22.43	92.95	88.94
Mobile	Total	63	117.88	27.08	64.81	170.95	92.19
Sessile	Cryptogenic	11	11.98	1.72	11.00	15.35	98.12
Sessile	Introduced	35	50.68	12.99	35.00	76.14	98.24
Sessile	Native	17	27.45	13.54	17.00	53.99	85.93
Sessile	Unresolved	24	39.68	15.44	24.00	69.93	93.91
Sessile	Total	87	134.32	16.55	101.88	166.76	96.52
Total	Cryptogenic	17	21.41	5.91	17.00	33.00	98.04
Total	Introduced	52	76.01	29.08	52.00	133.01	97.67
Total	Native	33	51.38	26.90	33.00	104.09	86.70
Total	Unresolved	38	74.75	28.98	38.00	131.55	92.04
Total	Total	140	217.32	21.68	174.82	259.81	95.55

A1.4.4 Santa Catalina Island 2022

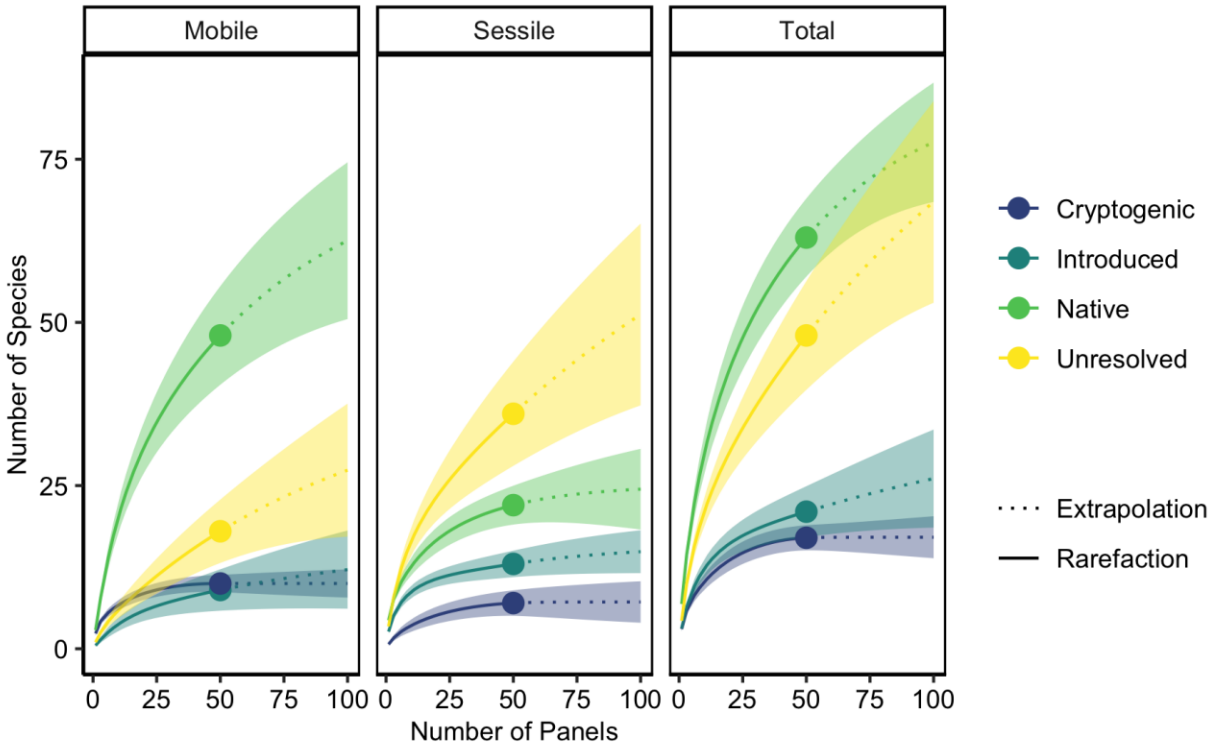

Figure A1.4.4: *Species accumulation curves (based on 1,000 random draws) by invasion status for marine macroinvertebrates in Santa Catalina Island hard substrate communities in 2022. Number of species detected as a function of panels for each invasion status. Invasion status is assigned based on literature and SERC National Exotic Marine and Estuarine Species Information System (NEMESIS) database (Fofonoff et al. 2018). Here, a sample represents one settlement plate; 5 plates were analyzed from each of 10 sites in Santa Catalina Island in 2022 . Shading around each line represents ± 1 SE. Rarefied estimates (solid line) up to the number of observed samples (dot), beyond which estimates are extrapolated (dashed line) up to twice the size of the reference (observed) samples.*

Table A1.4.4: *Species richness estimators by invasion status for sessile, mobile, and total marine macroinvertebrates in Santa Catalina Island hard substrate communities (2022). Invasion status is designated based on literature and SERC NEMESIS database (Fofonoff et al. 2018).*

Type	Status	Observed	Estimator	SE	LCL	UCL	SC
Mobile	Cryptogenic	10	10.00	1.38	10.00	12.71	100.00
Mobile	Introduced	9	16.84	7.87	9.00	32.26	84.16
Mobile	Native	48	75.01	20.10	48.00	114.40	85.54
Mobile	Unresolved	18	41.52	19.40	18.00	79.55	76.24
Mobile	Total	85	129.72	23.24	85.00	175.28	89.14
Sessile	Cryptogenic	7	7.16	2.12	7.00	11.32	97.38
Sessile	Introduced	13	15.94	2.61	13.00	21.06	97.76
Sessile	Native	22	25.06	6.20	22.00	37.22	97.78
Sessile	Unresolved	36	88.92	44.90	36.00	176.92	89.54
Sessile	Total	78	113.72	14.01	86.27	141.17	95.20
Total	Cryptogenic	17	17.08	3.58	17.00	24.09	99.47
Total	Introduced	21	38.64	14.82	21.00	67.68	96.16
Total	Native	63	86.56	12.73	63.00	111.52	93.42
Total	Unresolved	48	109.25	28.38	53.63	164.87	88.41
Total	Total	149	213.45	21.89	170.54	256.35	93.73

Appendix 1.5: Contribution of NIS to Total Species Richness per Estuary

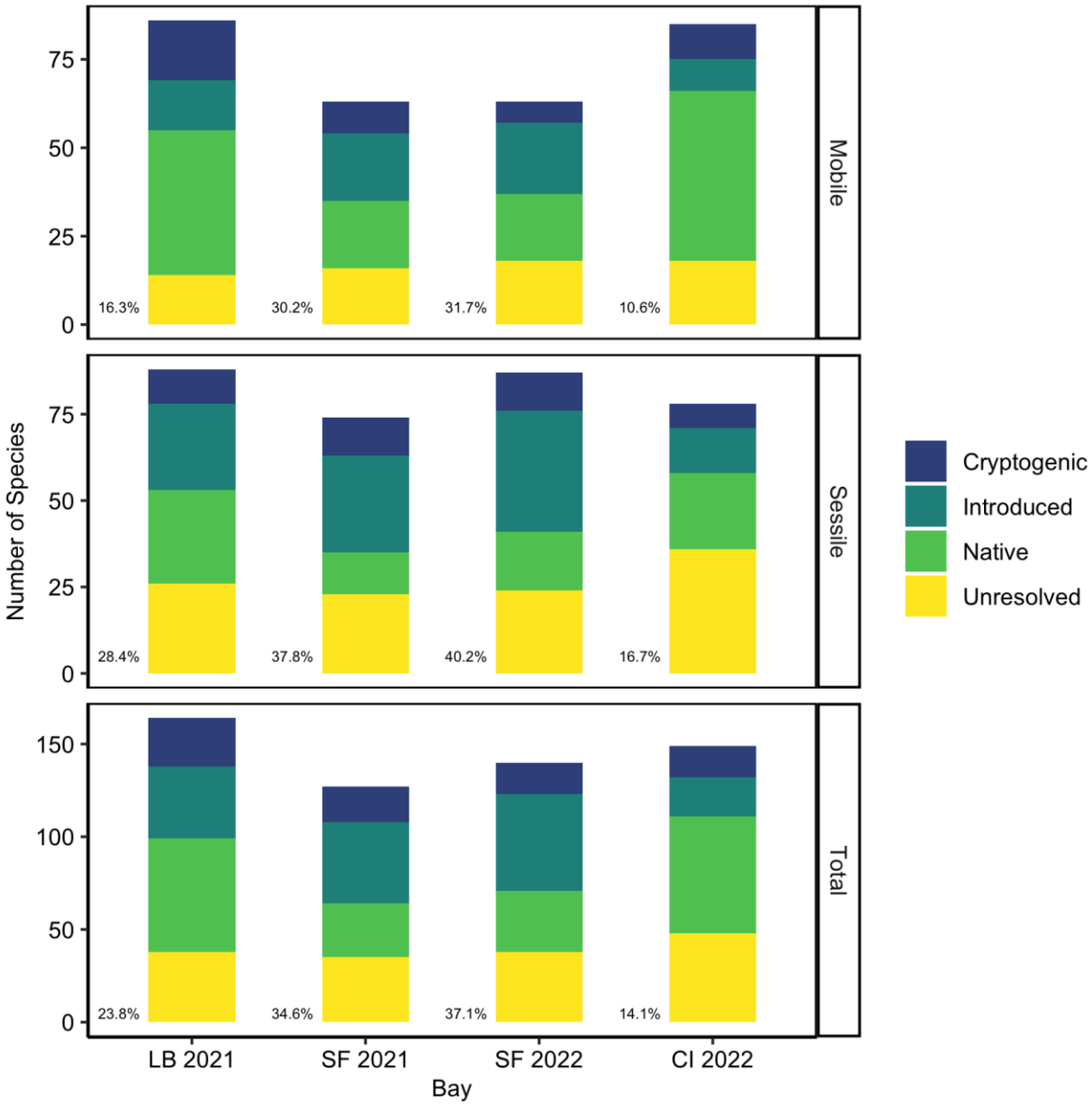

Figure A1.5.1*: Number of unique species for each sampling event by invasion status. Sampling events included hard substrate panel surveys of Los Angeles / Long Beach Harbor (LB) in 2021, San Francisco Bay (SF) in 2021 and 2022, and Santa Catalina Island (CI) in 2022. Status was assigned based on literature and SERC NEMESIS database (Fofonoff et al. 2018). Percentages to the left of each bar indicate the percentage contribution of NIS to total species richness per bay for each category.*

NIS contributed between 16.7% and 40.2% of the observed species richness per estuary for sessile invertebrates, and the percent contribution was highest in San Francisco Bay in 2022

(Figure A1.5.1). For mobile invertebrates, NIS accounted for 10.6% to 31.7% of observed richness and was again greatest in San Francisco Bay in 2022. When considering mobile and sessile invertebrates combined, NIS represented 14.1% to 31.7% of the total species richness, and again was highest in San Francisco Bay in 2022.

Appendix 1.6: NIS Richness Per Plate

A1.6.1 NIS Richness Per Plate in Los Angeles / Long Beach Harbor in 2021

The observed mean NIS richness per plate was 7.76 ± 2.24 (mean ± 1 SD) but varied among sites in Los Angeles / Long Beach Harbor in 2021 with Leeward Island Marina having the highest mean NIS richness and Alamitos Bay Marina having the lowest (Figure A1.6.1).

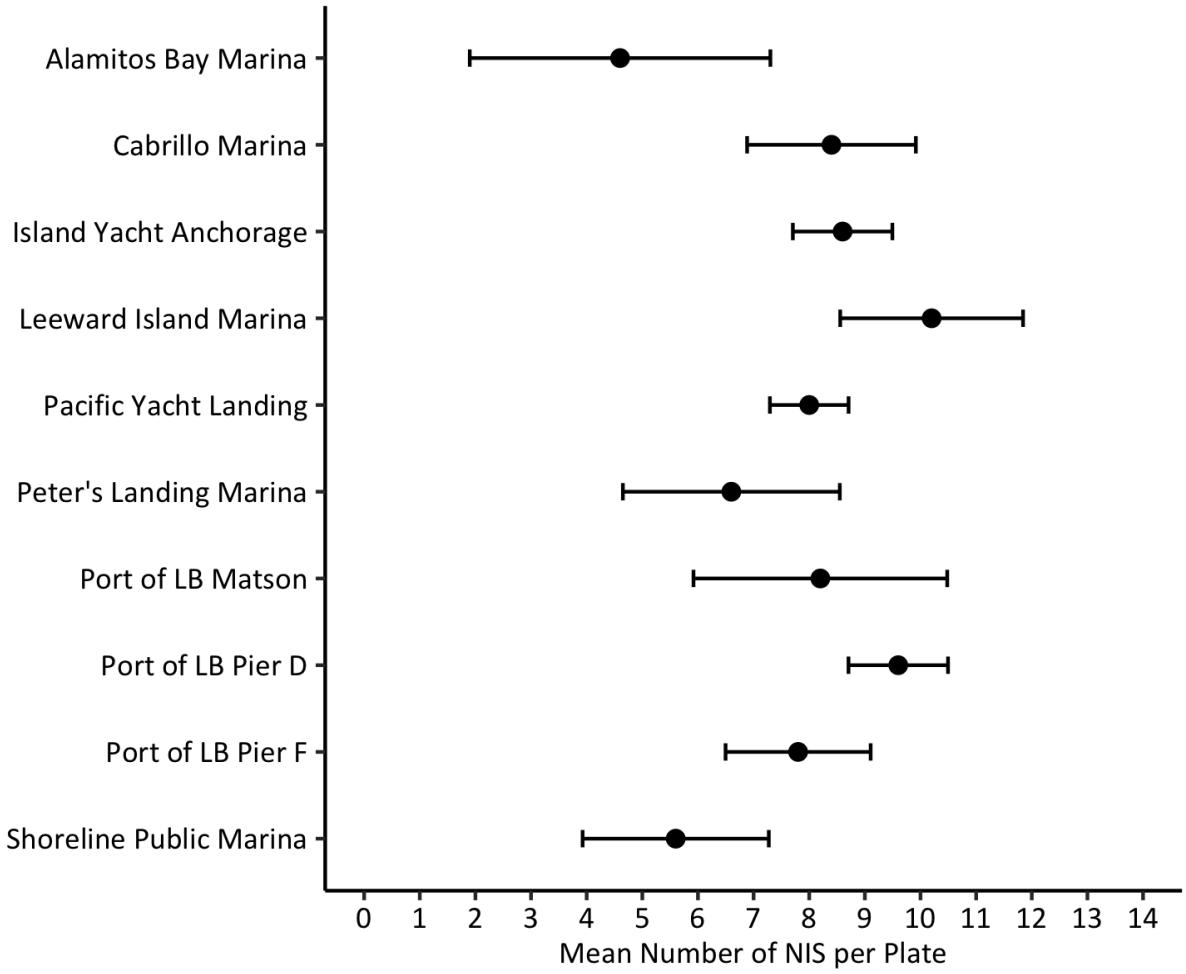

Figure A1.6.1: *Mean number of NIS detected per plate averaged within sites in Los Angeles / Long Beach Harbor in 2021. Error bars equal ± 1 SD.*

A1.6.2 NIS Richness Per Plate in San Francisco Bay in 2021

The observed mean NIS richness per plate was 8 ± 2.73 (mean ± 1 SD) but varied among sites in San Francisco Bay in 2021 with Redwood City Marina having the highest mean NIS richness and San Leandro Marina having the lowest (Figure A1.6.2).

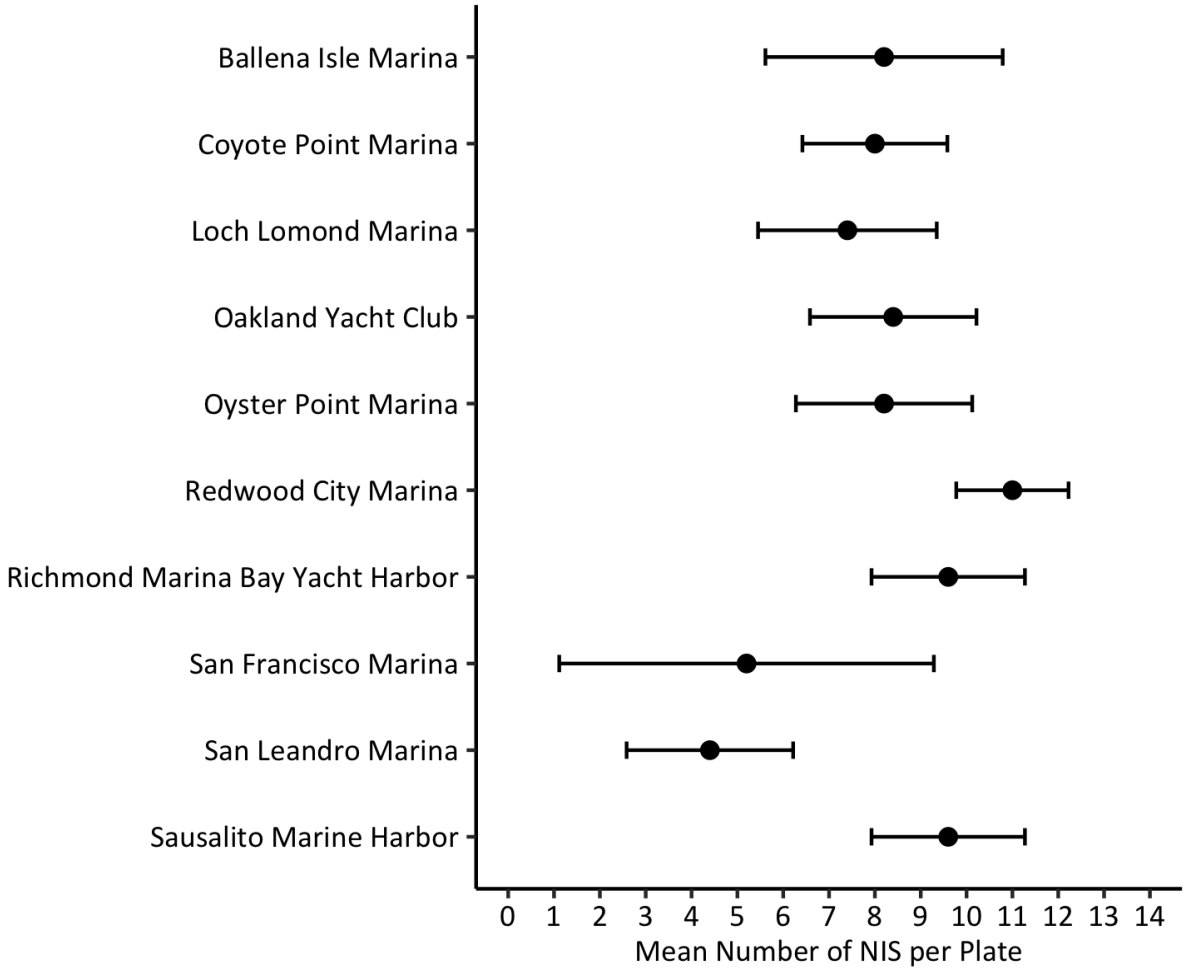

Figure A1.6.2: *Mean number of NIS detected per plate averaged within sites in San Francisco Bay in 2021. Error bars equal ± 1 SD.*

A1.6.3 NIS Richness Per Plate in San Francisco Bay in 2022

The observed mean NIS richness per plate was 9 ± 2.49 (mean ± 1 SD) but varied among sites in San Francisco Bay in 2022 with Richmond Marina Bay Yacht Harbor having the highest mean NIS richness and San Leandro Marina having the lowest (Figure A1.6.3).

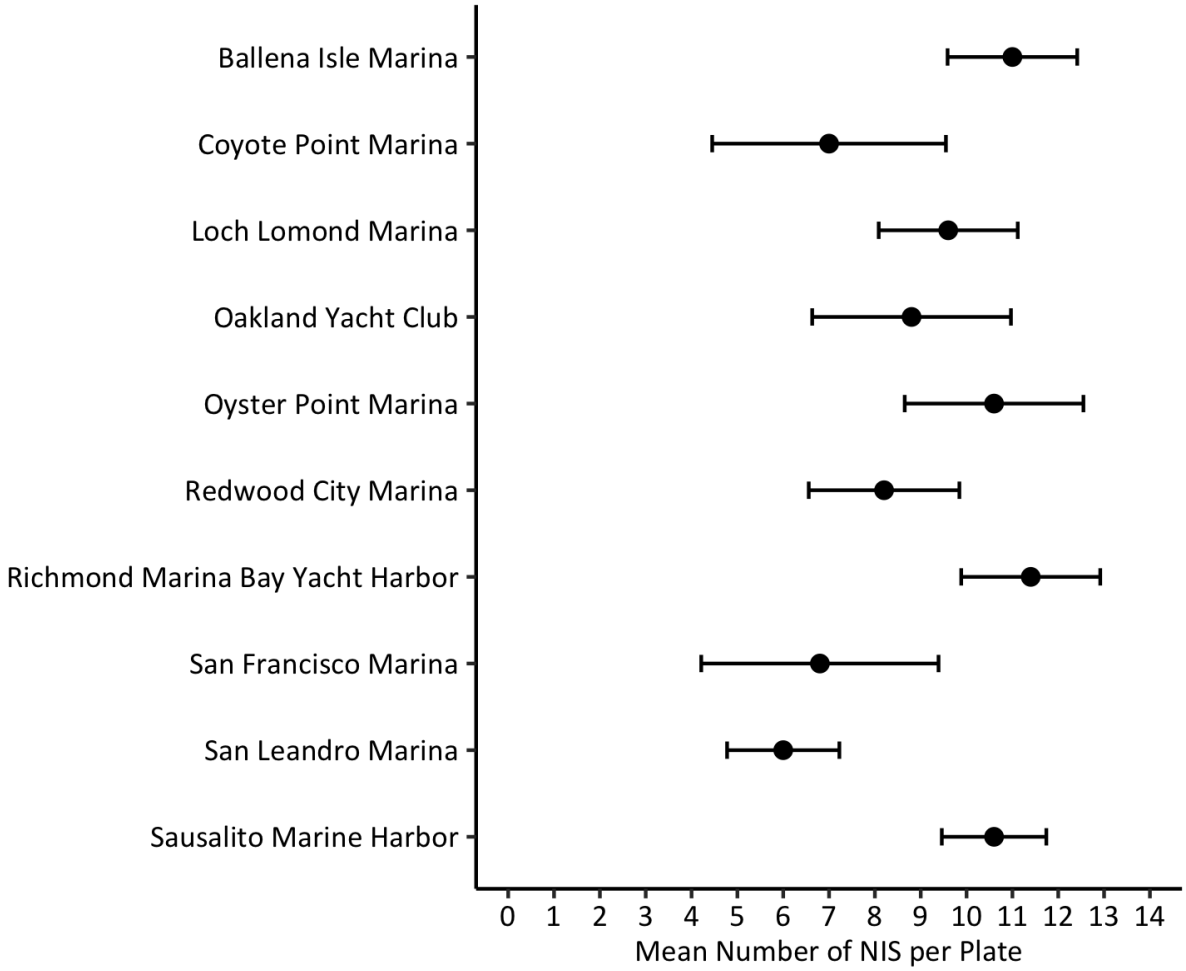

Figure A1.6.3: *Mean number of NIS detected per plate averaged within sites in San Francisco Bay in 2022. Error bars equal ± 1 SD.*

A1.6.4 NIS Richness Per Plate around Santa Catalina Island in 2022

The observed mean NIS richness per plate was 2.62 ± 1.75 (mean ± 1 SD), but varied among sites around Santa Catalina Island in 2022 with Cat Harbor having the highest mean NIS richness and Whites Cove having the lowest (Figure A1.6.4).

