Yerba Buena Island Intertidal and Eelgrass Surveys

Alison N. Young and Rebecca F. Johnson

Prepared for the Treasure Island Development Authority

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CALIFORNIA ACADEMY OF SCIENCES

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Introduction

Yerba Buena Island (YBI) is located about halfway between San Francisco and Oakland, in San Francisco Bay. Though connected to the human-made Treasure Island (TI) in 1936 via a causeway, and a long history of varied use, YBI retains many of its natural characteristics. YBI is well-known for its pockets of native plant diversity as well as for hosting a diverse assemblage of residential and migrant native bird species and other wildlife. Despite its immediate proximity to two of the three largest cities in the Bay Area and numerous academic and scientific institutions, the coast of Yerba Buena Island has been understudied as a whole in comparison to the terrestrial habitats on the island and to other shorelines within San Francisco Bay. Not including records from the community/citizen science platforms iNaturalist (est. 2008) and eBird (est. 2002), there are only 256 species occurrence records available on the Global Biodiversity Information Facility (GBIF) database from the YBI intertidal and surrounding marine areas, comprising 77 species total, and made between 1973 and 2010.

The composition of intertidal communities in San Francisco Bay can be highly site-specific. This is due to the great diversity of intertidal flora and fauna and species-level responses to ecological and environmental conditions such as substrate type, currents (and associated correlations to biological functions like nutrient availability and larval dispersal), salinity, wave action, freshwater runoff, and tidal fluctuation. Because of the variability of these kinds of conditions throughout San Francisco Bay, it is difficult to generalize or apply the findings at one intertidal site to another site within the Bay. This necessitates site-specific assessments to determine species composition.

For informed habitat management, and especially in light of the Treasure Island/Yerba Buena Island Development Project, the Treasure Island Development Authority (TIDA) needs to know the species currently present along the YBI coastline and in other associated marine influenced-areas. Construction activities combined with the subsequent increase in human use of the shoreline due to residential development on the islands and increased visitorship from a new ferry terminal have the potential to disturb the intertidal habitat and possibly lead to the loss of species, highlighting the need to have a "before" baseline to compare to. The objectives of this study were:

- To survey the biodiversity of YBI intertidal areas to develop species lists
- To survey the Treasure Island marina fouling community to develop a species list
- To understand which intertidal habitats harbor the most native diversity
- To survey for eelgrass along the southern edge of Clipper Cove
- Based on other studies, to situate the YBI intertidal in the context of San Francisco Bay

Methods

Personnel

Personnel who participated in the surveys for this study are presented in Table 1.

Table 1. Personnel for the Yerba Buena Island intertidal and eelgrass surveys

Name	Affiliation	Duties
Dr. Rebecca Johnson	California Academy of Sciences	Marine biologist, intertidal & eelgrass surveys TIDA liaison
Alison Young	California Academy of Sciences	Marine biologist, intertidal & eelgrass surveys
Annie Miller	California Academy of Sciences	Field assistant, intertidal & eelgrass surveys
Dr. Grace Ha	UC Davis Bodega Marine Lab	Coastal ecologist, eelgrass surveys
Dr. Katie DuBois	UC Davis Bodega Marine Lab	Coastal ecologist, eelgrass surveys
David McGuire	Shark Stewards	ROV pilot, eelgrass surveys

Survey Activities

The schedule of survey activities is presented in Table 2.

Table 2. Survey activities in the Yerba Buena Island intertidal and for eelgrass

Date	Activity
July 18, 2019	Survey of Torpedo Storehouse site
November 25, 2019	Surveys of Clipper Cove Sandy & Clipper Cove Rocky sites
December 27, 2019	Walking survey of Clipper Cove Eelgrass site
January 22, 2020	Surveys of Clipper Cove Sandy & Clipper Cove Rocky sites; walking survey of Clipper Cove Eelgrass sites
July 21, 2020	Surveys of Clipper Cove Sandy & Clipper Cove Rocky sites; walking survey of Clipper Cove Eelgrass sites
October 9, 2020	Survey of Treasure Island Marina site
February 26, 2021	ROV survey of Clipper Cove Eelgrass site
March 24, 2021	Survey of Southwest Cove site
April 5, 2021	Survey of Northwest Cove site
April 28, 2021	Survey of Southwest Cove site
June 11, 2021	ROV survey of Treasure Island & Clipper Cove Eelgrass sites