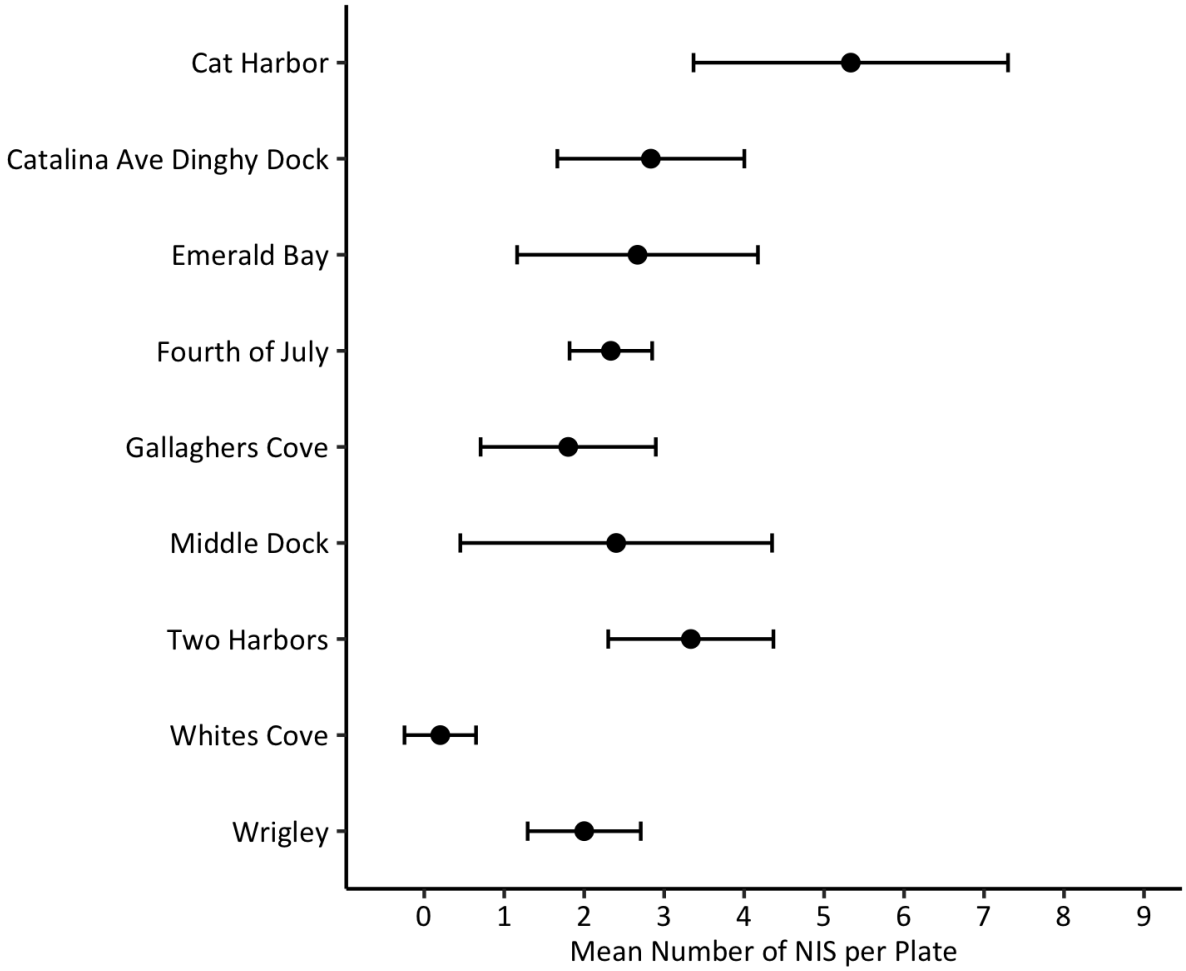

Figure A1.6.4: *Mean number of NIS detected per plate averaged within sites in Santa Catalina Island in 2022. Error bars equal ± 1 SD.*

Appendix 1.7: Relative Abundance of Sessile NIS per Plate within Bays

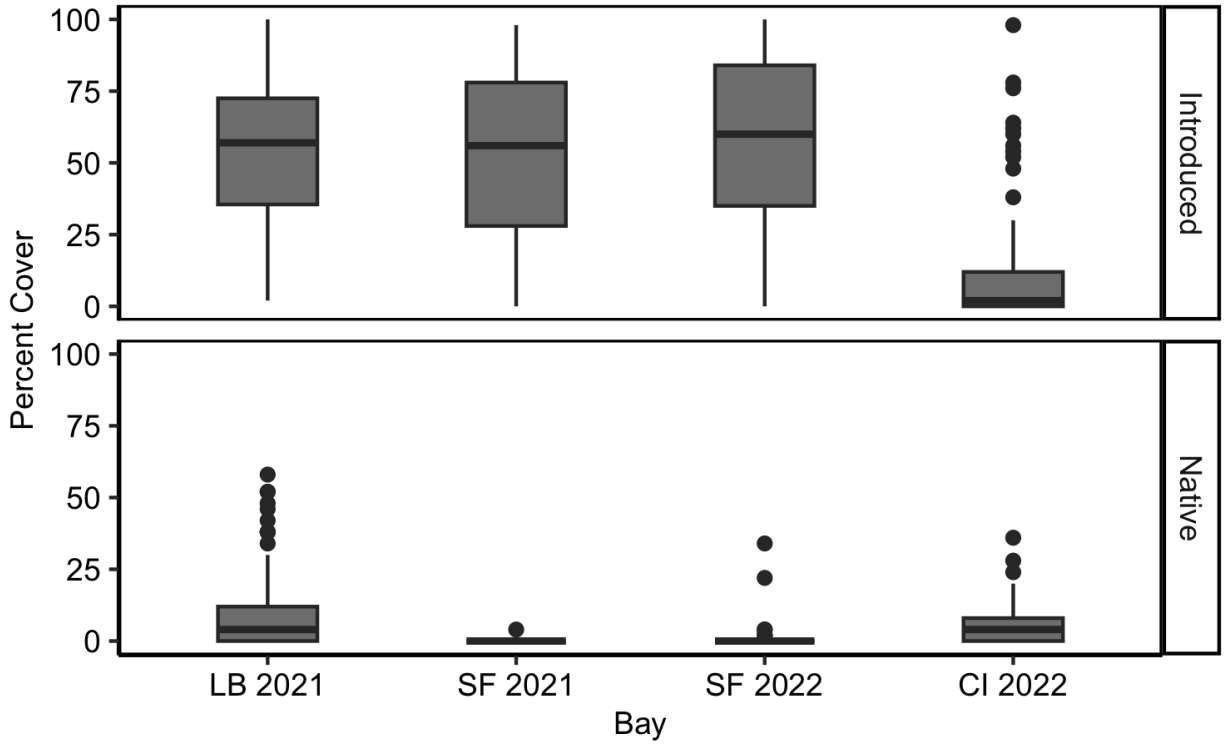

Figure A1.7.1: *Measures of percent cover of NIS (upper) and native species (lower) on plates in each bay for sessile taxa only. Sampling events included hard substrate panel surveys of Los Angeles / Long Beach Harbor (LB) in 2021, San Francisco Bay (SF) in 2021 and 2022, and Santa Catalina Island (CI) in 2022. 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 (Fofonoff et al. 2018). The lower and upper hinges of the box plots correspond to the first and third quartiles (the 25th and 75th percentiles); center line within boxes indicates medians, vertical lines indicate 95% confidence limits, and points indicate samples that extended beyond these limits.*

Appendix 1.8 Taxa Identified from Survey Events

The number of panels is given on which each taxon was observed (out of 5 per site). Species status is designated based on literature and SERC NEMESIS database (Fofonoff et al. 2018).

A1.8.1: Taxa Identified from 2021 Los Angeles / Long Beach Harbor Hard Substrate Surveys

2021 LOS ANGELES/ LONG BEACH SPECIES TABLE	Bay Species Status	Alamitos Bay Marina	Cabrillo Marina	Island Yacht Anchorage	Leeward Island Marina	Pacific Yacht Landing	Peter's Landing Marina	Port of LB Matson	Port of LB Pier D	Port of LB Pier F	Shoreline Public Marina
ALGAE											
Algae											
Chlorophyta	U		1	2	2	1					
Phaeophyceae	U			2					1		
Rhodophyta	U				2						
ARTHROPODA											
Amphipoda											
Amphilochidae	U								1		
Amphipoda	U		1								
Ampithoe lacertosa	C				1	1			1		
Ampithoe plumulosa	C							3	1		
Anamixis pacifica	N		1								
Aoroides secunda	I	2	4	5	3	4	4	3	1	2	5
Aoroides sp.	U		2								
Corophiidae	U					1					
Elasmopus bampo	C	4	3	5	2	4	4	4	3	4	5
Elasmopus sp.	U	1			1						2
Ericthonius brasiliensis	C			3			1	4	5	4	
Ericthonius sp.	U			1							
Gammaropsis sp.	N								1	3	
Hyalidae	U	1							1		
Jassa slatteryi	C			2	1				2	2	
Jassa sp.	U			2	1				1		
Laticorophium baconi	N			4	1			3	5		
Leucothoe nagatai	I	1	4	5		3					
Leucothoe sp.	U			1		1					
Leucothoe spinicarpa	C	1	2					2			
Liljeborgia geminata complex	C	3	1	1			4		1	2	
Lysianassidae	U	2	2	1		1	1		1	1	

2021 LOS ANGELES/ LONG BEACH SPECIES TABLE	Bay Species Status	Alamitos Bay Marina	Cabrillo Marina	Island Yacht Anchorage	Leeward Island Marina	Pacific Yacht Landing	Peter's Landing Marina	Port of LB Matson	Port of LB Pier D	Port of LB Pier F	Shoreline Public Marina
Metopella aporpis	N				1						
Monocorophium acherusicum	I			1	4	1					
Monocorophium insidiosum	I				1						
Monocorophium sp.	U			1						1	
Monocorophium uenoi	I						1				
Paradexamine sp.	U	1				1					
Podocerus brasiliensis	C									1	
Podocerus fulanus	N						1		1		
Podocerus sp.	U						3	1			
Shoemakerella cf. *cubensis*	I	1				1	1				
Stenothoidae	U				1		1		1		
Caprellidae											
Caprella californica	N			5	4	4	4	3	5	3	
Caprella equilibra	C						3				
Caprella mutica	I		5	5	5	5	1	4	4	5	
Caprella simia	I		1	2		1			4	1	
Caprella sp.	U	2	2				1		3		
Cirripedia											
Amphibalanus amphitrite	I							1			
Amphibalanus sp.	U							1			
Balanidae	U							1			
Balanus trigonus	N							5	4	4	
Isopoda											
Ianiropsis serricaudis	I			4		3			1	1	
Ianiropsis sp.	U	1		1		3		3	3	2	
Janiralata sp.	U					1					
Joeropsis dubia dubia	N							1			
Munnidae	U							1			
Paracerceis sculpta	N		2	2	4	4	2	4	1		
Paracerceis sp.	U			1							
Paranthura japonica	I	5	3	1	4	3	5	1		1	3
Pycnogonida											
Ammothea hilgendorfi	N							1		1	
Nymphon pixellae	N									1	
Tanystylum californicum	N								2	2	

2021 LOS ANGELES/ LONG BEACH SPECIES TABLE	Bay Species Status	Alamitos Bay Marina	Cabrillo Marina	Island Yacht Anchorage	Leeward Island Marina	Pacific Yacht Landing	Peter's Landing Marina	Port of LB Matson	Port of LB Pier D	Port of LB Pier F	Shoreline Public Marina
Tanaidae											
Zeuxo normani complex	U		5	4	3	3	1	4	5	3	4
Zeuxo sp.	U	1		1	1	1	1	1	2		1
BRYOZOA											
Bryozoa											
Amathia citrina	I									1	
Amathia sp.	U	1						1	1		
Amathia sp. *Bowerbankia*	U	2		1			1	3	5	3	
Amathia verticillata	I	3				1	1				1
Bugula neritina	I			3	5	4	3	5	5	2	
Bugulidae	U						2				
Bugulina cf. *foliolata*	I							1			
Bugulina longirostrata	N				1					1	
Bugulina stolonifera	I		3	1	5		3	5	3		
Buskia seriata	N						1				
Celleporaria brunnea	N		2		3	1	5	5	5	3	4
Celleporaria sp.	U							2		1	
Celleporina robertsoniae	N			2			4	1	5	1	
Celleporina sp.	N			2			1				
Conopeum sp.	U				1						
Crisia occidentalis	N							5	1	3	
Crisulipora occidentalis	N			3		2	2	5		3	
Cryptosula pallasiana	I	1	1	4	3	3	5	4		1	4
Diaperoeciidae	U		2								
Fenestrulina delicia	C									5	
Fenestrulina sp.	U									1	
Filicrisia franciscana	N							1	1		
Licornia diegensis	N								1		
Nevianipora floridana	I	5	3			4		3	1	5	
Nevianipora sp.	U									1	
Savignyella lafontii	C	2									
Schizoporella japonica	I				3			1			
Schizoporella occidentalae	N				1			2		3	
Schizoporella sp.	U			1	1						
Thalamoporella californica	N	4	3	5	1	4	3	1	5	5	2

2021 LOS ANGELES/ LONG BEACH SPECIES TABLE	Bay Species Status	Alamitos Bay Marina	Cabrillo Marina	Island Yacht Anchorage	Leeward Island Marina	Pacific Yacht Landing	Peter's Landing Marina	Port of LB Matson	Port of LB Pier D	Port of LB Pier F	Shoreline Public Marina
Tubulipora pacifica	N	3	1	4		4	2	3	3	5	
Tubulipora sp.	U	2	2	3	1	2	3	4	3	2	1
Watersipora arcuata	I		1	1				4	5	4	3
Watersipora subatra	I	5	5	5	5	5	5	5	5	5	3
CNIDARIA											
Anthozoa											
Actiniaria	U		1		1	1	1				2
Aiptasiidae	U				5	1					3
Diadumene sp.	U		1		4		2				1
Exaiptasia diaphana	C						2				
Hydrozoa											
Athecata	U	1					1			1	
Campanulariidae	U			1					1	1	
Halocordylidae	U	1	1								
Hydrozoa sp. B	U						2			1	
Hydrozoa sp. C	U	1									
Hydrozoa sp. D	U	2			2	1	1	2	2	2	1
Kirchenpaueriidae	U									1	
Oceaniidae	U									1	
Plumularioidea	U								1	1	
Tubulariidae	U						1				
Scyphozoa											
Scyphozoa	U						1				
ECHINODERMATA											
Ophiuroidea											
Amphipholis squamata	C								3	4	
Ophiactis simplex	N			1				2	1	1	
Ophiothrix spiculata	N								1		
MOLLUSCA											
Bivalvia											
Crassadoma gigantea	N									1	
Hiatella arctica	C				1	1		3	5	4	
Leptopecten latiauratus	N								5		
Mytilus galloprovincialis / trossulus complex	U	1	2	3	1	2	2	4	3	4	

2021 LOS ANGELES/ LONG BEACH SPECIES TABLE	Bay Species Status	Alamitos Bay Marina	Cabrillo Marina	Island Yacht Anchorage	Leeward Island Marina	Pacific Yacht Landing	Peter's Landing Marina	Port of LB Matson	Port of LB Pier D	Port of LB Pier F	Shoreline Public Marina
Mytilus sp.	U			1						1	
Ostrea lurida	N	1					1	2		1	
Ostreidae	U						1	2		1	
Sphenia sp.	U									1	
Gastropoda											
Alia carinata	N						1				
Crepidula onyx	N							2		1	
Crepipatella lingulata	N									3	
Zanassarina penicillata	N									1	
Nudibranchia											
Doto amyra	N								1		
Doto kya	N									1	
Eubranchus rustyus	N		1							1	
Nudibranchia	U									1	
Polycera atra	N				2		1		1		
Polycera hedgpethi	N							1			
Trinchesia albocrusta	N								1		
NEMERTEA											
Nemertea											
Amphiporus bimaculatus	N								1		
Nemertea	U	1					1				1
Tetrastemmatidae	U									1	
Tubulaniformes	U										1
Zygonemertes sp.	U					1				1	
Zygonemertes virescens	C		1	1						4	
PLATYHELMINTHES											
Platyhelminthes											
Acerotisa californica	N	1	4	1				2	2		3
Eurylepta aurantiaca	N		1								
Hoploplana californica	N							3			
Plagiostomum sp.	U		2		2	1	1	1	4	1	
Platyhelminthes	U								1	1	1
Prosthiostomum latocelis	N								1	1	
Pseudoceros mexicanus	N				1						
Stylostomum lentum	N		1	1	1	1	2				

2021 LOS ANGELES/ LONG BEACH SPECIES TABLE	Bay Species Status	Alamitos Bay Marina	Cabrillo Marina	Island Yacht Anchorage	Leeward Island Marina	Pacific Yacht Landing	Peter's Landing Marina	Port of LB Matson	Port of LB Pier D	Port of LB Pier F	Shoreline Public Marina
POLYCHAETA											
Capitellidae											
Capitella capitata complex	C	1		2					2	1	
Chrysopetalidae											
Paleanotus bellis	N			1				3		2	
Cirratulidae											
Cirratulidae	U					1					
Dorvilleidae											
Ophryotrocha sp.	C	1	4	1			2				
Schistomeringos longicornis	N		1		1						
Eunicidae											
Paucibranchia disjuncta	N						1				
Hesionidae											
Hesionidae	U									1	
Oxydromus pugettensis	N				1	2					
Nereididae											
Neanthes acuminata complex	C			3		2	1				
Nereididae	U									1	
Platynereis bicanaliculata	N		4	1					3		
Opheliidae											
Armandia brevis	N									1	
Polychaeta											
Polychaeta	U			3	1	2	2	2	4	1	1
Polynoidae											
Halosydna brevisetosa	N	1	2	3	2	5	1	3	5	4	
Halosydna johnsoni	N			1		1			3	2	
Halosydna sp.	U							1		2	
Harmothoe imbricata complex	C		3	3	3	2			3	3	
Polynoidae	U		1								
Sabellidae											
Acromegalomma sp.	U						1				
Branchiomma sp. SF	I				1		3	2	4	3	
Paradialychone ecaudata	N			1	1			3	2	1	
Parasabella pallida	N						3				
Serpulidae											

2021 LOS ANGELES/ LONG BEACH SPECIES TABLE	Bay Species Status	Alamitos Bay Marina	Cabrillo Marina	Island Yacht Anchorage	Leeward Island Marina	Pacific Yacht Landing	Peter's Landing Marina	Port of LB Matson	Port of LB Pier D	Port of LB Pier F	Shoreline Public Marina
Hydroides elegans	C			1				1	2	1	4
Hydroides gracilis	N						1	3	4	2	
Hydroides sp.	U	1	2					1	1		1
Salmacina tribranchiata	N	2	4			5		1	1		3
Serpulidae	U				1						
Spionidae											
Boccardiella hamata	C							1			
Polydora narica	N			1				2	1	1	
Polydora sp.	U									1	
Spionidae	U									2	
Spirorbidae											
Neodexiospira alveolata	C	5				2	1	4	5	4	
Neodexiospira pseudocorrugata	C	3	4	4	5	4	5	1	2		5
Neodexiospira sp.	U		1								
Simplaria pseudomilitaris	N	2		1				1		2	
Simplaria sp.	U	3	4	2	1	4	3	2	2	3	3
Spirorbidae	U		1					1	1		
Syllidae											
Amblyosyllis nigrolineata	I	1		1	2	2	1				
Amblyosyllis sp.	U				1						
Autolytinae	U							2	1	1	
Erinaceusyllis sp.	U				1						
Eusyllinae	U								1		
Exogone lourei	C										1
Megasyllis nipponica	I		4	4	4	5	3	2	4	3	
Myrianida pachycera	I				1	3					1
Myrianida pentadentata	I		2	1		5	1	2		4	
Myrianida sp.	U		1			1		2	4	1	
Odontosyllis sp.	U						1				
Salvatoria brevipharyngea	C	1									
Salvatoria sp.	U		1								
Syllidae	U	1	1					1		1	
Syllis sp.	U	1						2		3	
Terebellidae											

2021 LOS ANGELES/ LONG BEACH SPECIES TABLE	Bay Species Status	Alamitos Bay Marina	Cabrillo Marina	Island Yacht Anchorage	Leeward Island Marina	Pacific Yacht Landing	Peter's Landing Marina	Port of LB Matson	Port of LB Pier D	Port of LB Pier F	Shoreline Public Marina
Eupolymnia heterobranchia	N				1		1				
Nicolea cf. *amnis*	U			1					5	3	
Streblosoma sp. B	U								1		
Terebellidae	U				1	1	1	1	1	1	
PORIFERA											
Porifera											
Porifera	U						1				
Porifera sp. A	U	5		1	2	2	4	2			2
Porifera sp. B	U	1		2	4	2	2	4	1	3	1
Porifera sp. C	U	4	1	3		5	1	3	3	4	5
TUNICATA											
Tunicata											
Aplidium accarense	I		2	1							
Aplidium sp.	U		1	4	4	4	3		1		4
Aplousobranchia	U	1	2			1					
Ascidia sp.	U		1					2			
Ascidia zara	I					1	1				
Ascidiella aspersa	I	1	1	4	3	2		1	4	2	1
Ascidiidae	U		1			2	1	1	1	1	
Botryllinae	U	3	1		2	2	2	1	1	1	1
Botrylloides diegensis	C		2	5	1	3	1	3	1		3
Botrylloides sp.	U	2	2	3	3	2	2	1	1	4	1
Botrylloides violaceus	I	1	3	3		2	1			2	1
Botryllus schlosseri	I	3	5	4	5	3	5	2	2	2	4
Ciona robusta	I	2	4	5	5	5	2		4	2	4
Ciona savignyi	I	1	5	3	5	5		2	4	5	3
Ciona sp.	I		1	2			2	2	2	2	
Didemnidae	U								3	1	
Didemnum cf. *vexillum*	I								1		
Diplosoma listerianum	I	1	5	5	5	5	2	3	5	4	4
Diplosoma sp.	U	1					1				2
Distaplia sp.	U				1		1			1	
Molgula ficus	I				4		1		1		
Molgula sp.	U				3		1		1	1	
Stolidobranchia	U									1	

2021 LOS ANGELES/ LONG BEACH SPECIES TABLE	Bay Species Status	Alamitos Bay Marina	Cabrillo Marina	Island Yacht Anchorage	Leeward Island Marina	Pacific Yacht Landing	Peter's Landing Marina	Port of LB Matson	Port of LB Pier D	Port of LB Pier F	Shoreline Public Marina
Styela plicata	I		3	4	2		1	2	4	1	
Styela sp.	U		2	2	3	2	1		5	3	
Symplegma sp.	I		1								
Tunicata	U							1			

A1.8.2: Taxa Identified from 2021 San Francisco Bay Hard Substrate Surveys

2021 SAN FRANCISCO BAY SPECIES TABLE	Bay Species Status	Ballena Isle Marina	Coyote Point Marina	Loch Lomond Marina	Oakland Yacht Club	Oyster Point Marina	Redwood City Marina	Richmond Marina Bay	San Francisco Marina	San Leandro Marina	Sausalito Marine Harbor
ALGAE											
Algae											
Algae	U	1	1	1	1	1			1	2	
Chlorophyta	U		2	2	2		2		4	4	1
Phaeophyceae	U					3			2		1
Rhodophyta	U	1	1		1	3	1		4		1
ATHROPODA											
Amphipoda											
Amphipoda	U	1									
Ampithoe lacertosa	C				2		3	3	1		1
Ampithoe sp.	U				1						
Anamixis pacifica	N	2	3		4	4	5	5			
Aoroides secunda	I	4		4			3	3	2		4
Aoroides sp.	U	1							1		
Aoroides spinosus	N	1									
Corophiidae	U				1						
Ericthonius brasiliensis	C								1		
Grandidierella japonica	I		1							1	
Jassa slatteryi	C								1		1
Jassa sp.	U										2
Laticorophium baconi	N				2		1		3		1
Leucothoe alata	C	5	4	5	1	2	1	5			
Liljeborgia geminata complex	C				2			3			
Melita nitida	I			1							
Melita rylovae	I						3	4			
Microjassa sp.	U								1		
Monocorophium acherusicum	I	2	2	1				3		1	
Monocorophium insidiosum	I	1	4				1	1		2	
Monocorophium sp.	U	1					1	1		1	

2021 SAN FRANCISCO BAY SPECIES TABLE	Bay Species Status	Ballena Isle Marina	Coyote Point Marina	Loch Lomond Marina	Oakland Yacht Club	Oyster Point Marina	Redwood City Marina	Richmond Marina Bay	San Francisco Marina	San Leandro Marina	Sausalito Marine Harbor
Monocorophium uenoi	I	1	1					1		2	
Paradexamine sp.	U			2				1		1	1
Stenothoidae	U										1
Caprellidae											
Caprella californica	N								2		5
Caprella mutica	I	1			4			3			5
Caprella scaura	I				1	1		2			
Caprella simia	I		5	1	1	1	5		3		2
Caprella sp.	U				2				1		4
Cirripedia											
Amphibalanus amphitrite	I				4		4	1			
Amphibalanus improvisus	I				1	2	1	1	2		2
Amphibalanus sp.	U							1			
Balanidae	U								1		
Isopoda											
Ianiropsis analoga	N	2			3			2			
Ianiropsis serricaudis	I	3			2			4	1		1
Ianiropsis sp.	U				1		1	3	1		4
Munna stephenseni	N	2									
Paranthura japonica	I	5	3	4	2	4	5	5	1	2	5
Pycnogonida											
Ammothea hilgendorfi	N										2
Phoxichilidium femoratum	N									1	
Pycnogonida	U			1							
Tanaidae											
Anatanais pseudonormani	N								3	1	
Zeuxo sp.	U								1		
BRYOZOA											
Bryozoa											
Amathia sp. *bowerbankia*	C	5	3	2	3	1	5		2	5	5
Amathia verticillata	I				4						
Bugula neritina	I	4	5	5	4	3	3	5	3	5	5
Bugulidae	U								1		

2021 SAN FRANCISCO BAY SPECIES TABLE	Bay Species Status	Ballena Isle Marina	Coyote Point Marina	Loch Lomond Marina	Oakland Yacht Club	Oyster Point Marina	Redwood City Marina	Richmond Marina Bay	San Francisco Marina	San Leandro Marina	Sausalito Marine Harbor
Bugulina longirostrata	N	1									
Bugulina stolonifera	I	5	3	2	1	2	3	3	1	4	5
Buskia seriata	N	1								1	
Candidae	U				1						
Celleporella hyalina	C								2		
Conopeum reticulum	C										1
Conopeum sp.	U		1	1			1	1	1		3
Conopeum tenuissimum	I						2		1		3
Crisularia pacifica	N					1			1		
Cryptosula pallasiana	I	1						1	1	5	
Ctenostomatida	U		1								
Electra monostachys	I	1									
Fenestrulina delicia	C								1		2
Filicrisia franciscana	N								1		
Schizoporella japonica	I								1	1	5
Smittoidea prolifica	N										1
Tricellaria inopinata	C		1	1	3	4		1		1	1
Watersipora subatra	I	2	1	1		1		4	4		5
CNIDARIA											
Anthozoa											
Actiniaria	U	2				1	3	1		3	
Diadumene franciscana	I		1				4				
Diadumene leucolena	I						1				
Diadumene lineata	I	3					1	1			
Diadumene sp.	U	3		1		2	2	1		1	
Hydrozoa											
Athecata	U			2		1	1				1
Bougainvilliidae	U								1	2	
Campanulariidae	U	1						2	1		
Eudendriidae	U				1						2
Haleciidae	U			1							
Hydrozoa sp. D	U		1	1	1	1			2	1	1
Hydrozoa sp. E	U						2			3	

2021 SAN FRANCISCO BAY SPECIES TABLE	Bay Species Status	Ballena Isle Marina	Coyote Point Marina	Loch Lomond Marina	Oakland Yacht Club	Oyster Point Marina	Redwood City Marina	Richmond Marina Bay	San Francisco Marina	San Leandro Marina	Sausalito Marine Harbor
Thecata	U	1	1								
Tubulariidae	U				1			1			
Scyphozoa											
Scyphozoa	U	2				1	1				
ENTOPROCTA											
Kamptozoa											
Barentsia sp.	U		2				2				
Kamptozoa	U	2	3	1	1	3	2			4	2
MOLLUSCA											
Bivalvia											
Arcuatula senhousia	I				4		5		1		
Hiatella arctica	C								1		
Ostrea lurida	N	3		1	4	3			1		3
Ostreidae	U		1		1	1			1		1
Ruditapes philippinarum	I		1		1				1		
Gastropoda											
Crepidula onyx	N								1		
Haminoea japonica	I		1			1	1			1	
Nudibranchia											
Coryphella verrucosa	N										1
Janolus barbarensis	N										1
Polycera hedgpethi	N										1
Sakuraeolis enosimensis	I										1
NEMERTEA											
Nemertea											
Tubulanidae	U	1									
Tubulaniformes	U	2	2			1				3	
OLIGOCHAETA											
Oligochaeta											
Oligochaeta	U									1	
PLATYHELMINTHES											
Platyhelminthes											
Acerotisa californica	N							4	1		1

2021 SAN FRANCISCO BAY SPECIES TABLE	Bay Species Status	Ballena Isle Marina	Coyote Point Marina	Loch Lomond Marina	Oakland Yacht Club	Oyster Point Marina	Redwood City Marina	Richmond Marina Bay	San Francisco Marina	San Leandro Marina	Sausalito Marine Harbor
Eurylepta aurantiaca	N				1	3	2				
Plagiostomum sp.	U	3	1	1	1		5	5	1		4
Platyhelminthes	U	1							2		2
POLYCHAETA											
Capitellidae											
Capitella capitata complex	C	1	2		2		2			1	
Cirratulidae											
Cirratulidae	U					1		1		1	
Cirratulus multioculatus	N								1		
Cirriformia sp.	N		5	1	1	4	5			2	1
Ctenodrilus serratus	C							1	1		1
Ctenodrilus sp.	U						1				
Dorvilleidae											
Ophryotrocha sp.	U	4	1	2	3	2	5				
Schistomeringos longicornis	N							1			
Eunicidae											
Marphysa sp.	U									1	
Lumbrineridae											
Lumbrineris sp.	N				2						
Nereididae											
Neanthes acuminata complex	C				1			5			
Nereididae	U								2		1
Platynereis bicanaliculata	N					1			2		3
Polychaeta											
Polychaeta	U		2	1	1		1	2		1	3
Polynoidae											
Harmothoe imbricata complex	C	1	4		5	5	1			1	5
Sabellidae											
Parasabella pallida	N	1			4		5	1			
Sabellidae	U				1						

2021 SAN FRANCISCO BAY SPECIES TABLE	Bay Species Status	Ballena Isle Marina	Coyote Point Marina	Loch Lomond Marina	Oakland Yacht Club	Oyster Point Marina	Redwood City Marina	Richmond Marina Bay	San Francisco Marina	San Leandro Marina	Sausalito Marine Harbor
Serpulidae											
Ficopomatus enigmaticus	I			1			4				
Hydroides sp.	U				2						
Spionidae											
Dipolydora socialis	C	1						1			1
Dipolydora sp.	U	1						1			
Polydora cornuta	I	1		2	1	4	2	2	3		1
Polydora narica	N								1		4
Polydora sp.	U								1		
Spionidae	U							1		1	
Spirorbidae											
Spirorbidae	U	2					1		1		
Syllidae											
Amblyosyllis nigrolineata	I	2		3							
Erinaceusyllis sp. 8 Harris	U	1	2							1	
Exogone lourei	C	2	4			1	1	1	1		4
Megasyllis nipponica	I	5	4	5	3	4	4	5	5		1
Myrianida pentadentata	I								1		4
Myrianida sp.	U										1
Syllidae	U	1	1	1							2
Syllis sp.	U	2		4	1		2	1			
Terebellidae											
Neoamphitrite sp. A	I		4			1	4				
Nicolea cf. *amnis*	U	5			4			5			
Terebellidae	U	1			1		1				
PORIFERA											
Porifera											
Clathria prolifera	U		1								
Porifera	U						1			1	
Porifera sp. A	U	3	4	3	3	3	5	1	3	3	5
Porifera sp. B	U	5	2	2	3	5	4	2	2	2	3
Porifera sp. C	U	2				2					1
Protista											

2021 SAN FRANCISCO BAY SPECIES TABLE	Bay Species Status	Ballena Isle Marina	Coyote Point Marina	Loch Lomond Marina	Oakland Yacht Club	Oyster Point Marina	Redwood City Marina	Richmond Marina Bay	San Francisco Marina	San Leandro Marina	Sausalito Marine Harbor
Protista											
Protista sp. B	U								1	1	
Protista sp. C	U		1						1	2	
Protista sp. D	U	1	3	1	2	2	2	1		2	2
Protista sp. E	U	1							1		
TUNICATA											
Tunicata											
Aplousobranchia	U							1	1		
Ascidia sp.	U	1			1		1			1	
Ascidia zara	I	5	5	4	5	5	3	4	1	2	
Ascidiidae	U								1		
Botryllinae	U	2	1	1	2	1	1	2	2	2	2
Botrylloides diegensis	C	4	2	1	3	5	2	4	1		5
Botrylloides sp.	U	4	1	2	2	2		2	2		3
Botrylloides violaceus	I	1		3	1			3	1		4
Botryllus schlosseri	I	5	3	4	3	4	2	4	1		3
Ciona robusta	I	3	4	1	5	5	5	5	1		1
Ciona savignyi	I	4	1	5	5	5	4	5	1		5
Ciona sp.	I	3	3	1			1		1	1	2
Didemnidae	U	2	3	1	3	5		5	3		3
Didemnum vexillum	I		1		1				2		4
Diplosoma listerianum	I	3	4	3	2	4	5	5	1		5
Distaplia sp.	U								1		
Molgula manhattensis	I	3	5	5		3	1	4		4	
Molgula sp.	U	1				1	3			3	
Perophora annectens	N							2			
Perophora sp.	U						1				
Perophoridae	U							1			
Stolidobranchia	U				2		2	1		1	
Styela clava	I		1	1		1					
Styela sp.	U	5	1	1	2	2	1		2	2	5

A1.8.3: Taxa Identified from 2022 San Francisco Bay Hard Substrate Surveys

2022 SAN FRANCISCO SPECIES TABLE	Bay Species Status	Ballena Isle Marina	Coyote Point Marina	Loch Lomond Marina	Oakland Yacht Club	Oyster Point Marina	Redwood City Marina	Richmond Marina Bay	San Francisco Marina	San Leandro Marina	Sausalito Marine Harbor
ALGAE											
Algae											
Algae	U		1			1			2	4	
Chlorophyta	U			1		2			1		
Phaeophyceae	U					1					
Rhodophyta	U					4			3		
ARTHROPODA											
Amphipoda											
Amphipoda	U			1				1			
Ampithoe lacertosa	C		1					1	2		1
Aoroides secunda	I	5	1			3		5	4		5
Aoroides sp.	U	2				2		2	1		4
Corophiida	U								1		2
Corophiidae	U	1	1			1			1		
Elasmopus sp.	U							1			
Ericthonius brasiliensis	C								2		
Jassa slatteryi	C				1			1	2		2
Jassa sp.	U							3			1
Laticorophium baconi	N	4				1	1	5	1		3
Leucothoe nagatai	I					1			1		
Melita sp.	U										1
Monocorophium acherusicum	I	1	5	3	3	2	5	1			
Monocorophium insidiosum	I		2	2		1	4			2	
Monocorophium sp.	U	2	4	1		1	1			1	
Paradexamine sp.	U					1			1		1
Stenothoidae	U								1		1
Caprellidae											
Caprella californica	N								3		3
Caprella equilibra	C								1		
Caprella mutica	I	3						5	3		5
Caprella scaura	I		3	1		3		4			
Caprella simia	I	4							3		
Caprella sp.	U	4	2			1		3	3		5
Cirripedia											

2022 SAN FRANCISCO SPECIES TABLE	Bay Species Status	Ballena Isle Marina	Coyote Point Marina	Loch Lomond Marina	Oakland Yacht Club	Oyster Point Marina	Redwood City Marina	Richmond Marina Bay	San Francisco Marina	San Leandro Marina	Sausalito Marine Harbor
Amphibalanus amphitrite	I	2		4	5		5	5		5	1
Amphibalanus improvisus	I	1	3	4	1	3		5	4	5	5
Amphibalanus sp.	U									1	
Decapoda											
Palaemon macrodactylus	I			1							
Isopoda											
Ianiropsis serricaudis	I	1							1		
Ianiropsis sp.	U								1		2
Paranthura japonica	I	3	3			4		2	1		5
Pycnogonida											
Ammothella sp.	U	1									
Phoxichilidium femoratum	N	1		1	3					2	
Pycnogonida	U				1		1			1	1
Tanaidae											
Tanaidae	U								4		2
Zeuxo normani complex	U					1			2		2
Zeuxo sp.	U								1		1
BRYOZOA											
Bryozoa											
Amathia dichotoma	I		1								
Amathia sp.	U			1							
Amathia sp. *Bowerbankia*	C	3	4	5	4	4	4		3	5	5
Amathia verticillata	I				3						
Anguinella palmata	I		1	1		1					
Bugula neritina	I	3	3	5	5	3	5	5	2	5	5
Bugulina longirostrata	N								2		
Bugulina stolonifera	I	4	5		5	4	4	4	1	5	5
Buskia seriata	N	2						1			
Celleporaria brunnea	N					1					
Celleporella hyalina	C								3		
Conopeum chesapeakensis	I			1							
Conopeum sp.	U	4		2	3		1	5	2	5	4
Conopeum tenuissimum	I				1		1				
Cryptosula pallasiana	I	5	2	1	1		1	3	1		1
Electra monostachys	I	1									

2022 SAN FRANCISCO SPECIES TABLE	Bay Species Status	Ballena Isle Marina	Coyote Point Marina	Loch Lomond Marina	Oakland Yacht Club	Oyster Point Marina	Redwood City Marina	Richmond Marina Bay	San Francisco Marina	San Leandro Marina	Sausalito Marine Harbor
Fenestrulina delicia	C								1		2
Licornia diegensis	N					1					
Membraniporoidea	U	1						1			1
Nolella sp.	U		1								
Schizoporella japonica	I								1		
Smittoidea prolifica	N			1							
Thalamoporella californica	N	4									
Tricellaria inopinata	C	3	1	3		1		4			
Victorella pavida	I		1	1			2			1	
Watersipora subatra	I	5	2	4		1		5	3		5
CNIDARIA											
Anthozoa											
Actiniaria	U		1					1			
Diadumene franciscana	I					1		1	1		2
Diadumene leucolena	I					1	2	1			
Diadumene lineata	I	4				1				1	
Diadumene paranaensis	I					1					
Diadumene sp.	U	1	2			4	3	2		1	2
Hydrozoa											
Athecata	U	2	1	1	2	2	5		1		
Bougainvilliidae	U		1	1	3	1					
Campanulariidae	U	1	1						1	2	
Eudendriidae	U										2
Hydrozoa	U	1									
Hydrozoa sp. D	U				1	1					
Hydrozoa sp. E	U				1					4	
Pandeidae	U	2					1				
Plumularioidea	U							1			
Tubulariidae	U				1			1	1		2
Scyphozoa											
Scyphozoa	U										4
ECHINODERMATA											
Ophiuroidea											
Amphiuridae	U					1					
Ophiuroidea	U					1					

2022 SAN FRANCISCO SPECIES TABLE	Bay Species Status	Ballena Isle Marina	Coyote Point Marina	Loch Lomond Marina	Oakland Yacht Club	Oyster Point Marina	Redwood City Marina	Richmond Marina Bay	San Francisco Marina	San Leandro Marina	Sausalito Marine Harbor
ENTOPROCTA											
Kamptozoa											
Barentsia conferta	N			1							
Barentsia parva	N			2	1					1	1
Barentsia sp.	U			2	1						
Kamptozoa	U	1	2	3	3		4			3	1
Pedicellina cernua	N				2						
Pedicellinidae	U				1						
Urnatella gracilis	I			1							
MOLLUSCA											
Bivalvia											
Arcuatula senhousia	I	4		1	5	3		4	1	1	1
Leukoma staminea	N					1					
Modiolus modiolus	N				1						
Ostrea lurida	N					1					
Gastropoda											
Crepidula plana	I	1									
Urosalpinx cinerea	I		1								
Nudibranchia											
Okenia plana	I				1						
Polycera atra	N										1
Polycera hedgpethi	N				1						1
Sakuraeolis enosimensis	I					1					
Tenellia adspersa	I	1									
Trinchesia albocrusta	N				1						
NEMERTEA											
Nemertea											
Nemertea	U	2	2			4			2	2	2
PLATYHELMINTHES											
Platyhelminthes											
Acerotisa californica	N							3	1		3
Cotylea	U					1					
Eurylepta aurantiaca	N					2					
Leptoplanidae	U							1			
Phaenoplana longipenis	N						1				