Intertidal site selection

Sites were chosen with these considerations:

- To maximize diversity of intertidal/marine habitats (e.g., natural rocky shoreline, artificial rip-rap, cobble/rocky beach, sandy beach, etc.)
- To sample a diversity of intertidal aspects and open-ocean exposures around Yerba Buena Island
- Accessibility, by walking or by boat, and avoiding areas off-limits due to construction and/or land ownership

Keeping those considerations in mind, sites were chosen before surveys began and then refined in the field as needed. Six intertidal sites were chosen (see Figure 1): Clipper Cove sandy, Clipper Cove rocky, Torpedo Storehouse, Northwest cove, Southwest cove, and Treasure Island Marina.

Figure 1. Intertidal sites selected and surveyed in this study.

Intertidal site descriptions

Clipper Cove Sandy

Sandy stretch of beach. Willows and other upland vegetation grow right to the edge of the beach, creating some hard substrate. Fallen trees on the beach also provide hard habitat. Some cobbles and small rocks at low tide. Shells, algae, and eelgrass wash up seasonally. Easy public access.

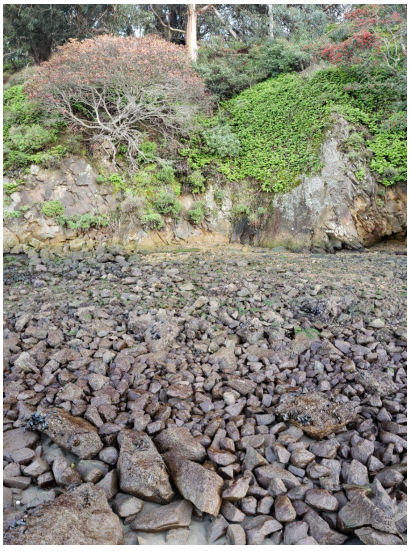
Clipper Cove sandy site looking east.

Clipper Cove sandy site looking west.

Clipper Cove Rocky

Mixed rocky intertidal, cobbles, and riprap on the eastern part of the beach. Tafoni in the natural rock sandstone. Upland plants end before the high intertidal. Public access from Clipper Cove or the parking lot near the Coast Guard at low tide.

Clipper Cove rocky site looking west.



Clipper Cove rocky site cobble beach.

Clipper Cove rocky site looking west.

Torpedo Storehouse

Cobble with riprap from the Storehouse to the subtidal. Some larger boulders. Upland is mostly invasive plants along the edges of the building. Public access from the parking lot near the Coast Guard and new fishing area.

East side of Torpedo Storehouse site, looking north.

East side of Torpedo Storehouse site, looking south.

Southwest cove site

Rocky cobble and rock outcroppings, tafoni in some of the sandstone. Lots of washed up debris. Upland habitat mostly native flowering plants and some grasses. Upland vegetation stops on cliffs above high tide line. No public access. Access by boat only.

Southwest cove site looking north.

Southwest cove site looking south.

Northwest cove site

Large rocks and boulders, with cobbles and rocky outcrops. Upland vegetation comes to just above the high tide line. No public access. Access only by boat.

Northwest cove site looking north.

Northwest cove site looking south.

Treasure Island Marina

Wooden docks with wood and styrofoam undersides. Buoys, ropes, and tanks in the water with invertebrates and algae fouling. Access limited to boat owners. Permission to access from the harbor master.

Treasure Island Marina looking north.

Treasure Island Marina looking south.

Eelgrass site selection

The initial objective of this project was to survey just Clipper Cove for eelgrass, based on previous studies that had found eelgrass just offshore of Clipper Cove beach and east toward the Bay Bridge. As surveys progressed and it appeared that we would not find eelgrass in Clipper Cove, we added a second eelgrass site off the east shore of Treasure Island, as there were confirmed eelgrass sightings in that area. See Figure 2 for the extent of the two sites surveyed.

Figure 2. Subtidal/eelgrass sites selected and surveyed in this study.