2022 SAN FRANCISCO SPECIES TABLE	Bay Species Status	Ballena Isle Marina	Coyote Point Marina	Loch Lomond Marina	Oakland Yacht Club	Oyster Point Marina	Redwood City Marina	Richmond Marina Bay	San Francisco Marina	San Leandro Marina	Sausalito Marine Harbor
Plagiostomidae	U										1
Plagiostomum sp.	U	1	1	1	4			5			
Platyhelminthes	U		1					1			1
Stylochus sp.	U				1						
Stylostomum lentum	N		1			1			1		
POLYCHAETA											
Chrysopetalidae											
Paleanotus bellis	N										1
Cirratulidae											
Cirratulidae	U			1							
Cirratulus sp.	U								1		
Cirriformia sp.	N		1			2			1		
Ctenodrilus serratus	C	1	2	3	2	2	1		3	1	1
Ctenodrilus sp.	U									3	
Dorvilleidae											
Dorvilleidae	U	1					1				
Ophryotrocha sp.	U	1	1	2	1	1	4				1
Schistomeringos annulata	N					1					
Lumbrineridae											
Lumbrineris perkinsi	I								1		
Nereididae											
Nereididae	U			2					1		
Nereis latescens	N							1	1		
Platynereis bicanaliculata	N							1	1		2
Stratonice succinea	I			1	2		3				
Phyllodocidae											
Eulalia quadrioculata	N										1
Polychaeta											
Polychaeta	U		1	3	1	1		1	3		2
Polynoidae											
Harmothoe imbricata complex	C	1	2	1	2	4	3	1	3		5
Sabellidae											
Paradialychone sp.	U									1	
Parasabella pallida	N	5	1		4		5	3			2

2022 SAN FRANCISCO SPECIES TABLE	Bay Species Status	Ballena Isle Marina	Coyote Point Marina	Loch Lomond Marina	Oakland Yacht Club	Oyster Point Marina	Redwood City Marina	Richmond Marina Bay	San Francisco Marina	San Leandro Marina	Sausalito Marine Harbor
Sabellidae	U						1		1		
Serpulidae											
Ficopomatus enigmaticus	I	2	1	5	5		4			1	
Hydroides elegans	I	5			5			4			
Hydroides gracilis	N								1		1
Hydroides sp.	U	1			1			4	2		1
Spionidae											
Dipolydora socialis	C						1		2		
Polydora cornuta	I		2	4	4	2	5	2	3	1	5
Polydora narica	N								1		5
Polydora websteri	C						1				
Spionidae	U										2
Spirorbidae											
Neodexiospira alveolata	C	1									
Neodexiospira pseudocorrugata	C	4						2	2		
Spirorbidae	U	1									
Syllidae											
Erinaceusyllis sp. 8 Harris	U										1
Exogone lourei	C		2			2		2	2		5
Megasyllis nipponica	I	5	3	3		2		5	2		3
Myrianida pentadentata	I										1
Myrianida sp.	U										1
Syllis adamantea	N						1				
Syllis sp.	U		1	1		1					
Terebellidae											
Neoamphitrite sp. A	I		1	4	1	2	5				
Nicolea cf. *amnis*	U	4		1	5			5			4
Terebellidae	U	1		1		2		2	1		
PORIFERA											
Porifera											
Porifera	U			1		1					
Porifera sp. A	U	5	2	1		3		3	2		2
Porifera sp. B	U					1			1		
Porifera sp. C	U	5									

2022 SAN FRANCISCO SPECIES TABLE	Bay Species Status	Ballena Isle Marina	Coyote Point Marina	Loch Lomond Marina	Oakland Yacht Club	Oyster Point Marina	Redwood City Marina	Richmond Marina Bay	San Francisco Marina	San Leandro Marina	Sausalito Marine Harbor
PROTISTA											
Protista											
Protista sp. A	U		1								
Protista sp. B	U		1							4	
Protista sp. C	U						1				
Protista sp. D	U	3	3	2	4	1	1		1		2
TUNICATA											
Tunicata											
Aplousobranchia	U			1							3
Ascidia sp.	U		1					1	1		
Ascidia zara	I	5	4	4		5	1	3	3		2
Ascidiidae	U								1		
Botryllinae	U	1	1	2				1	2		1
Botrylloides diegensis	C	2	1	3		4		2	2		4
Botrylloides sp.	U	3	1	2		3		4	1		2
Botrylloides violaceus	I					1		2	3		4
Botryllus schlosseri	I	3	1			4			3		4
Ciona robusta	I	4	2	1	3	5	5	4	2		2
Ciona savignyi	I	1	1			4			2		2
Ciona sp.	I				2		1	1	2		
Didemnidae	U	1	2			2			4		
Didemnum vexillum	I			1		1		5	1		5
Diplosoma listerianum	I	2	2	1		4		4	3		3
Distaplia occidentalis	N										1
Distaplia sp.	U								1		1
Molgula ficus	I					2					
Molgula manhattensis	I	3	2	5		4	1			5	1
Molgula sp.	U		1			2					
Perophora sp.	U							1			
Stolidobranchia	U	1	1								
Styela sp.	U	4				2		1	2		4
Styelidae	U					2					
Tunicata	U	1		1							

A1.8.4: Taxa Identified from 2022 Santa Catalina Island Hard Substrate Surveys

2022 SANTA CATALINA ISLAND SPECIES TABLE	Bay Species Status	Cat Harbor	Catalina Ave Dinghy Dock	Emerald Bay	Fourth of July	Gallaghers Cove	Middle Dock	Two Harbors	Whites Cove	Wrigley
ALGAE										
Algae										
Algae	U		1	3	5	2		4	3	4
Chlorophyta	U			2	1	1	1		3	1
Phaeophyceae	U		2		5					2
Rhodophyta	U	1	4	4	5	2	2		4	4
ARTHROPODA										
Amphipoda										
Amphipoda	U		2				3		2	
Ampithoe longimana	I	2			1					1
Ampithoe plumulosa	C	5			1			1	1	
Ampithoe sectimana	N								1	
Ampithoe sp.	U	1		1			1		2	
Ampithoe valida	I		2	1						
Ampithoidae	U				1		1			
Aoridae	U									1
Aoroides secunda	I		1	1						
Aoroides sp.	U						1			
Elasmopus bampo	C	6	2	6	4	4	2	6		1
Elasmopus sp.	U	2	3					4		1
Ericthonius brasiliensis	C	1	6	4	4	4	5	3	5	5
Ericthonius sp.	U		1			2	1	1	3	1
Eusiroidea	U		1							
Gammaropsis thompsoni	N							2		
Hadzioidea	U	1								
Hyalidae	U	1								
Isaeidae	U						2			
Ischyroceridae	U							1	1	
Jassa slatteryi	C					1			2	
Jassa sp.	U		2	1			1		2	1
Jassa staudei	N		1	1			1		4	
Laticorophium baconi	N	2		2					3	

2022 SANTA CATALINA ISLAND SPECIES TABLE	Bay Species Status	Cat Harbor	Catalina Ave Dinghy Dock	Emerald Bay	Fourth of July	Gallaghers Cove	Middle Dock	Two Harbors	Whites Cove	Wrigley
Monocorophium acherusicum	I								1	
Nasageneia quinsana	N	1	1	1				1	2	
Nasageneia sp.	U	1		1						
Neoischyrocerus claustris	N						1			
Paradexamine sp.	U				2		3	1	1	1
Pleustidae	I		4	1					2	
Podocerus brasiliensis	C				1		2			
Podocerus cristatus complex	C					1		1		
Podocerus fulanus	N	1		1						
Podocerus sp.	U	2					1	1		
Pontogeneiidae	U								1	
Quadrimaera carla	N	1								
Quadrimaera sp.	U	1	1							
Shoemakerella cf. *cubensis*	I	1								
Stenothoe estacola	N		1	3	2	2		2		
Stenothoe sp.	U		2	3			1			
Stenothoe valida	I								1	
Stenothoidae	U		1				1			
Stenothoides sp.	U						1			
Tethygeneia opata	N								1	
Caprellidae										
Aciconula acanthosoma	N		2				2			
Caprella californica	N		2	1			1			
Caprella equilibra	C		2	3	1	4	3	2	4	4
Caprella penantis	C							1	1	
Caprella sp.	U		4	5	4	4	5	4	4	1
Caprella verrucosa	N		1	1						
Caprellidae	U						1			
Cirripedia										
Balanidae	U		1	1	1			3	1	1
Balanomorpha	U		1					1		
Balanus trigonus	N		4	5	6	5	4	6	2	5
Cirripedia	U						1			

2022 SANTA CATALINA ISLAND SPECIES TABLE	Bay Species Status	Cat Harbor	Catalina Ave Dinghy Dock	Emerald Bay	Fourth of July	Gallaghers Cove	Middle Dock	Two Harbors	Whites Cove	Wrigley
Megabalanus californicus	N		4	6	6	5	2	4		2
Crustacea										
Peracarida	U								1	
Decapoda										
Caridea	U	1								
Crab	U	1								
Decapoda	U							1		
Heptacarpus taylori	N	1								
Hippolyte clarki	N	1								
Hippolyte sp.	U								1	
Synalpheus lockingtoni	N	1		1						
Isopoda										
Anthuroidea	U						1			
Paracerceis sculpta	N	5								
Paracerceis sp.	U	1								
Paranthura japonica	I	5								
Sphaeromatidae	U	2								
Pycnogonida										
Callipallene californiensis	N						2			
Callipallene pacifica	N		1				1			
Pycnogonida	U						1			
Tanystylum californicum	N					1	2			
Tanystylum duospinum	N		1							
Tanaidae										
Zeuxo normani complex	U		1							
Zeuxo sp.	U				1	1				
BRYOZOA										
Bryozoa										
Aetea anguina	I									1
Amathia dichotoma	I	3								
Amathia sp. *Bowerbankia*	U		2		2	1	1	2		1
Amathia verticillata	I	6								
Bugula neritina	I	2	4	2	6	4	3	4	1	4
Bugulina sp.	U				1					
Celleporaria brunnea	N	5	6	6	5	2	4	6		3

2022 SANTA CATALINA ISLAND SPECIES TABLE	Bay Species Status	Cat Harbor	Catalina Ave Dinghy Dock	Emerald Bay	Fourth of July	Gallaghers Cove	Middle Dock	Two Harbors	Whites Cove	Wrigley
Celleporina sp.	N						1	1		
Cheilostomatida	U						1			
Cradoscrupocellaria gorgonensis	C				3		2			
Cradoscrupocellaria sp.	U		1	1	3			5		
Crisia sp.	U		1	1	1		1			
Crisia sp. 1 Catalina	U				4		1			
Crisiidae	U				1					
Crisulipora occidentalis	N			1	1					2
Disporella buskiana	N		1	1						
Disporella novaehollandiae	N		2	2	5	1	3	5	1	
Disporella sp.	U		3	1	3	1	2	3	1	1
Filicrisia sp.	U			1						
Lichenoporidae	U		2		1		1	1		1
Microporella cribrosa	N			1						
Rhynchozoon sp.	U		1							
Schizoporella occidentalae	N		1				2			
Scruparia ambigua	C				1			1		
Scruparia sp.	U			1						1
Thalamoporella californica	N		3	1		2	2	1	1	1
Tubulipora pacifica	N		1		3		1	1		1
Tubulipora sp.	U		2	4	3		3	5		1
Watersipora arcuata	I	1	1					1		1
Watersipora sp.	I						1			
Watersipora subatra	I	6	6	5	6	3	4	6		3
Watersipora subtorquata	I	2	3	4	1		1	2		
CNIDARIA										
Anthozoa										
Actiniaria	U		1	1				1		
Aiptasiidae	U				2			1		
Diadumene lineata	I	1	1	4			1	2		1
Diadumene sp.	U	2		1						
Exaiptasia diaphana	C	2	1	2	4	2	2	4		1
Octocorallia	U	1								
Hydrozoa										

2022 SANTA CATALINA ISLAND SPECIES TABLE	Bay Species Status	Cat Harbor	Catalina Ave Dinghy Dock	Emerald Bay	Fourth of July	Gallaghers Cove	Middle Dock	Two Harbors	Whites Cove	Wrigley
Athecata	U	2	1	2	2		1	3		1
Bougainvilliidae	U			1		2	1	2	1	3
Campanulariidae	U	1	5	6	3	4	1	5	4	2
Eudendriidae	U		1			2		1		
Halocordylidae	U		1							
Hydrozoa sp. C	U							1		
Hydrozoa sp. D	U	1	2	2	3	1		3		1
Oceaniidae	U									1
Pandeidae	U		1		1		1			1
Plumularioidea	U		1							
Thecata	U		1	2	2	1	4	1		1
Tubulariidae	U			6						1
ECHINODERMATA										
Ophiuroidea										
Ophiactis simplex	N	3								
ENTOPROCTA										
Kamptozoa										
Pedicellina cernua	C			2						
MOLLUSCA										
Bivalvia										
Anomiidae	U							1		
Bivalvia	U						1			
Clam	U					1				
Myidae	U				1					
Mytilus galloprovincialis / trossulus complex	U						1			1
Ostrea lurida	N	3								
Saxidomus nuttalli	N						2			
Gastropoda										
Archierato columbella	N						1			
Crepipatella lingulata	N				3			1		1
Elysia hedgpethi	N					1				
Eratoidae	U							1		
Hespererato vitellina	N				1					
Littorinidae	U						1			

2022 SANTA CATALINA ISLAND SPECIES TABLE	Bay Species Status	Cat Harbor	Catalina Ave Dinghy Dock	Emerald Bay	Fourth of July	Gallaghers Cove	Middle Dock	Two Harbors	Whites Cove	Wrigley
Thylacodes squamigerus	N			2	1		1	1		
Urosalpinx cinerea	I		1							
Nudibranchia										
Anteaeolidiella oliviae	N				1					
Eubranchus rustyus	N		1	2		3	1	1		1
Eubranchus sp.	U					1				
Hermissenda opalescens	N							1		
Nudibranchia	U						1			
Polycera atra	N		1							
Polycera hedgpethi	N				1					
Vayssierea felis	C				1		1			
NEMATODA										
Nematoda										
Nematoda	U			1				1		
NEMERTEA										
Nemertea										
Nemertea	U	4				1	1	1		1
Nemertopsis gracilis	N							1		
Oerstedia dorsalis	N				1					
PLATYHELMINTHES										
Platyhelminthes										
Cotylea	U							1		
Hoploplana californica	N				1		2			
Leptoplanidae	U		1	1	2	1	1	1		
Phaenoplana longipenis	N		1	1	3			5		1
Plagiostomidae	U	1	1			1		2		
Plagiostomum sp.	U		2		4	1	1	1		2
Platyhelminthes	U		1	2	2			4	1	2
Pseudoceros mexicanus	N				1					
POLYCHAETA										
Capitellidae										
Capitella capitata complex	C	1								
Chaetopteridae										
Chaetopteridae	U							1		
Cirratulidae										

2022 SANTA CATALINA ISLAND SPECIES TABLE	Bay Species Status	Cat Harbor	Catalina Ave Dinghy Dock	Emerald Bay	Fourth of July	Gallaghers Cove	Middle Dock	Two Harbors	Whites Cove	Wrigley
Cirratulidae	U				1					
Ctenodrilus serratus	C				1					1
Fabriciidae										
Fabriciidae	U						1			
Nereididae										
Nereididae	U				2			1		
Nereis sp.	U	1	2	4	5			3	1	2
Platynereis bicanaliculata	N		1	1	2	1		1		1
Opheliidae										
Opheliidae	U				1					
Polyophthalmus pictus complex	C			1	2	1	1			1
Phyllodocidae										
Eumida longicornuta	N									1
Phyllodoce sp.	U			2	1					
Pterocirrus burtoni	N							1		
Polychaeta										
Polychaeta	U	1		1			1	2		
Polynoidae										
Halosydna brevisetosa	N			2	2	1		2		
Halosydna johnsoni	N				1			1		
Halosydna sp.	U				1					
Polynoidae	U							1		
Sabellidae										
Paradialychone sp.	U					1				
Sabellidae	U									1
Serpulidae										
Pseudochitinopoma occidentalis	N							1		
Salmacina tribranchiata	N			1	1					
Serpulidae	U	1		1						
Spirobranchus spinosus	U			1						1
Spionidae										
Microspio sp.	U			1	3					1
Spirorbidae										

2022 SANTA CATALINA ISLAND SPECIES TABLE	Bay Species Status	Cat Harbor	Catalina Ave Dinghy Dock	Emerald Bay	Fourth of July	Gallaghers Cove	Middle Dock	Two Harbors	Whites Cove	Wrigley
Neodexiospira pseudocorrugata	C	1	1		1			1		
Neodexiospira sp.	U	5	3	4	4		3	4		2
Protolaeospira eximia	N		1				2			
Simplaria pseudomilitaris	N	6	6	4	6	4	5	6		5
Spirorbidae	U								1	
Spirorbidae sp. 1	U						1			
Syllidae										
Eusyllinae	U		1				1			
Odontosyllis phosphorea	N		1		2					1
Odontosyllis sp.	U				1		1			
Proceraea nigropunctata	N			1		1		1		
Salvatoria californiensis	N							1		
Salvatoria heterocirra	N				1					
Salvatoria sp.	U				1			1		
Syllidae	U				2			1		
PORIFERA										
Porifera										
Porifera	U					2				
Porifera sp. A	U	1								
Porifera sp. B	U		3		4	2	4			
Porifera sp. C	U		1		2	2	4	2		
PROTISTA										
Protista										
Protista sp. E	U									1
TUNICATA										
Tunicata										
Aplousobranchia	U							1		
Botryllinae	U	1								
Botrylloides giganteus	I	1								
Botrylloides sp.	U	2								
Botryllus schlosseri	I	2					3			
Didemnidae	U		1			1				
Diplosoma listerianum	I	2	1	1	1	2		5		
Diplosoma sp.	U		2	2	4	1	3	1		

2022 SANTA CATALINA ISLAND SPECIES TABLE	Bay Species Status	Cat Harbor	Catalina Ave Dinghy Dock	Emerald Bay	Fourth of July	Gallaghers Cove	Middle Dock	Two Harbors	Whites Cove	Wrigley
Polyandrocarpa cf. *zorritensis*	I	6								
Stolidobranchia	U	1								
Styela sp.	U	4								
Styelidae	U	1								
Tunicata	U	1								

Chapter 2: Soft Sediment Communities

2.1: Introduction

2.1.1: Field Collections

The original contract called for two soft sediment surveys in San Francisco Bay, in 2020 and 2021; as described in Chapter 1, due to the COVID-19 pandemic, we were not able to conduct soft sediment survey work in 2020 or 2021. Following discussion with CDFW, we completed one soft sediment survey of San Francisco Bay in 2022 and completed a hard substrate survey of San Francisco Bay in 2022 in lieu of a second soft sediment survey.

For surveys of invertebrate communities in soft sediment habitats in San Francisco Bay in 2022, we used a stratified sampling scheme to sample at 10 sites. At each site, five replicate grab samples were collected at 200 m intervals, in shallow subtidal depths (2 m below Mean Lower Low Water (MLLW)), generating a total of 50 morphological and 50 metagenetic samples (5 replicates x 10 sites). Salinity and temperature were measured at each site using a YSI Model 2030 (Yellow Springs Instrument Co.) meter, and depth was recorded with a depth sensor on the boat.

We used a standard Young-modified Van Veen grab (Dauer and Lane 2005; EPA 2009), deployed via hydraulic winch with shovels capturing grab samples with a surface area of 0.1 m^2. The entire grab sample was sieved on a 1 mm mesh screen, and the retained organisms were soaked in filtered seawater from the site for 4 hours, then preserved in 95% ethanol (except polychaetes and soft-bodied organisms, which were preserved in 10% formalin). The soak water from each sample was filtered through 0.2 µm polyethersulfone filters attached to a vacuum pump and frozen at -20°C for delivery to MLML for metagenetic processing.

2.1.2: 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:

1. 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.
2. Laboratory sorting of grab samples using dissecting microscopes where necessary and identification by SERC staff to the lowest taxonomic level using California faunal identification keys (Kozloff 1996; Carlton 2007) and consultation with taxonomic experts.
3. Expert 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 more detailed morphological analysis and targeted genetic analyses, when 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.

2.1.3: 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 San Francisco Bay as of 2022, based upon previous analyses and using a synthesis of information in the SERC NEMESIS database (Fofonoff et al. 2018). Four categories were used for this classification: NIS, native, cryptogenic (of uncertain status, *sensu* Carlton 1996), and unresolved (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, native, cryptogenic, and unresolved taxa detected at each site and for the entire bay. We then constructed accumulation curves and calculated species richness estimators using similar methods as for hard substrate communities (Chapter 1).

2.2: Results

2.2.1: Detection of NIS in San Francisco Bay Soft Sediment Communities in 2022

A total of 51 morphospecies was detected for the soft sediment community survey in San Francisco Bay: 19 native, 15 NIS, 5 cryptogenic and 12 unresolved.

Out of a total of 4870 individuals, native species accounted for a total of 1201 individuals (24.66% of the community), NIS for 3005 individuals (61.7% of the community), cryptogenic species for a total of 98 individuals (2.01% of the community) and unresolved taxa comprised 566 individuals (11.62% of the community). In general, the unresolved taxa are comprised of juveniles and partial specimens, often in poor condition, limiting taxonomic resolution based solely on morphology, and the relative proportion of such taxa found here are in line with results from previous surveys of both hard substrate and soft sediment habitats (Ruiz and Geller 2015, 2018, 2021; Ruiz, Geller, and Chang 2022).

The analyses indicate that our sampling program performed well in detecting and characterizing NIS in the soft sediment community in San Francisco Bay in 2022. The figure below shows the number of species detected compared to the asymptotic richness estimator, which incorporates sampling effort and rareness of taxa to estimate the actual total number of NIS, including those not observed. This value is equivalent to the number of NIS taxa that would be found with infinite sampling. Indeed, sample coverage for NIS was estimated at 98.84%. Species accumulation curves (Appendix 2.3) indicate relatively complete sampling of NIS in San Francisco Bay in 2022, with relatively little error around the asymptotic richness estimator, suggesting low variation in NIS occurrence across samples. Statistical analyses were carried out

using R 4.2.3 (R Core Team 2023) and the R packages vegan 2.6-4 (Oksanen et al. 2022), and iNEXT.3D 1.0.1 (Hu and Chao 2023).

There were no previously unreported NIS detected in this survey.

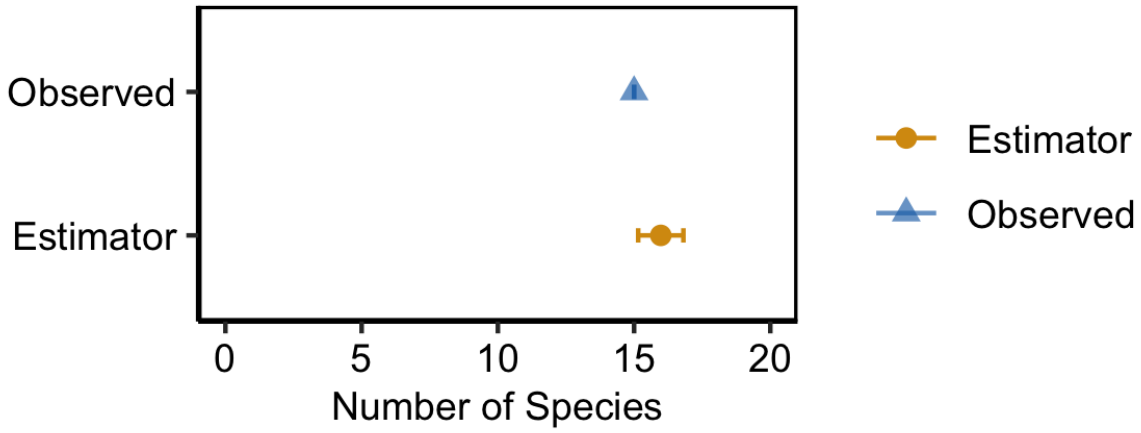

Figure 2.1: *Number of unique NIS detected for 2022 soft sediment survey of San Francisco Bay ("Observed") and asymptotic estimate of NIS richness ± standard error ("Estimator"). NIS status was assigned based on literature and SERC NEMESIS database (Fofonoff et al. 2018).*

2.3: References

Carlton, James T. 1996. “Biological Invasions and Cryptogenic Species.” *Ecology* 77 (6): 1653–55.

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———. 2021. “Spatial and Temporal Analysis of Marine Invasions: Supplemental Studies to Evaluate Detection Through Quantitative and Molecular Methodologies.” California Department of Fish and Wildlife. 153 pp.

Ruiz, Gregory M, Jonathan B Geller, and Andrew L Chang. 2022. “Spatial and Temporal Analysis of Marine Invasions: Los Angeles / Long Beach Harbor and San Francisco Bay.” California Department of Fish and Wildlife. 78 pp.

Appendix A2.1: Survey Locations

The map and table below indicate locations and dates for soft sediment surveys for San Francisco Bay in 2022.

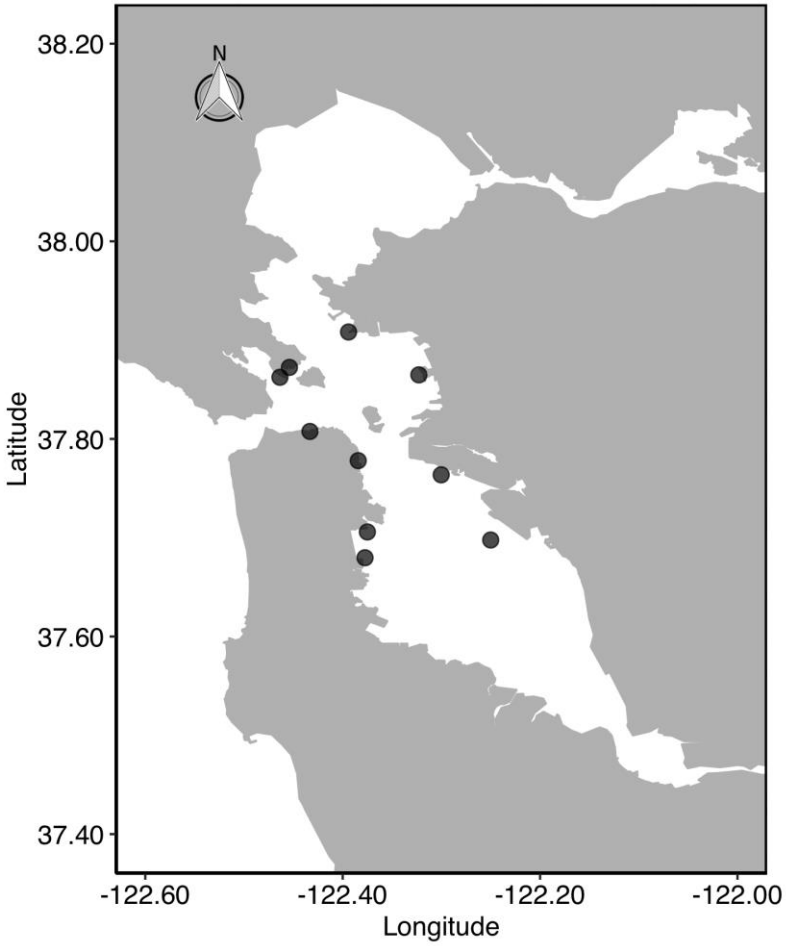

Figure A2.1.1: *Map of soft sediment community sampling locations in San Francisco Bay (2022).*

Table A2.8.1: *Soft sediment community sampling locations in San Francisco Bay (2022).*

Site Name	Latitude (N)	Longitude (W)
Albany	37.865	-122.323
Ballena Isle	37.764	-122.300
Hunter's Point	37.706	-122.375
Oakland	37.698	-122.250
Oracle Park	37.778	-122.384
Oyster Point	37.680	-122.377
Point Richmond	37.908	-122.394
Richardson Bay	37.862	-122.464
San Francisco Marina	37.808	-122.433
Tiburon Ferry	37.872	-122.454

Appendix A2.2: Non-Native Species Richness by Site

The heat map below shows non-native invertebrate species richness detected in soft sediment samples from San Francisco Bay in 2022. Taxonomic identification was based on morphological characteristics.

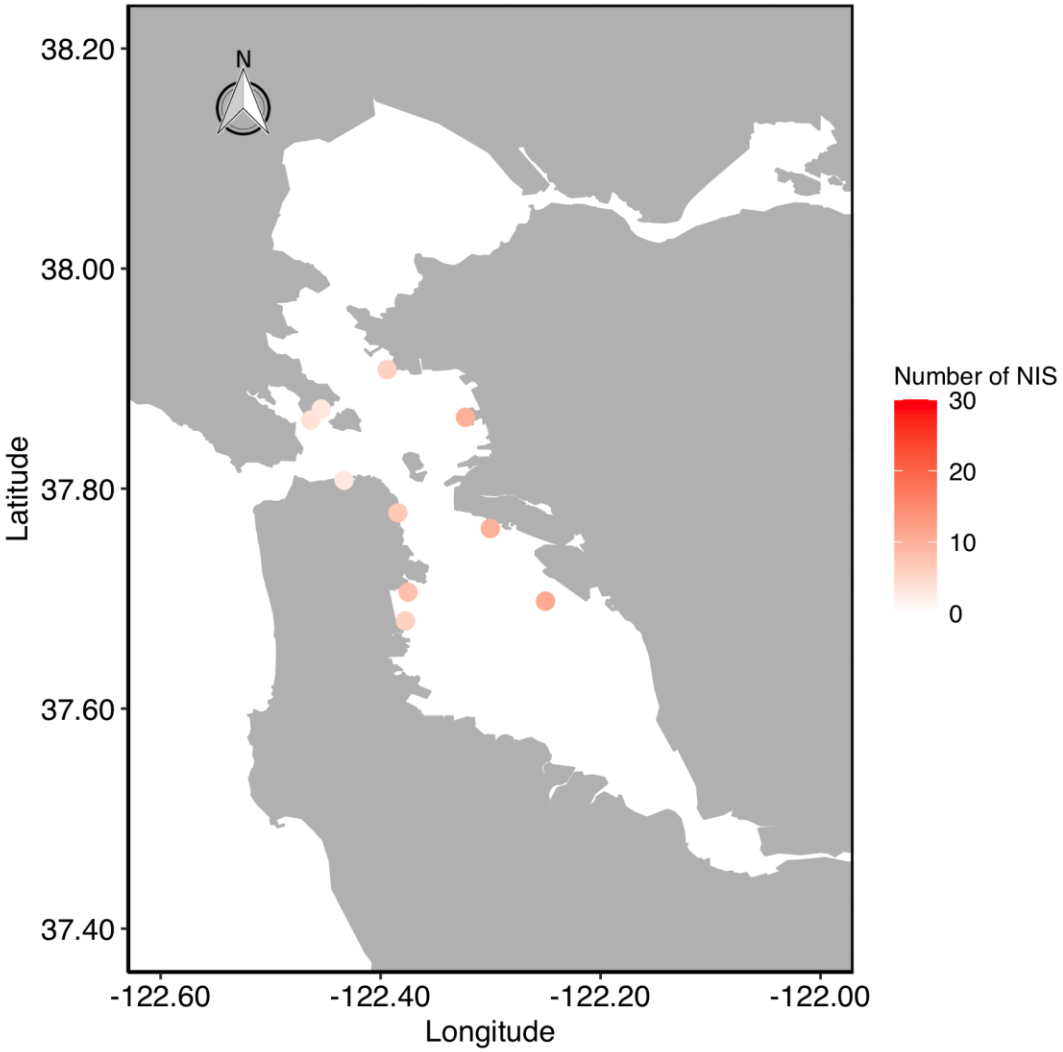

Figure A2.2.1: *Map of non-native invertebrate species richness detected in soft sediment samples from San Francisco Bay in 2022.*

Appendix A2.3: Species Accumulation Curves by Invasion Status

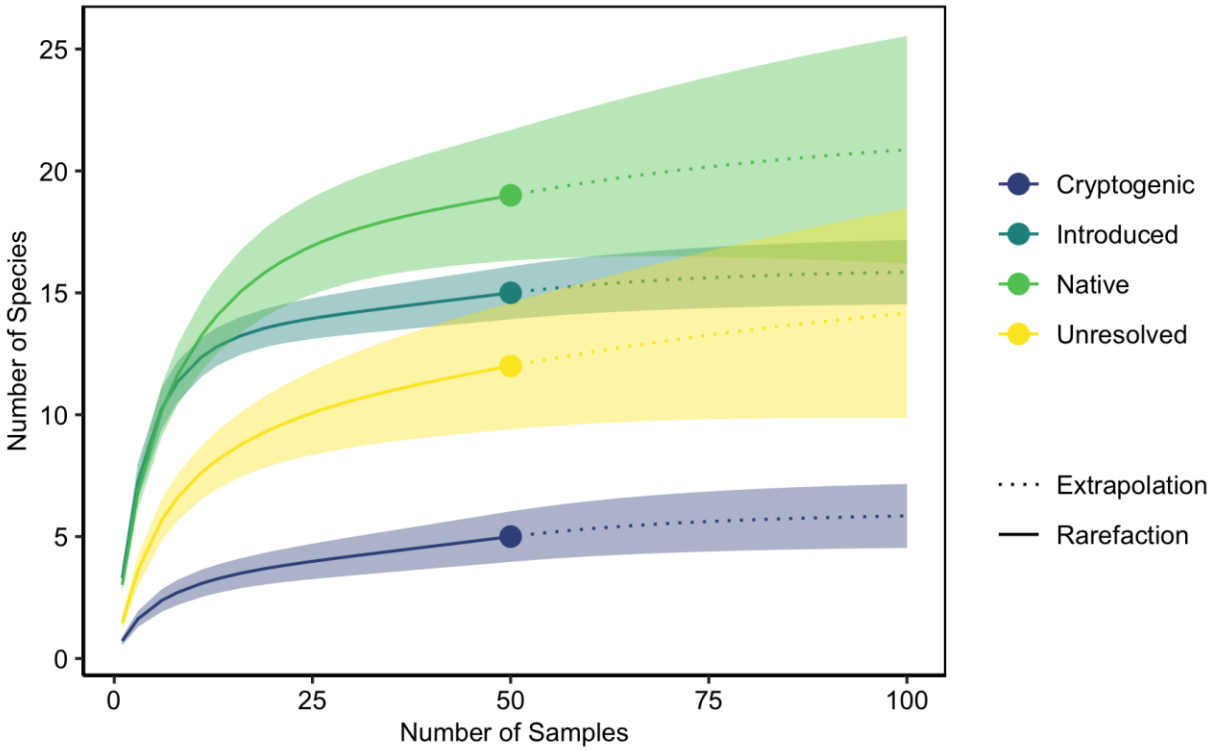

Figure A2.3.1: *Species accumulation curves (based on 1,000 random draws) by invasion status for sessile marine macroinvertebrates in San Francisco Bay soft sediment communities in 2022. Number of species detected as a function of panels for each invasion status. Invasion status is assigned based on literature and SERC National Exotic Marine and Estuarine Species Information System (NEMESIS) database (Fofonoff et al. 2018). Here, a sample represents grab sample; 5 grabs were taken from each of 10 sites. Shading around each line represents ± 1 SE. Rarefied estimates (solid line) up to the number of observed samples (dot), beyond which estimates are extrapolated (dashed line) up to twice the size of the reference (observed) samples.*

Table A9.3.1: *Species richness and sample coverage estimators by invasion status for marine macroinvertebrates in San Francisco Bay soft sediment communities (2022). Invasion status is designated based on literature and SERC NEMESIS database. The sample coverage estimator (SC), observed number of species (Observed), richness estimator (Estimator), standard error of the estimator (SE), 95% lower confidence limit (LCL), and 95% upper confidence limit (UCL) are given.*

Status	SC	Observed	Estimator	SE	LCL	UCL
Cryptogenic	94.66	5	5.98	0.59	5	7.14
Introduced	98.84	15	15.98	0.83	15	17.62
Native	98.05	19	21.94	2.94	19	27.71
Unresolved	95.95	12	16.41	3.88	12	24.01

NIS richness approached an asymptote rapidly in shallow water subtidal habitats in San Francisco Bay (Figure A2.3.1). The accumulation curves, richness estimators, and sample coverage estimators suggest that we have detected most of the estimated total NIS present in 2022 in San Francisco Bay shallow water habitats (Table A2.3.1).

Appendix A2.4: Percent Contribution of NIS to Total Species Richness

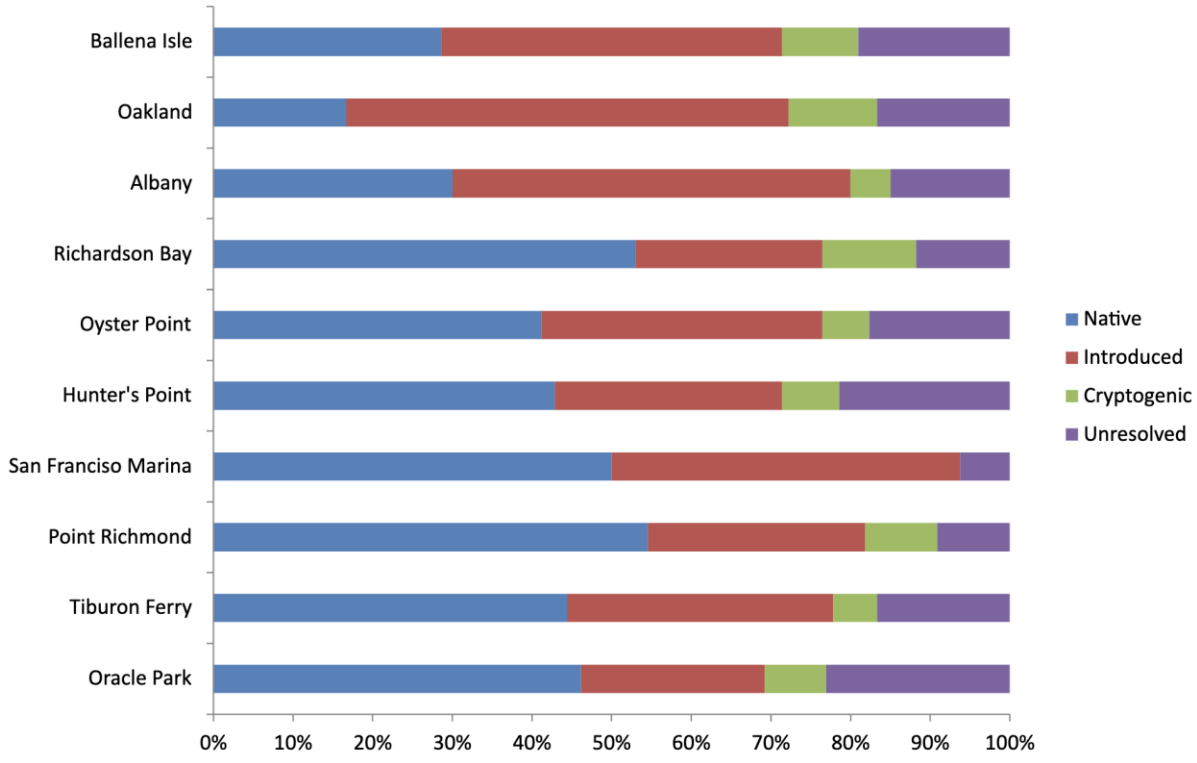

Figure A2.4.1: *Number of unique species detected in San Francisco Bay soft sediment communities in 2022 by invasion status. Status was assigned based on literature and SERC NEMESIS database (Fofonoff et al. 2018).*

Across all sites in 2022 San Francisco Bay soft sediment communities, NIS contributed an average of 35.22% of species present.

The percentage of all taxa comprised of NIS varied from a low of 21.43% at Tiburon Ferry to 55% at Oakland (Figure A2.4.1). Both cryptogenic and unresolved taxa made up relatively small proportions of the species present across sites, while native taxa richness was slightly higher than NIS on average (39.29%).

Appendix A2.5: Relative Contribution of NIS Per Site to Total Abundance of Individuals

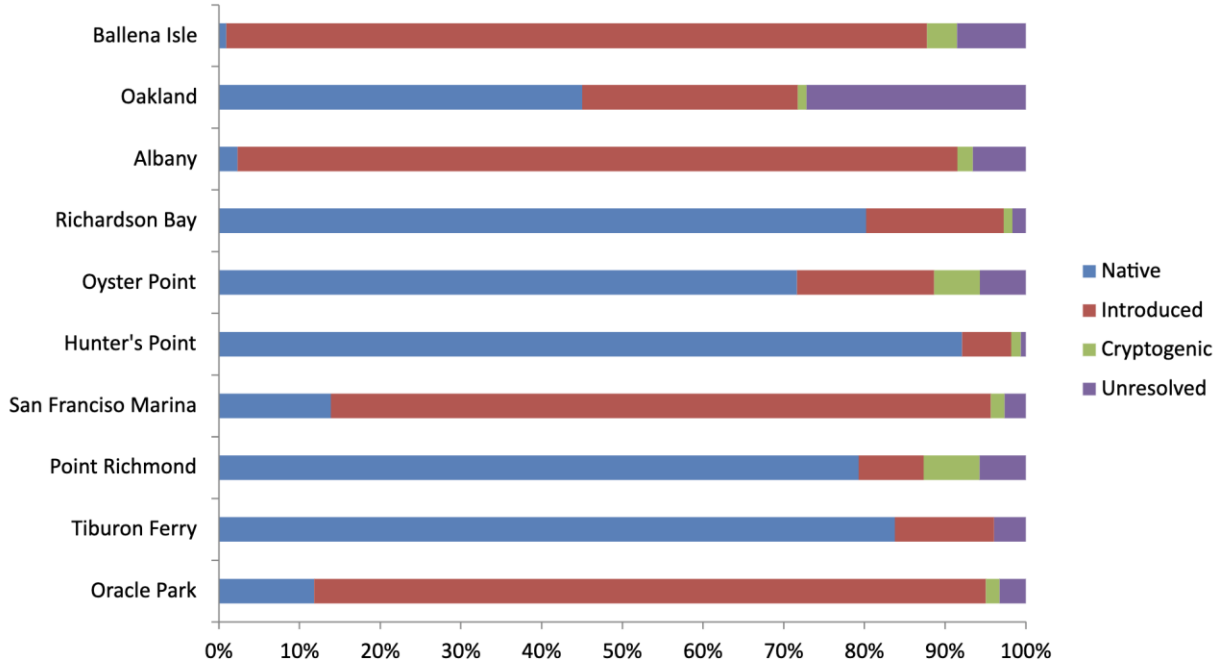

Figure A2.5.1: *Number of individuals of taxa of each invasion status per site in San Francisco Bay soft sediment communities in 2022. Status was assigned based on literature and SERC NEMESIS database (Fofonoff et al. 2018).*

Just as NIS contributed a significant percentage of all taxa present across sites (Figure A2.4.1), NIS also made up a relatively large percentage of overall individual abundances, averaging 42.131% per site.

However, the proportion of NIS individuals in the community varied widely, from 6.06% at San Francisco Marina to 88.22% at Ballena Isle (Figure A2.5.1). Both cryptogenic and unresolved taxa made up relatively small proportions of the individuals present across sites. Native taxa made up a very widely varying percentage of individuals per site and were present in high abundance when NIS individuals were relatively rare, and conversely were rare when NIS individuals were very abundant.

Appendix A2.6: Taxa Identified Morphologically in San Francisco Bay in 2022

The number of grabs is given (out of five replicate grabs per site) in which each taxon was found. Species invasion status is designated based on literature and SERC NEMESIS database (Fofonoff et al. 2018).