Survey methodology

Intertidal and eelgrass surveys took place between July 2019 and June 2021, coinciding with low tides that ranged between -0.2 ft. to -1.3 ft. The only survey not planned to coincide with a low tide was the October 2020 marina survey as the fouling organisms on the docks can be seen at any tidal level.

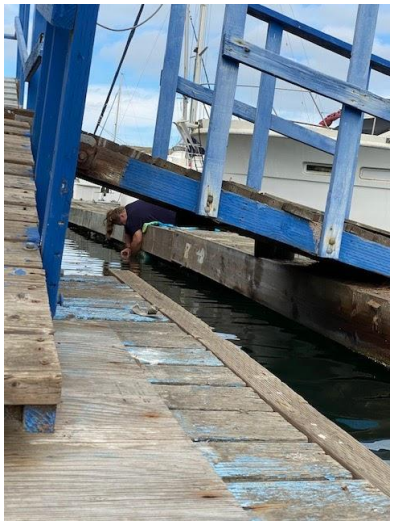
Intertidal survey methods

Each intertidal site (Clipper Cove Sandy, Clipper Cove Rocky, Torpedo Storehouse, Southwest Cove, Northwest Cove) was surveyed 1-3 times for 2-4 hours each time, depending on the size and diversity of the site. We carefully walked throughout the area, from the splash/high intertidal down to the water's edge and across the width of the intertidal zone, photographing the species encountered. Where possible,

rocks were occasionally turned to document the species living underneath, then replaced. Marine invertebrates, sea grasses, algae, and seaweed were the focal species of the surveys. All documented organisms were identified as close to species as possible in the field, and uploaded to iNaturalist with the identification, date/time observed, and latitude/longitude at which it was observed. Once uploaded to iNaturalist, all observations had identifications rechecked and/or refined through both the iNaturalist community and by Academy staff, and photos of organisms were checked to determine if individuals of each species were found alive at sites or only found washed up and/or dead.

Marina survey methods

The fouling organisms on the Treasure Island Marina floating docks were surveyed on October 9, 2020 with permission from the harbor master. First, we quickly inspected a series of docks in varying locations in the marina to determine the best area of the marina to focus on. The docks near the ends of the rows (i.e., the docks furthest into Clipper Cove) had the greatest diversity of species living on them and thus surveys were primarily focused there. We laid down on the docks with heads hanging over to see the fouling organisms, and either photographed them in situ or brought them up into buckets to photograph. After inspecting and documenting species in one area, we moved to a new area to survey, looking for new species to document. All documented organisms were identified as close to species as possible in the field, and uploaded to iNaturalist with the identification, date/time observed, and latitude/longitude at which it was observed. Once uploaded to iNaturalist, all observations had identifications rechecked and/or refined through both the iNaturalist community and by Academy staff.



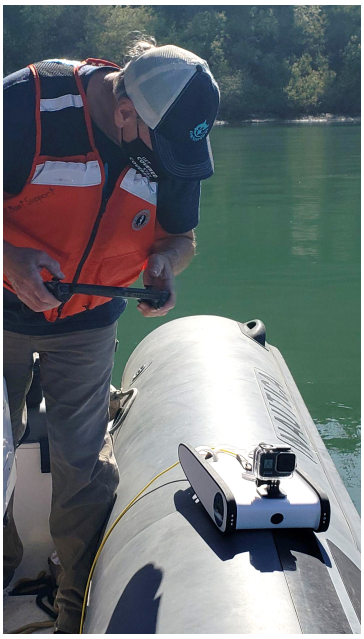
Eelgrass survey methods

Walking surveys

To determine if there was eelgrass present in Clipper Cove, two walking surveys were first conducted in Winter 2019-2020 (December 2019, January 2020) by Dr. Grace Ha and Dr. Katie DuBois. They waded into Clipper Cove to the approximate depth eelgrass would be expected to be found if present, and both visually inspected for eelgrass as well as felt for eelgrass rhizomes in the sediment. No eelgrass was detected during the winter surveys, but since eelgrass biomass can vary seasonally and tends to peak in summer in San Francisco Bay, one additional walking survey was conducted in July 2020.

ROV surveys

To visually look for eelgrass as well as to get a sense of the subtidal macro flora and fauna, surveys via Trident ROV, a small underwater drone, were carried out. We conducted two surveys of Clipper Cove



(February 2021, June 2021) and one off the east shore of Treasure Island (June 2021) via boat. David McGuire launched and piloted the ROV, while Academy staff visually scanned for organisms and inspected the eelgrass accessible from the boat to document the species living on the blades. The ROV recorded video from the built-in HD camera as well as from a GoPro attached to top of the ROV. Organisms found by Academy staff were identified as close to species as possible in the field, and uploaded to iNaturalist with the identification, date/time observed, and latitude/longitude at which it was observed. Once uploaded to iNaturalist, all observations had identifications rechecked and/or refined through both the iNaturalist community and by Academy staff. Organisms seen from the boat while conducting the surveys were added to the species list. The ROV footage was reviewed by Academy staff to confirm the presence or absence of eelgrass in the two survey areas. Organisms seen in the videos were identified when possible, and added to the survey species lists.

Species Lists

Species lists were generated from the marine (intertidal and subtidal) organisms observed and documented from the above mentioned surveys, as well as from other observations of intertidal and marine species uploaded to iNaturalist (for example, from the Yerba Buena Island bioblitzes), representing species documented from 2014 to present day; altogether this was approximately 1200 observations total. We included species on the list that were only found washed up and/or dead, as these are often species that either (1) live subtidally adjacent to the intertidal areas surveyed (e.g., bivalves, crabs), or (2) wash into the area from other parts of the Bay or from the outer coast and could potentially be carrying spores, eggs, or other species that could establish themselves on YBI (e.g., kelp, algae). We also included a few non-marine species that we found evidence of utilizing the intertidal (e.g., raccoons).

These species lists were compiled by geographic area (see Figure 3): (1) Clipper Cove and Eastern Yerba Buena Island, (2) Western Yerba Buena Island, (3) Treasure Island Marina, and (4) Eastern Treasure Island eelgrass/subtidal. We compared species lists between areas to understand the similarities and differences of the intertidal and marine communities in these different regions. We also compared these current species lists to species documented in a previous study of intertidal Treasure Island and Western Yerba Buena Island (Applied Marine Sciences 2009) to note any change through time. The current species lists were also compared to species documented in San Francisco Bay overall, drawn from iNaturalist, the Global Biodiversity Information Facility (GBIF), and previous studies of San Francisco Bay, to look at the Yerba Buena intertidal community in the context of the Bay.

Figure 3. Geographic areas used to compile species lists, based on species found in this study and previous observations uploaded to iNaturalist.

The list of introduced species was determined through referencing publications (e.g., Mooi *et al*. 2007), reports (e.g., Cohen and Carlton 1995), and websites like the Smithsonian Environmental Research Center's National Estuarine and Marine Exotic Species Information System (NEMESIS). It's important to note that not all sources agree on which species are introduced versus cryptogenic (of unknown origin) in San Francisco Bay, so in some cases we had to use our best judgement.

Results

In total, 198 species were documented through our surveys and via iNaturalist. Of those 198 species, 115 were found along Western Yerba Buena Island, 108 in Clipper Cove & Eastern Yerba Buena Island, 42 on the Treasure Island Marina, and 15 during the eelgrass/subtidal surveys of Eastern Treasure Island (see Tables 3 and 4). One species was found at all four sites, the introduced colonial tunicate *Botrylloides violaceus*, aka Chain Tunicate. We also made a Guide to the Intertidal Life of Yerba Buena Island in iNaturalist. In the guide you will find photos of the species and maps indicating where on YBI or TI (you will need to zoom out in the maps to see species found in the ETI eelgrass bed) they were found. In order to see the maps, make sure to view the guide in 'Card' view.

Table 3. List of animals found in this study. An 'x' indicates that species was found at that site. CC & EYBI = Clipper Cove and Eastern Yerba Buena Island, WYBI = Western Yerba Buena Island, TI Marina = Treasure Island Marina, ETI = Eastern Treasure Island.