2022 SAN FRANCISCO BAY SOFT SEDIMENT SPECIES TABLE	Bay Species Status	Point Richmond	San Francisco Marina	Hunter's Point	Oyster Point	Richardson Bay	Albany	Oakland	Ballena Isle	Tiburon Ferry	Oracle Park
ANNELIDA											
Capitellidae											
Heteromastus sp.	C	2	2							3	
Cirratulidae											
Cirriformia moorei	N			5	2		3				
Cirriformia sp.	U		1		1				2		2
Eunicidae											
Marphysa sp. C Harris	C							4	2		
Glyceridae											
Glycera americana	C					1					
Glycera sp.	U							1			
Goniadidae											
Glycinde picta	N			1		2		1			
Glycinde sp.	U	1		1	3					1	3
Lumbrineridae											
Scoletoma tetraura complex	N	1		3	5	1	1		1		3
Maldanidae											
Sabaco elongatus	I	3		4	1	1	5	1	2		
Nephtyidae											
Nephtys caecoides	N	2			1						1
Neididae											
Platynereis bicanaliculata	N	1									
Oligochaeta											
Oligochaeta	U									2	
Orbiniidae											
Leitoscoloplos pugettensis	N	1	2	2	1	1				3	5
Polynoidae											
Harmothoe imbricata complex	C			2	4	1	5	4	4		

2022 SAN FRANCISCO BAY SOFT SEDIMENT SPECIES TABLE	Bay Species Status	Point Richmond	San Francisco Marina	Hunter's Point	Oyster Point	Richardson Bay	Albany	Oakland	Ballena Isle	Tiburon Ferry	Oracle Park
Sabellidae											
Euchone limnicola	N			1			2				
Spionidae											
Scolelepis squamata complex	C			1							
Syllidae											
Typosyllis sp.	U			1							
Terebellidae											
Amaeana sp. A Harris	I	1	3								2
ATHROPODA											
Ampeliscidae											
Ampelisca abdita	I	5	1	5		2	5	3	3	1	3
Aoridae											
Grandidierella japonica	I						2		3		2
Caprellidae											
Caprella californica	N					1	5		1		
Caprella sp.	U							1	2		
Corophiidae											
Corophium heteroceratum	I			1			1	1		1	2
Monocorophium acherusicum	I							5	3		
Crangonidae											
Crangon nigricauda	N	1	1	1		1				1	
Idoteidae											
Synidotea laticauda	I						1				
Inachoididae											
Pyromaia tuberculata	N			1							
Isaeidae											
Photis brevipes	N	3	1								
Leptocheliidae											
Leptochelia sp.	U			1	1	1	4		4		
Oedicerotidae											
Cumacean	U		1		2	1					
Paranthuridae											
Paranthura japonica	I	1			2		3	4	1		

2022 SAN FRANCISCO BAY SOFT SEDIMENT SPECIES TABLE	Bay Species Status	Point Richmond	San Francisco Marina	Hunter's Point	Oyster Point	Richardson Bay	Albany	Oakland	Ballena Isle	Tiburon Ferry	Oracle Park
Pinnotheridae											
Scleroplax granulata	N			1				2	1		1
Upogebiidae											
Upogebia pugettensis	N									1	
Varunidae											
Cancer magister	N			1		1			1		
Virgulariidae											
Stylatula elongata	N	2	4			4	3			5	1
CNIDARIA											
Anthozoa											
Anemone	U			1			5	5	4		
Hydrozoa											
Hydrozoan	U	1		1			3		1		
MOLLUSCA											
Calyptraeidae											
Crepidula convexa	I			1	1			4	2		
Haminoeoidea											
Haloa japonica	I										1
Lyonsiidae											
Lyonsia californica	N			1	2		4	3	4		1
Myidae											
Cryptomya californica	N	2	5	3	4	5				4	5
Mytilidae											
Arcuatula senhousia	I			3	3		4	1	4		
Philinidae											
Philine orientalis	I	2	1	2	3	2	1	1	1	2	2
Semelidae											
Theora lubrica	I	4		4	1	2	5	1			2
Solenidae											
Solen sicarius	N			1		1				1	
Veneridae											
Ruditapes philippinarum	I			1			2	3	4		
PLATYHELMINTHES											

2022 SAN FRANCISCO BAY SOFT SEDIMENT SPECIES TABLE	Bay Species Status	Point Richmond	San Francisco Marina	Hunter's Point	Oyster Point	Richardson Bay	Albany	Oakland	Ballena Isle	Tiburon Ferry	Oracle Park
Platyhelminthes	U	1		2						1	

Chapter 3: Zooplankton

3.1: Introduction

3.1.1: Field Collections

Surveys of zooplankton communities were conducted in a total of 7 bays during 2021-2022, continuing our series of standardized surveys of zooplankton communities in California Bays. Previous survey events are described in Ruiz and Geller (2015, 2018, 2021) and Ruiz, Geller, and Chang (2022). These surveys included Humboldt Bay, Bodega Harbor and Tomales Bay, San Francisco Bay, Los Angeles / Long Beach Harbor, Santa Catalina Island, Mission Bay, and San Diego Bay, with all samples forwarded to MLML for metagenetic processing.

In each bay, at least 10 stations were chosen using a stratified random scheme to distribute sampling across the main stem of the bay in waters with average salinity above 20. At each site, we used a modified trash pump (North Star S106120 model; Honda GX160 gas motor) coupled to a plankton net assembly (0.75 m diameter net; 80 µm mesh size) to collect and filter 5 m^3 of water drawn from 1 m below the surface. After samples were filtered, the net was rinsed down the sides, and samples were preserved for metagenetic processing in DNE solution (a salt-saturated DMSO-EDTA solution for DNA preservation). Three replicate samples were taken per site for a total of 30 samples per bay.

Salinity and temperature were measured at each site using a YSI Pro 2030 meter (Yellow Springs Instrument Co.), and depth was recorded with a depth sensor on the boat.

All samples and metadata were then delivered to MLML for metagenetic processing.

3.2: References

Ruiz, Gregory M, and Jonathan B Geller. 2015. “Spatial and Temporal Analysis of Marine Invasions in California: Morphological and Molecular Comparisons Across Habitats.” California Department of Fish and Wildlife. 190 pp.

———. 2018. “Spatial and Temporal Analysis of Marine Invasions in California, Part II: Humboldt Bay, Marina Del Rey, Port Hueneme, and San Francisco Bay.” California Department of Fish and Wildlife. 239 pp.

———. 2021. “Spatial and Temporal Analysis of Marine Invasions: Supplemental Studies to Evaluate Detection Through Quantitative and Molecular Methodologies.” California Department of Fish and Wildlife. 153 pp.

Ruiz, Gregory M, Jonathan B Geller, and Andrew L Chang. 2022. “Spatial and Temporal Analysis of Marine Invasions: Los Angeles / Long Beach Harbor and San Francisco Bay.” California Department of Fish and Wildlife. 78 pp.

Appendix A3.1: Survey Locations

The maps and tables below indicate locations and dates for each zooplankton survey event.

A3.1.1: San Francisco Bay 2021

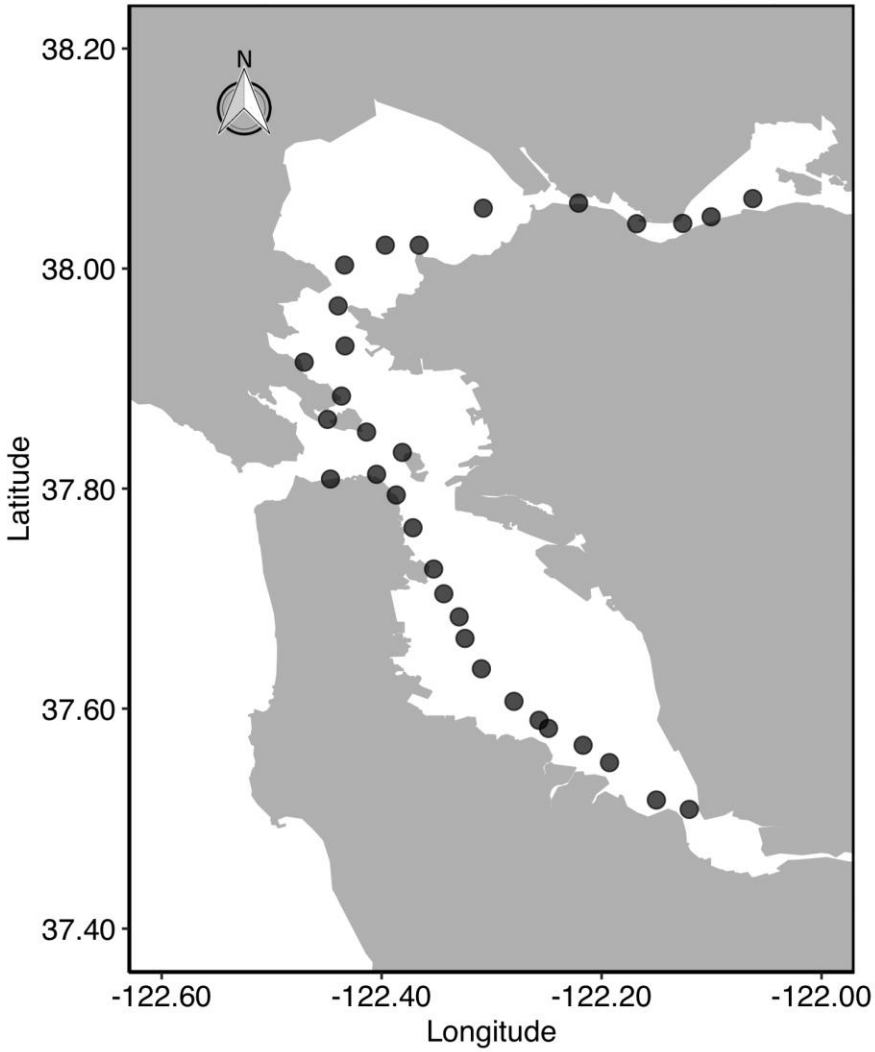

Figure A3.1.1: *Map of zooplankton community sampling locations in San Francisco Bay (2021).*

Table A3.10.1: *Zooplankton community sampling locations in San Francisco Bay (2021).*

Site Code	Site Name	Latitude (N)	Longitude (W)
SFHS-01	North of Dumbarton Bridge	37.508	-122.120
SFHS-02	Dumbarton Bridge	37.517	-122.150
SFHS-03	Between Dumbarton and San Mateo Bridges	37.551	-122.193
SFHS-04	Between Dumbarton and San Mateo Bridges	37.567	-122.217
SFHS-05	San Mateo Bridge	37.582	-122.248
SFHS-06	San Mateo Bridge	37.589	-122.257
SFHS-07	North of San Mateo Bridge	37.607	-122.280
SFHS-08	Burlingame	37.636	-122.309
SFHS-09	San Francisco International Airport	37.664	-122.324
SFHS-10	South San Francisco	37.683	-122.329
SFHS-11	South San Francisco	37.704	-122.344
SFHS-12	Richmond Marina	37.727	-122.353
SFHS-13	Across from Alameda	37.764	-122.371
SFHS-14	Bay Bridge	37.794	-122.387
SFHS-15	Fisherman's Wharf	37.813	-122.405
SFHS-16	Golden Gate	37.809	-122.447
SFHS-17	Treasure Island	37.833	-122.381
SFHS-18	Angel Island	37.851	-122.414
SFHS-19	Between Tiburon and Angel Island	37.863	-122.449
SFHS-20	Tiburon	37.884	-122.436
SFHS-21	San Quentin Prison	37.915	-122.470
SFHS-22	Richmond	37.930	-122.433
SFHS-23	Southern San Pablo Bay	37.966	-122.440
SFHS-24	Bay Bridge	38.003	-122.434
SFHS-25	San Pablo	38.021	-122.397
SFHS-26	San Pablo	38.021	-122.366
SFHS-27	Northeast San Pablo Bay	38.055	-122.308
SFHS-28	Carquinez Strait, Highway 80 bridge	38.059	-122.221
SFHS-29	Carquinez Strait, Benecia	38.041	-122.168
SFHS-30	Carquinez Strait, Highway 680 bridge	38.041	-122.126
SFHS-31	Suisun Bay, Pacheco Creek	38.047	-122.100
SFHS-32	Suisun Bay, Roe Island	38.064	-122.062

A3.1.2: Los Angeles / Long Beach Harbor 2021

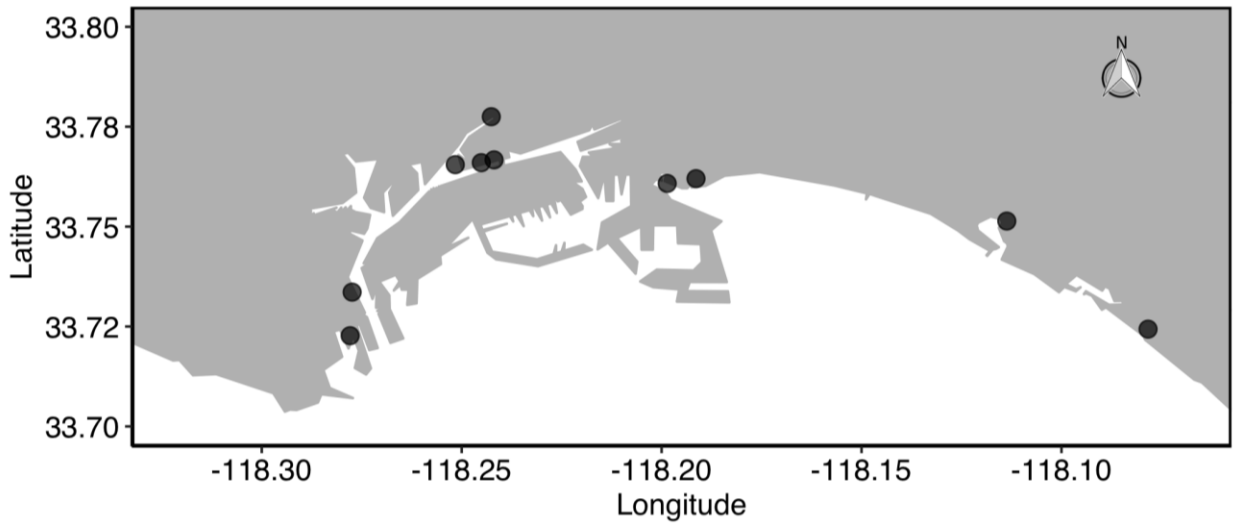

Figure A3.1.2: *Map of zooplankton community sampling locations in Los Angeles / Long Beach Harbor (2021).*

Table A3.1.11: *Zooplankton community sampling locations in Los Angeles / Long Beach Harbor (2021).*

Site Code	Site Name	Latitude (N)	Longitude (W)
SP-P02	Alamitos Bay Marina Center (Long Beach Marina Headquarters)	33.751	-118.114
SP-P01	Cabrillo Way Marina	33.723	-118.278
SP-P04	Formerly Ports O' Call Restaurant/Village	33.734	-118.277
SP-P08	Island Yacht Anchorage	33.767	-118.242
SP-P05	Leeward Bay Marina	33.778	-118.243
SP-P06	Lighthouse Yacht Landing	33.766	-118.245
SP-P10	Long Beach Shoreline Marina	33.762	-118.191
SP-P07	Pacific Yacht Landing	33.766	-118.252
SP-P03	Peter's Landing Marina	33.724	-118.078
SP-P09	Pierpoint Landing	33.761	-118.199

A3.1.3: Mission Bay 2021

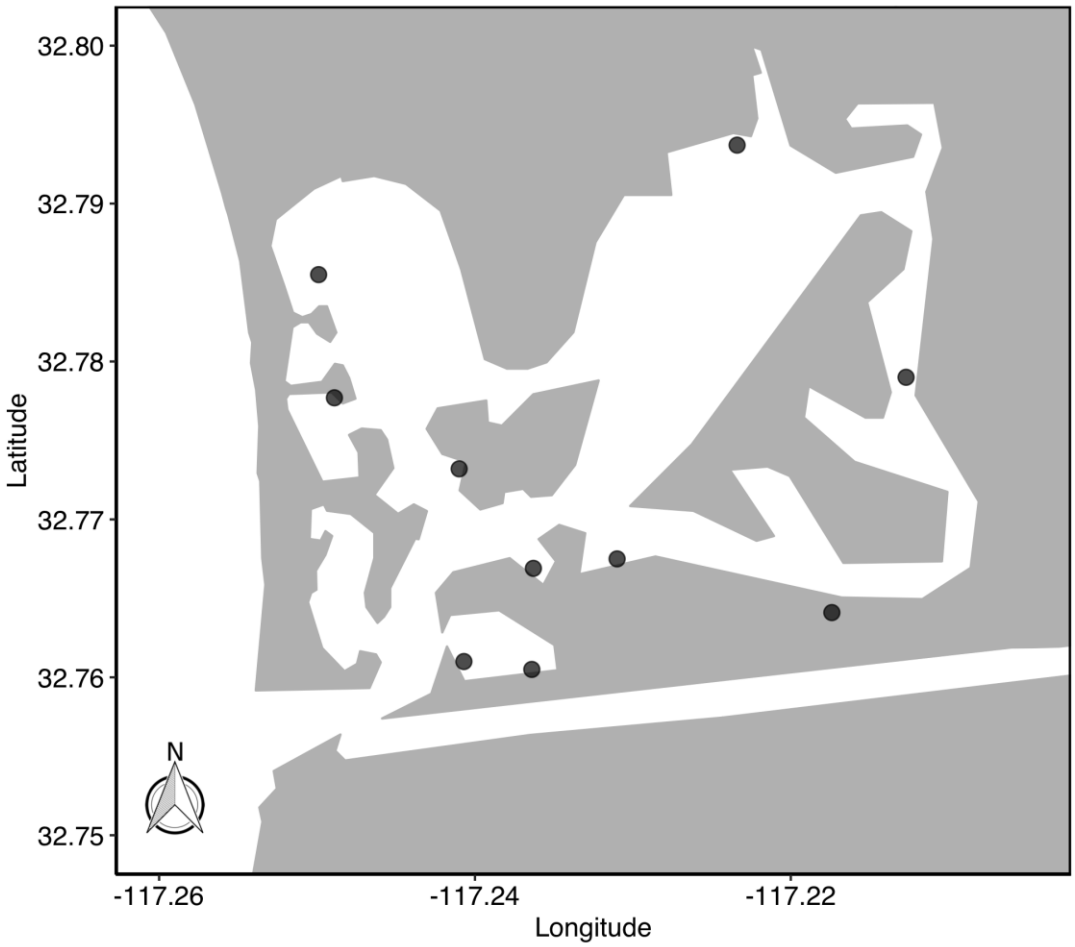

Figure A3.1.3: *Map of zooplankton community sampling locations in Mission Bay (2021).*

Table A3.1.12: *Zooplankton community sampling locations in Mission Bay (2021).*

Site Code	Site Name	Latitude (N)	Longitude (W)
MI-P06	Campland on the Bay	32.794	-117.223
MI-P05	Hilton San Diego Resort and Spa Hotel	32.779	-117.213
MI-P01	Marina Village Marina	32.761	-117.236
MI-P07	Mission Bay Sport Center	32.785	-117.250
MI-P08	Mission Bay Yacht Club	32.778	-117.249
MI-P10	Paradise Point Resort Spa Hotel and Marina	32.773	-117.241
MI-P02	San Diego Life Guard Station	32.761	-117.241
MI-P04	SeaWorld Marina	32.767	-117.231
MI-P09	South Shores Boat Landing Area	32.764	-117.217
MI-P03	The Dana on Mission Bay Hotel	32.767	-117.236

A3.1.4: San Diego Bay 2021

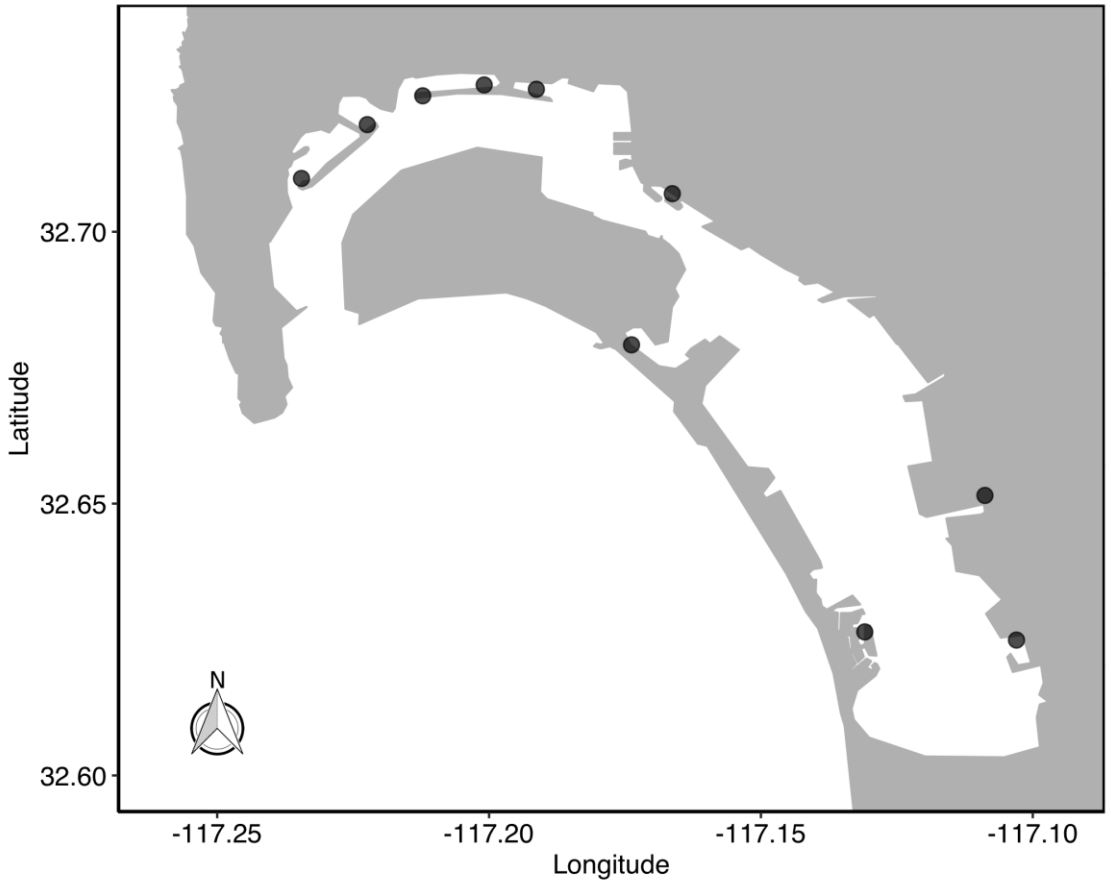

Figure A3.1.4: *Map of zooplankton community sampling locations in San Diego Bay (2021).*

Table A3.1.13: *Zooplankton community sampling locations in San Diego Bay (2021).*

Site Code	Site Name	Latitude (N)	Longitude (W)
SD-P04	Cabrillo Isle Marina	32.727	-117.201
SD-P10	Chula Vista Marina	32.625	-117.103
SD-P09	Coronado Cays Yacht Club	32.626	-117.131
SD-P07	Glorietta Marina & Public Dock	32.679	-117.174
SD-P02	Harbor Island West Marina	32.725	-117.212
SD-P08	Pier 32 Marina	32.651	-117.109
SD-P01	San Diego Harbor Police Transient Docks	32.710	-117.234
SD-P06	San Diego Marriott Marquis Hotel & Marina	32.707	-117.166
SD-P03	Shelter Cove Marina	32.720	-117.222
SD-P05	Sunroad Resort Marina	32.726	-117.191

A3.1.5: Humboldt Bay 2022

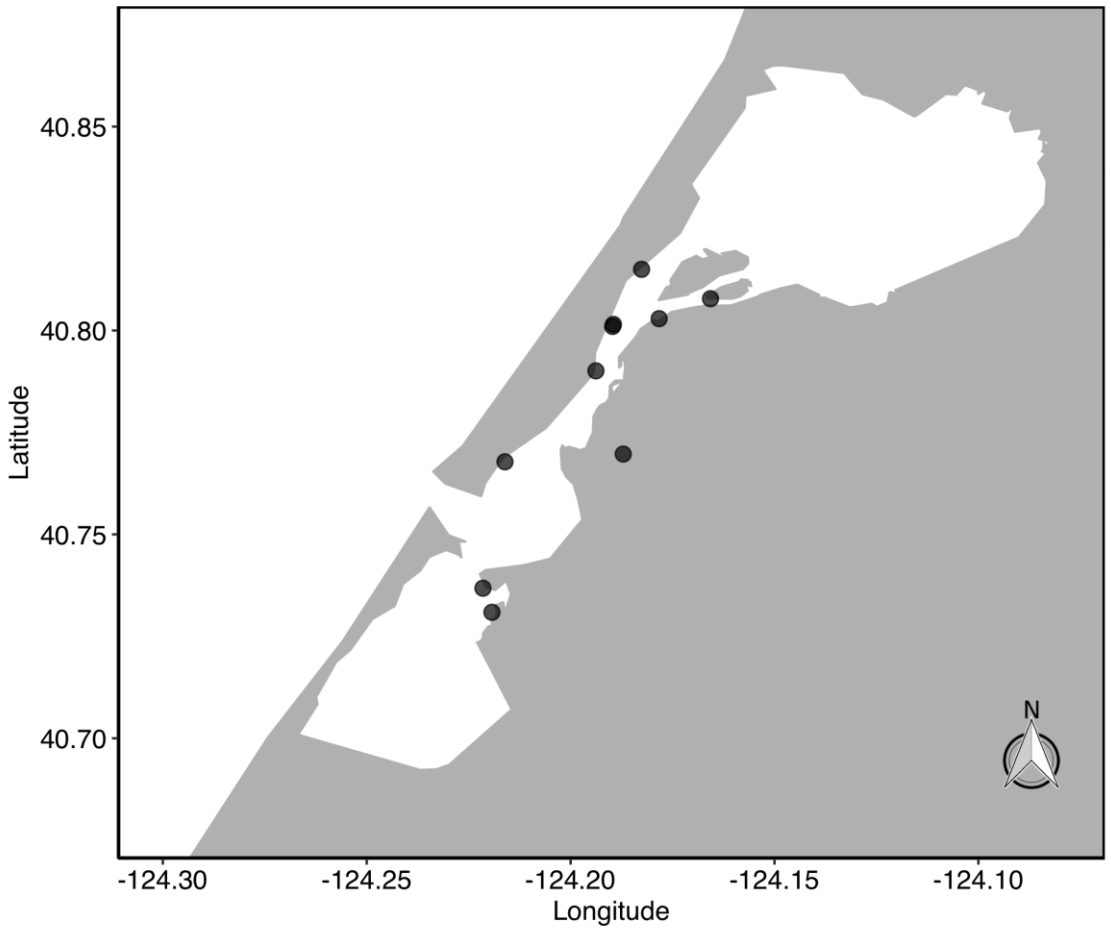

Figure A3.1.5: *Map of zooplankton community sampling locations in Humboldt Bay (2022).*

Table A3.1.14: *Zooplankton community sampling locations in Humboldt Bay (2022).*

Site Code	Site Name	Latitude (N)	Longitude (W)
HB-P06	CA Redwood Chip Export (pulp dock)	40.801	-124.190
HB-P09	EZ Landing Marina	40.737	-124.222
HB-P03	Eureka Public Marina	40.803	-124.178
HB-P07	Fairhaven Terminal	40.790	-124.194
HB-P10	HB Forest Products Terminal	40.731	-124.219
HB-P04	Redwood Marine Terminal Berth #1	40.815	-124.183
HB-P05	Redwood Marine Terminal Berth #2	40.801	-124.189
HB-P02	Schneider Dock	40.770	-124.187
HB-P08	US Coast Guard	40.768	-124.216
HB-P01	Woodley Island Marina	40.808	-124.166

A3.1.6: Bodega Harbor and Tomales Bay 2022

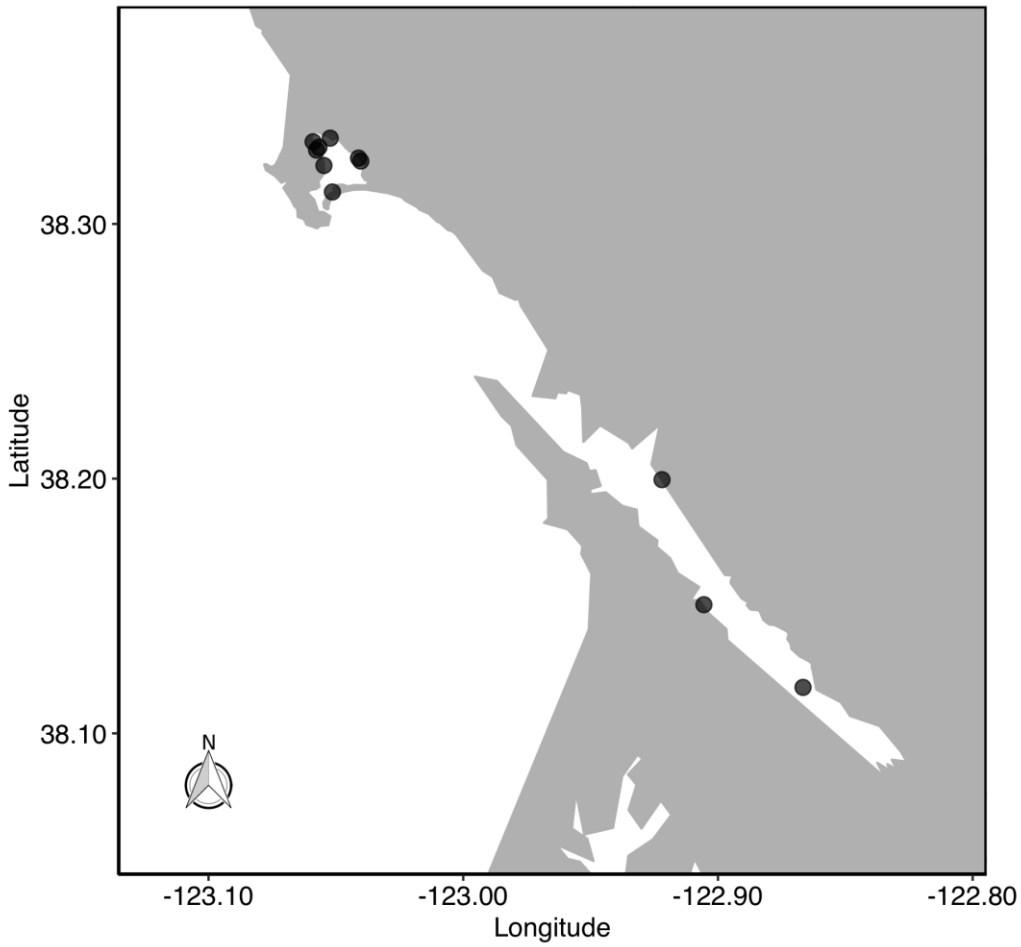

Figure A3.1.6: *Map of zooplankton community sampling locations in Bodega Harbor and Tomales Bay (2022).*

Table A3.1.15: *Zooplankton community sampling locations in Bodega Harbor and Tomales Bay (2022).*

Site Code	Site Name	Latitude (N)	Longitude (W)
BT-P07	Bodega Harbor Boat Ramp	38.323	-123.055
BT-P05	Lucas Wharf	38.326	-123.041
BT-P04	Mason's Marina	38.332	-123.059
BT-P09	Miller Park Boat Launch	38.200	-122.922
BT-P10	National Park Service Dock	38.151	-122.906
BT-P03	Porto Bodego	38.334	-123.052
BT-P01	Spud Point A	38.330	-123.057
BT-P02	Spud Point B	38.329	-123.058
BT-P11	Tomales BML Buoy Inverness Mooring	38.118	-122.867
BT-P08	USCG Dock	38.313	-123.051
BT-P06	Yacht Club Dock	38.325	-123.040

A3.1.7: Santa Catalina Island 2022

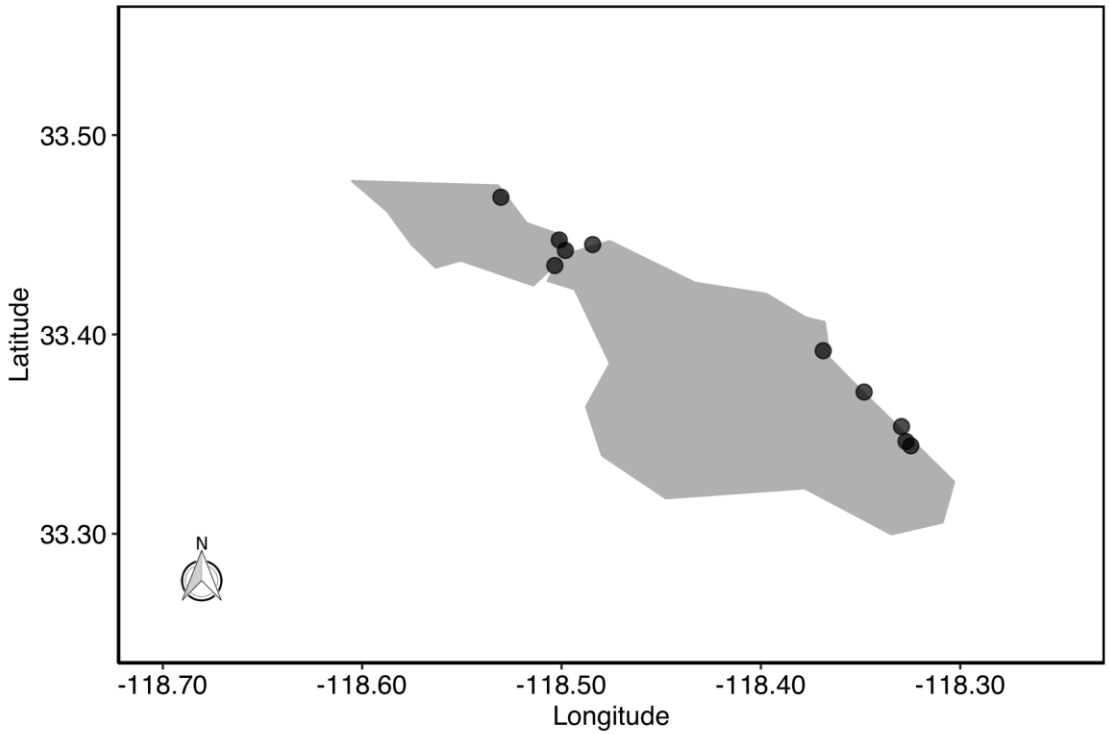

Figure A3.1.7: *Map of zooplankton community sampling locations at Santa Catalina Island (2022).*

Table A3.1.16: *Zooplankton community sampling locations at Santa Catalina Island (2022).*

Site Code	Site Name	Latitude (N)	Longitude (W)
CI-P10	Cat Harbor (Public Dock)	33.435	-118.503
CI-P02	Catalina Avenue Dinghy Dock	33.344	-118.325
CI-P09	Emerald Bay	33.469	-118.530
CI-P08	Fourth of July Yacht Club	33.447	-118.501
CI-P04	Gallaghers Cove	33.371	-118.348
CI-P03	Hamilton Beach	33.354	-118.329
CI-P01	Middle Dock	33.346	-118.327
CI-P07	Two Harbors Harbor Department Dock	33.442	-118.498
CI-P06	USC Wrigley Marine Lab Dock	33.445	-118.484
CI-P05	Whites Cove	33.392	-118.369

Chapter 4: BioBlitzes

4.1: Introduction

The strength of SERC's and MLML's standardized, systematic approach to surveying for non-native marine and estuarine species in California is undergirded by a reference library of diverse morphological specimens identified by recognized taxonomic experts and DNA barcodes corresponding to those specimens and species identifications. This barcode library, a resource unique to our collaborative group, undergoes constant updates and refinement as new samples are collected and identified and the states of taxonomy and genetic methods both advance.

The MLML barcode library originated with specimens and sequences assembled by MLML and was initially bolstered by a robust sampling effort of hard substrate communities in San Francisco Bay by this group of collaborators (2009-2011). Subsequent efforts added to the barcode library (Ruiz and Geller 2015, 2018, 2021; Ruiz, Geller, and Chang 2022).

In order to boost the taxonomic coverage of the barcode library, we undertook several BioBlitzes, or targeted sampling efforts focused on collecting taxa from groups poorly represented in the library and in available genetic databases.

We conducted three BioBlitz events in 2022: a polychaete BioBlitz in northern California, a hydroid BioBlitz in San Francisco Bay, and a BioBlitz covering a broad range of taxa in southern Oregon that included anemones, barnacles, bryozoans, crustaceans, hydroids, molluscs, and tunicates. In total, we collected and delivered to MLML samples representing more than 50 taxa.

Below, we summarize the methods and findings of each event.

4.2: Results

4.2.1: Polychaetes

In May 2022, Erica Keppel (SERC) led a polychaete BioBlitz with assistance from several SERC staff and three invited taxonomists: Ricardo Castro Alvarez (Universidade Federal do Paraná, Brazil), Leslie Harris (Los Angeles County Natural History Museum, Los Angeles, CA), and Tony Phillips (Dancing Coyote Environmental, Aliso Viejo, CA). The group visited 11 sites in locations spanning Bodega Harbor to Half Moon Bay in northern California (Table 4.1).

The group collected and identified 47 species (191 specimens) from a number of different habitats, including docks, natural rocky shoreline, mudflat, and sandy bottoms. Only six of these were limited to genus-level identifications, and genetic vouchers were collected for all 47 of these species, including five or more replicate DNA vouchers for 24 of the taxa (Table 4.2). The BioBlitz also yielded one possible new record for California, the spionid *Pseudopolydora bassarginensis* (Zachs 1933) (subject to genetic confirmation), which was found at Dillon Beach. This species is from the Sea of Japan, and although this species was previously collected in Oregon, Washington, and British Columbia, it has not yet been detected in SERC's other standardized surveys.

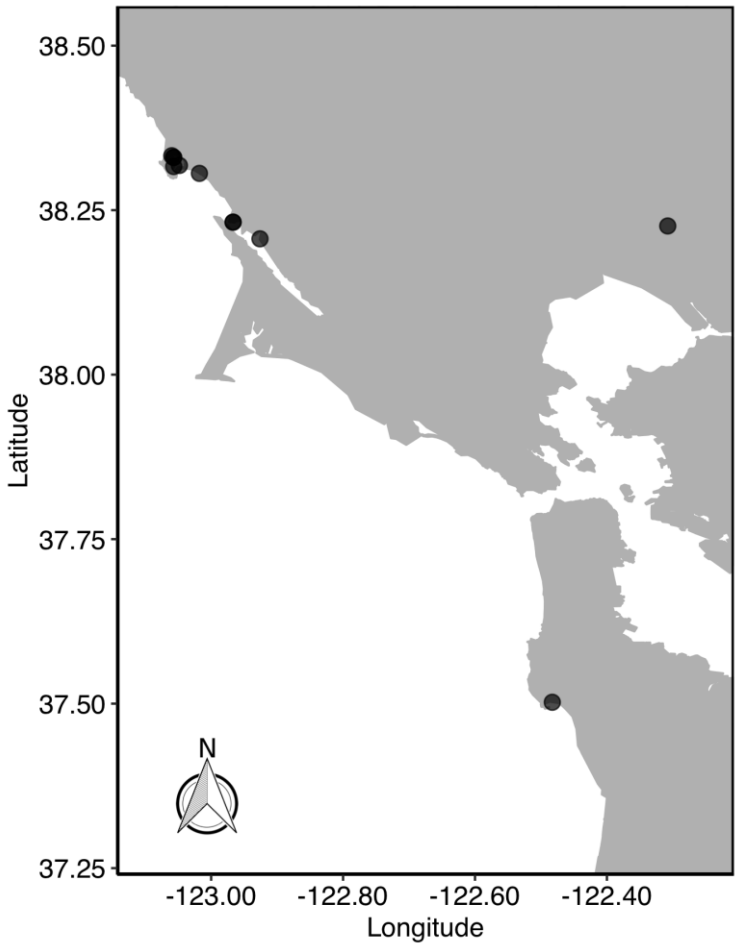

Figure 4.1: *Map of Polychaete BioBlitz sampling locations in Bodega Harbor and the greater San Francisco Bay area (2022).*

Table 4.17: *Polychaete BioBlitz sampling locations in Bodega Harbor and the greater San Francisco Bay area (2022).*

Site Code	Site Name	Latitude (N)	Longitude (W)
1	Bodega Harbor, Spud Point Marina, Dock A	38.330	-123.057
2	Tomales Bay, Hamlet	38.206	-122.926
3	Dillon Beach, Lawson's Landing	38.232	-122.967
4	Bodega Harbor, Spud Point Marina, Dock A	38.330	-123.057
5	Pillar Point Harbor Marina	37.502	-122.483
6	Napa Valley Marina, Boat ramp	38.226	-122.308
7	Dillon Beach, Lawson's Landing	38.232	-122.967
8	Bodega Bay South (soft sediment)	38.318	-123.048
9	Bodega Bay Harbor (rocks)	38.333	-123.060
10	Bodega Harbor, Gaffney Point (mudflat)	38.316	-123.057
11	Pinnacle Point (rocks)	38.306	-123.018

Table 4.2: *Species collected during the 2022 Polychaete BioBlitz. The number of replicate samples taken for morphological and genetic analysis is given, along with invasion status.*

Species	Number of Samples	Status
Alitta cf. *succinea*	5	NIS
Ampharete labrops	2	Native
Armandia brevis	5	Native
Axiothella rubrocincta	5	Native
Bispira sp.	6	Unresolved
Boccardia proboscidea	5	Native
Capitella sp.	5	Unresolved
Chaetozone columbiana	1	Native
Chaetozone hedgpethi	2	Native
Chone mollis	5	Native
Cirratulus sp.	1	Unresolved
Cirriformia moorei	5	Native
Cirriformia sp.	3	Unresolved
Dipolydora socialis	2	Cryptogenic
Dorvillea moniloceras	5	Native
Exogone lourei	5	Cryptogenic
Glycera robusta	1	Native
Glycinde picta	3	Native
Gycera americana	1	Native
Halosydna johnsoni	1	Native
Harmothoe sp. C Harris	1	Unresolved
Hemipodia simplex	4	Native
Hydroides gracilis	1	Native
Leitoscoloplos pugettensis	5	Native
Marphysa sp. C Harris	4	Unresolved
Mediomastus sp.	5	Unresolved
Neanthes sp. LH1	1	Unresolved

Species	Number of Samples	Status
Nephtys caecoides	5	Native
Nereis latescens	5	Native
Nereis sp. A	2	Unresolved
Nereis vexillosa	4	Native
Notomastus magnus	4	Native
Notomastus tenuis	5	Native
Onuphis eremita parva	1	Native
Ophryotrocha sp.	1	Unresolved
Paradialychone ecaudata	3	Native
Pectinaria californiensis	1	Native
Phyllodoce hartmanae	5	Native
Phyllodoce williamsi	5	Native
Pista brevibranchiata	1	Native
Polycirrus sp.	5	Unresolved
Polydora narica	1	Native
Prionospio lighti	1	Native
Pseudopolydora bassarginensis	2	NIS
Pseudopolydora kempi	6	NIS
Pseudopolydora paucibranchiata	5	NIS
Scoletoma zonata	5	Native
Scoloplos acmeceps	6	Native
Scoloplos sp. SF1	1	Unresolved
Spiophanes duplex	11	Native
Syllis adamantea	2	Native
Syllis elongata complex	5	Native
Syllis gracilis complex	2	Cryptogenic

4.2.2: Hydroids

In October 2022, Henry Choong (Royal British Columbia Museum) joined the SERC team for a Hydroid BioBlitz before and during the retrieval of panels for the 2022 San Francisco Bay hard substrate survey. Samples were collected from docks at a number of locations and panels from the hard substrate survey (Table 4.3).