ANIMALS FOUND IN SURVEYS			**SITE**			
Family	**Species**	**Common Name**	**CC & EYBI**	**WYBI**	**TI Marina**	**ETI**
PORIFERA – SPONGES						
Amphoriscidae	Amphoriscidae sp.				x	
Amphoriscidae	*Leucilla nuttingi*	Smooth Urn Sponge		x		
Raspailiidae	Raspailiidae sp.[SF,YBI]			x		
Chalinidae	*Haliclona cinerea* [YBI]			x		
Microcionidae	*Clathria pennata* [YBI]	Red Velvet Sponge	x			
Microcionidae	*Clathria prolifera* [I,YBI]	Red Beard Sponge	x			
Halichondriidae	*Halichondria panicea*	Bread-crumb Sponge	x	x		
Halichondriidae	*Halichondria bowerbanki* [I]		x	x	x	
–	Porifera spp.	Sponges	x	x	x	
CNIDARIA – CNIDARIANS						
Hydrozoa – Hydrozoans						
Corynidae	*Polyorchis* sp.				x	
Corynidae	*Scrippsia pacifica*	Giant Bell Jelly	x*		x	x
–	Sublcass Hydroidolina spp.	Hydroids		x		
Sertulariidae	Sertulariidae sp.[YBI]		x			
Tubulariidae	*Ectopleura* sp.[YBI]				x	
Scyphozoa – True Jellies						
Pelagiidae	*Chrysaora fuscescens*	Pacific Sea Nettle	x			
Anthozoa – Sea anemones and corals						
Actiniidae	*Anthopleura artemisia* [YBI]	Moonglow Anemone		x		
Andvankiidae	*Flosmaris grandis* [YBI]	White Burrowing Anemone	x			

Table 3 (continued)

Family	Species	Common Name	CC & EYBI	WYBI	TI Marina	ETI
Diadumenidae	*Diadumene lineata* [I]	Striped Green Sea Anemone	x		x	
Diadumenidae	*Diadumene* spp.[I] (*D. franciscana, D. leucolena)*			x		
Metridiidae	*Metridium senile*	Plumose Anemone			x	
Virgulariidae	*Stylatula elongata* [YBI]	Slender Sea Pen	x			
CTENOPHORA - COMB JELLIES						
Pleurobrachiidae	*Pleurobrachia bachei* [YBI]	Pacific Sea Gooseberry	x		x	
Pleurobrachiidae	*Pleurobrachia* sp.		x		x	
PLATYHELMINTHES – FLATWORMS						
–	Superfamily Stylochoidea sp.				x	
NEMERTEA – RIBBON WORMS						
Emplectonematidae	*Emplectonema gracile* [YBI]	Green ribbon worm	x			
Neesidae	*Paranemertes peregrina* [YBI]	Purple Ribbon Worm	x			
Tubulanidae	*Tubulanus* sp.[YBI]		x			
ANNELIDA – SEGMENTED WORMS						
Polychaeta – Polychaete Worms						
Arenicolidae	*Arenicola* sp.[YBI]	Lugworms (eggs)	x			
Nereididae	Nereididae sp.			x		
Nereididae	*Nereis vexillosa*	Pile Worm	x			
Polynoidae	*Halosydna brevisetosa*	Eighteen-scaled Worm	x	x		
Polynoidae	*Harmothoe imbricata*	Fifteen-scaled Worm	x	x	x	
Sabellariidae	Sabellariidae sp.[YBI]	Honeycomb Worms		x		
Sabellidae	*Myxicola* sp.				x	
Sabellidae	*Schizobranchia insignis* [YBI]	Split-branch Feather Duster Worm			x	
Syllidae	*Megasyllis nipponica* [I]	Japanese Green Syllid			x	
Terebellidae	*Pista pacifica* [SF,YBI]	Fringed-hood Spaghetti Worm		x		
Terebellidae	Terebellidae spp.	Spaghetti Worms	x		x	
ARTHROPODA – ARTHROPODS						
Cirripedia – Barnacles						
Balanidae	*Balanus glandula*	Pacific Acorn Barnacle	x	x	x	
Chthamalidae	*Chthamalus* spp.	Little Brown Barnacles	x	x		
Pollicipedidae	*Pollicipes polymerus*	Gooseneck Barnacle		x		
Tetraclitidae	*Tetraclita rubescens* [YBI]	Pink Volcano Barnacle		x		

Table 3 (continued)