Despite a general paucity and reduction in abundance of Bay fauna due to an unprecedented bloom of the microalga *Heterosigma akashiwo* during late summer 2022, the group was able to collect paired morphological and genetic vouchers for 18 taxa, including at least 9 probable NIS across a range of hydroid groups for which we were lacking sequences associated with reliable morphological identifications.

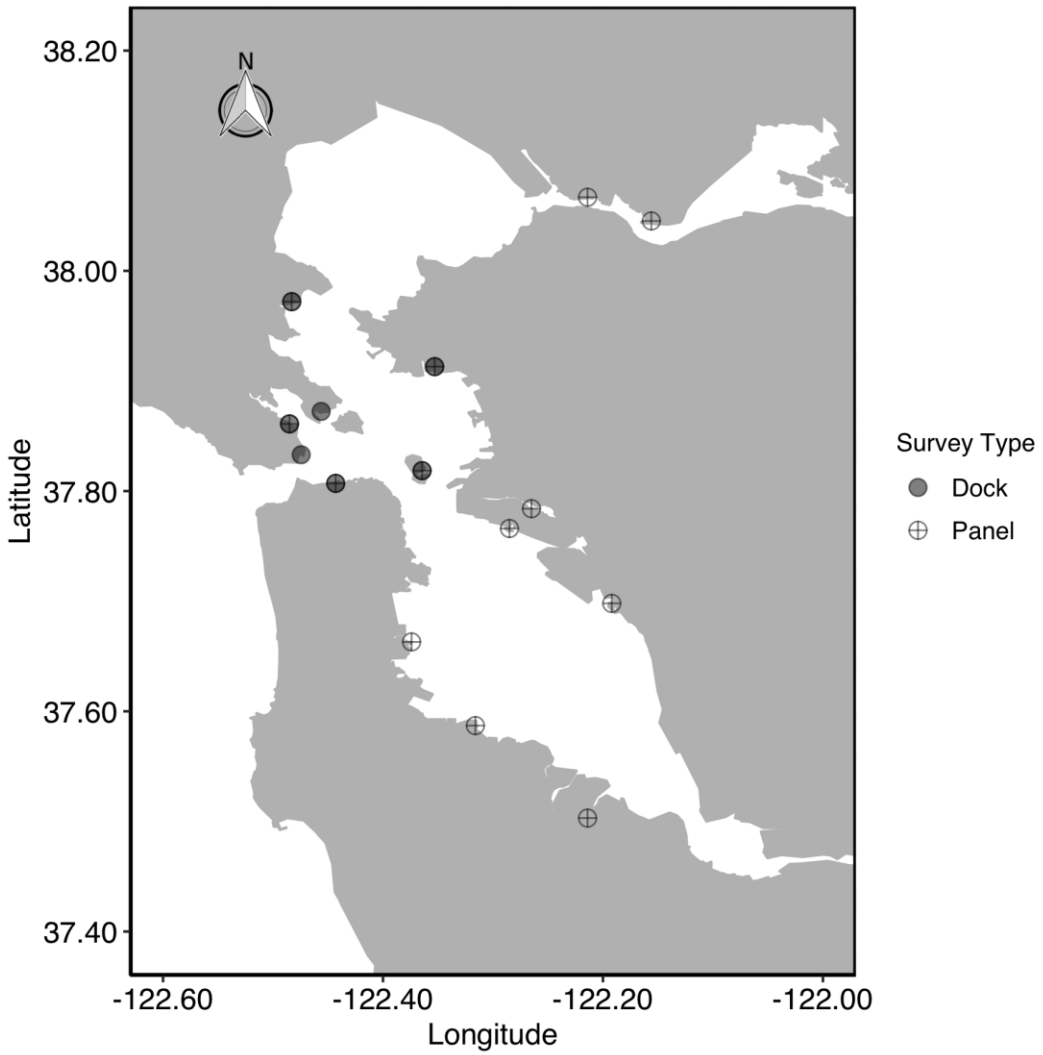

Figure 4.2: *Map of Hydroid BioBlitz sampling locations in San Francisco Bay (2022).*

Table 4.3: *Hydroid BioBlitz sampling locations in San Francisco Bay (2022).*

Site Name	Survey Type	Latitude (N)	Longitude (W)
Corinthian Yacht Club	Dock	37.872	-122.456
Loch Lomond Marina	Dock	37.972	-122.483
Richmond Marina	Dock	37.913	-122.353
San Francisco Marina	Dock	37.807	-122.443
Sausalito Marine Harbor	Dock	37.861	-122.485
Travis Marina	Dock	37.833	-122.474
Treasure Island Sailing Center	Dock	37.819	-122.364
Antioch Marina	Panel	38.020	-121.821
Ballena Isle Marina	Panel	37.766	-122.285
Benicia Marina	Panel	38.045	-122.156
Coyote Point Marina	Panel	37.587	-122.316
Glen Cove Marina	Panel	38.067	-122.214
Loch Lomond Marina	Panel	37.972	-122.483
Oakland Yacht Club	Panel	37.784	-122.265
Oyster Point	Panel	37.663	-122.374
Redwood City Marina	Panel	37.503	-122.214
Richmond Marina	Panel	37.913	-122.353
San Francisco Marina	Panel	37.807	-122.443
San Leandro Marina	Panel	37.698	-122.192
Sausalito Marine Harbor	Panel	37.861	-122.485
Treasure Island Sailing Center	Panel	37.819	-122.364

The following taxa were found in the Hydroid BioBlitz:

Table 4.4: *Species collected during the 2022 Hydroid BioBlitz. The number of replicate samples taken for morphological and genetic analysis is given, along with invasion status.*

Species	Number of Samples	Status
Aglaophenia diegensis	2	Native
Bougainvillia muscus	2	NIS
Bougainvillia sp.	1	Unresolved
Calyptospadix cerulea	13	NIS
Cordylophora caspia	4	NIS
Ectopleura crocea	2	NIS
Ectopleura dumortierii	7	NIS
Ectopleura larynx	5	Unresolved
Ectopleura sp.	2	Unresolved
Eudendrium cf. *capillare*	1	Unresolved
Eudendrium sp.	5	Unresolved
Gonothyraea loveni	1	NIS
Laomedea sp.	1	Unresolved
Mitrocomium sp.	3	Unresolved
Obelia bidentata	2	NIS
Obelia dichotoma	6	NIS
Obelia longissima	2	Cryptogenic
Pachycordyle sp.	16	Unresolved

4.3.3: Multiple Taxa - Southern Oregon

Much of the coastal fauna in California waters overlaps with taxa found in nearby regions. Taking advantage of a convergence of several experts in Coos Bay, OR in July 2022, we worked with James Carlton, editor of *The Light and Smith Manual of Intertidal Invertebrates* (Carlton 2007) to facilitate collections and morphological identifications of samples focused on NIS across a range of taxa. Matching samples were forwarded to MLML. Participating experts included James Carlton (Williams College - Mystic Seaport, emeritus), Evangelina Schwindt (Instituto de Biologia de Organismos Marinas, Argentina), Richard Emlet (University of Oregon), Nancy Treneman (University of Oregon), and Leslie Harris (Los Angeles County Museum).

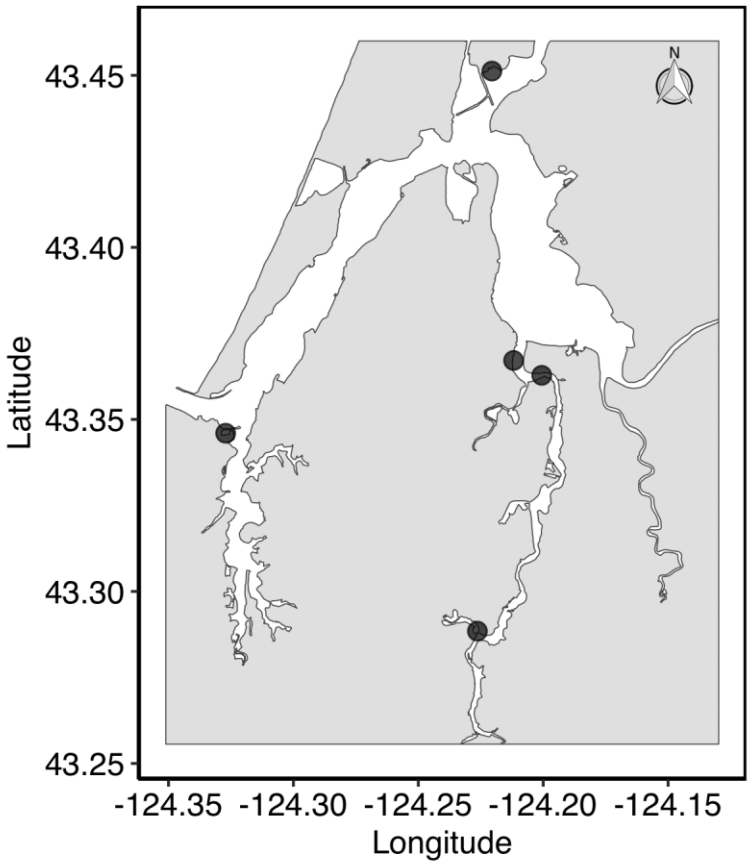

Figure 4.3: *Map of Bioblitz sampling locations in Coos Bay, OR (2022).*

Table 4.5: *Bioblitz sampling locations in Coos Bay, OR (2022).*

Site Name	Survey Type	Latitude (N)	Longitude (W)
Charleston Inner Boat Basin	Dock	43.346	-124.327
Coos Bay City Docks	Dock	43.367	-124.212
Isthmus Slough	Dock	43.363	-124.201
Davis Slough	Dock and debris	43.288	-124.226
Haynes Inlet	Mudflat	43.451	-124.221

Twenty different taxa were collected and identified for barcoding with approximately 2-5 specimens per taxon (Table 4.6).

Nearly all taxa are NIS to the Pacific Coast. *Uromunna* sp. appears to be an undescribed, introduced species of Asian origin (J. T. Carlton, pers. comm.). The encrusting bryozoan *Conopeum lingdingensis* may be the same as *C. chesapeakensis*, which is established in San Francisco Bay (e.g. Newcomer et al. 2018). Further genetic and morphological analyses are in progress.

Table 4.6: *Species collected during the 2022 Oregon BioBlitz. The number of replicate samples taken for morphological and genetic analysis is given, along with invasion status in CA.*

Group	Species	Number of Samples	Status
Anthozoa	*Diadumene lineata*	6	NIS
Anthozoa	*Nematostella vectensis*	4	NIS
Ascidiacea	*Botrylloides violaceus*	5	NIS
Ascidiacea	*Botryllus schlosseri*	2	NIS
Ascidiacea	*Molgula citrina*	2	NIS
Ascidiacea	*Molgula manhattensis*	5	NIS
Ascidiacea	*Styela clava*	5	NIS
Bivalvia	*Mya arenaria*	5	NIS
Bivalvia	Ostreidae	5	Unresolved
Bivalvia	*Teredo bartschi*	5	NIS
Bryozoa	*Conopeum lingdingensis*	5	NIS
Bryozoa	*Conopeum seurati*	5	NIS
Bryozoa	*Einhornia crustulenta*	5	NIS
Bryozoa	*Schizoporella japonica?*	3	NIS
Cirripedia	*Amphibalanus subalbidus*	5	NIS
Cumacea	*Nippoleucon hinumensis*	5	NIS
Gastropoda	*Assiminea parasitologica*	> 15	NIS
Gastropoda	*Myosotella myosotis*	5	NIS
Gastropoda	*Tenellia adspersa*	3	NIS
Hydrozoa	*Clava leptostyla*	5	NIS

Group	Species	Number of Samples	Status
Hydrozoa	*Cordylophora caspia*	5	NIS
Hydrozoa	*Obelia* sp.	5	Unresolved
Isopoda	*Uromunna* sp.	5	Unresolved
Tanaidacea	*Sinelobus* sp.	5	Unresolved

4.4: References

Carlton, James T. 2007. *The Light and Smith Manual: Intertidal Invertebrates from Central California to Oregon*. Univ of California Press. 1019 pp.

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Chapter 5: Cal-NEMO Database Updates

5.1: Overview

The California Non-native Estuarine and Marine Organisms (Cal-NEMO) database was created by SERC in 2015 as a regional portal of SERC's National Estuarine and Marine Exotic Species Information System (NEMESIS) to provide public access to NIS information and occurrence data in California as required by law (Fofonoff et al. 2018a, 2018b).

Cal-NEMO is a collaboration between SERC and the California Department of Fish & Wildlife's Marine Invasive Species Program (CDFW). The system synthesizes prior data and new records to document the occurrence of NIS in California's marine and estuarine waters. Data uploads are conducted on an annual schedule, with routine improvements to functionality and regular meetings among SERC staff to review data status and coordination with CDFW staff.

As described in the previous report (Ruiz, Geller, and Chang 2022), the Cal-NEMO portal and other portals of the NEMESIS database were upgraded to a new server, web framework, and website design in 2021-2022. The server upgrade accommodates more concurrent users and provides for faster page loads, and the web framework upgrade extended the site's previous capabilities to allow more dynamically generated maps and graphs. An updated layout also produces a responsive design that works on a variety of devices and meets current accessibility standards.

Both broad overviews of geographic and temporal trends in invasion patterns and detailed, species-specific information are provided by Cal-NEMO. A variety of bay-level summary data visualizations and outputs derived from the database are provided (Figures 5.1 and 5.2), as well as species-specific summaries with maps showing known occurrences (Figure 5.3).

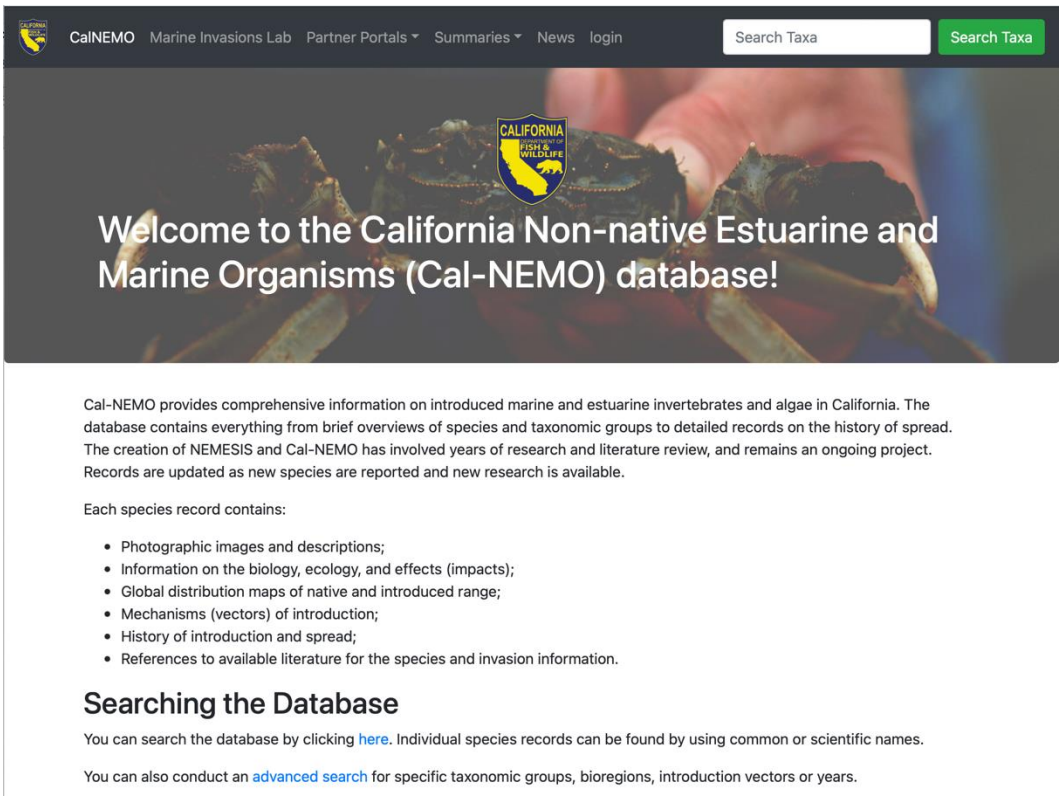

Figure 5.1: *Cal-NEMO website with access to search interface, summary data, and partner portals.*

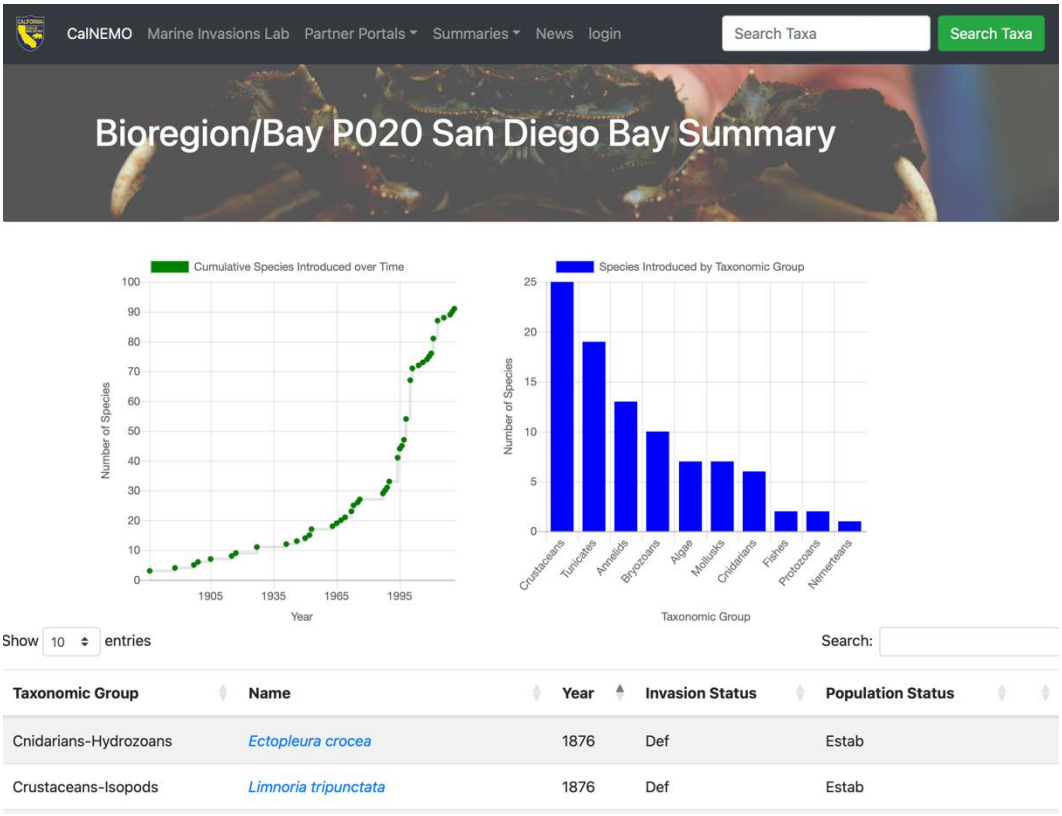

Figure 5.2: *An example of bay-level summary data available from Cal-NEMO. Marine and estuarine invasions over time known from the literature and our survey records to San Diego Bay are shown here.*

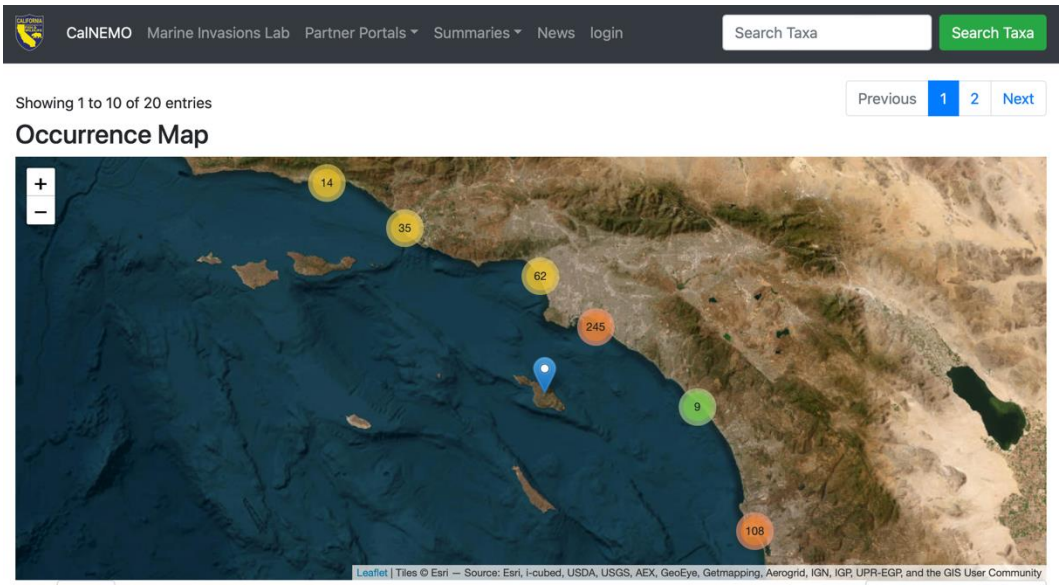

Figure 5.3: *An example of a species-specific occurrence map from Cal-NEMO for the solitary tunicate* Ciona robusta *in the Southern California Bight. The number of records from each location is shown, with warmer colors corresponding to a greater number of records. The map is responsive, so records are aggregated regionally when viewed on a larger scale, but individual records appear with increasingly specific location detail as the view is magnified.*

5.2: References

Fofonoff, PW, GM Ruiz, B Steves, and JT Carlton. 2018a. "California Non-Native Estuarine and Marine Organisms (Cal-NEMO) System." https://invasions.si.edu/nemesis/calnemo/.

———. 2018b. "National Exotic Marine and Estuarine Species Information System." http://invasions.si.edu/nemesis/.

Ruiz, Gregory M, Jonathan B Geller, and Andrew L Chang. 2022. "Spatial and Temporal Analysis of Marine Invasions: Los Angeles / Long Beach Harbor and San Francisco Bay." California Department of Fish and Wildlife. 78 pp.