Family	Species	Common Name	CC & EYBI	WYBI	TI Marina	ETI
Isopoda – Isopods						
Anthuroidea	*Anthuroidea* sp.[YBI]	Wormpods			x	
Cirolanidae	*Cirolanidae* sp.[YBI]		x			
Idoteidae	*Idotea* sp.[YBI]	Valvetails	x			
Idoteidae	*Pentidotea resecata* [YBI]	Eelgrass Isopod				x
Idoteidae	*Pentidotea wosnesenskii*	Rockweed isopod	x	x		
Ligiidae	*Ligia occidentalis*	Western Sea Slater	x			
Sphaeromatidae	*Gnorimosphaeroma* sp.			x		
Sphaeromatidae	*Sphaeroma quoianum* [I]	New Zealand Burrowing Isopod	x			
Sphaeromatidae	*Sphaeromatidae* sp.	Typical Seapills		x	x	
Amphipoda – Amphipods						
Caprellidae	*Caprellidae* spp.	Skeleton Shrimp		x		x
Melitidae	*Melitidae* sp.	Bivalve Scuds	x	x		
Talitridae	*Megalorchestia californiana* [YBI]	California Beach Flea	x			
Talitridae	*Traskorchestia traskiana* [YBI]	Pacific beach hopper	x			
–	*Amphipoda* spp.	Amphipods	x			
Decapoda – Decapods						
Cancridae	*Cancer productus*	Red Rock Crab	x	x		
Cancridae	*Metacarcinus gracilis*	Graceful Rock Crab	x*			
Cancridae	*Metacarcinus magister*	Dungeness Crab	x*			
Cancridae	*Metacarcinus magister*	Dungeness Crab	x			
Cancridae	*Romaleon antennarium*	Pacific Rock Crab	x	x	x	
Epialtidae	*Pugettia producta* [YBI]	Northern Kelp Crab	x			
Grapsidae	*Pachygrapsus crassipes*	Striped Shore Crab	x	x		
Inachoididae	*Pyromaia tuberculata* [YBI]	Tuberculate Pear Crab	x*			
Paguridae	*Pagurus hirsutiusculus*	Pacific Hairy Hermit Crab	x	x		
Paguridae	*Pagurus* sp.	Hermit Crabs	x	x		
Porcellanidae	*Pachycheles pubescens* [YBI]	Pubescent Porcelain Crab		x		
Porcellanidae	*Pachycheles rudis*	Thickclaw Porcelain Crab		x		
Porcellanidae	*Petrolisthes manimaculis* [SF, YBI]	Chocolate Porcelain Crab		x		
Porcellanidae	*Petrolisthes* sp.	Porcelain Crabs		x		
Thoridae	*Heptacarpus* spp.	Coastal Caridean Shrimp		x		
Varunidae	*Hemigrapsus nudus* [YBI]	Purple Shore Crab	x			

Table 3 (continued)

Family	Species	Common Name	CC & EYBI	WYBI	TI Marina	ETI
Varunidae	*Hemigrapsus oregonensis*	Yellow Shore Crab	x	x		
Pycnogonida – Sea Spiders						
Ammotheidae	*Ammothea hilgendorfi* YBI				x	
–	Order Pantopoda sp.	Sea Spiders	x	x		
Arachnida – Arachnids						
Bdellidae	*Neomolgus littoralis*	Coastal Snout Mite	x			
MOLLUSCA – MOLLUSKS						
Polyplacophora – Chitons						
Mopaliidae	*Mopalia hindsii* YBI	Hind's Chiton	x	x	x	
Mopaliidae	*Mopalia muscosa* YBI	Mossy Chiton	x	x		
Mopaliidae	*Mopalia* spp.		x	x		
Tonicellidae	*Cyanoplax dentiens* YBI	Gould's baby chiton		x		
Tonicellidae	*Nuttallina californica* YBI	California Spiny Chiton		x		
Tonicellidae	*Tonicella lineata* YBI	Lined Chiton		x		
Tonicellidae	*Tonicella lokii* SF, YBI	Flame Lined Chiton		x		
Gastropoda – Gastropods (Snails and Slugs)						
Caenogastropoda – Caenogastropods						
Buccinidae	*Lirabuccinum dirum* YBI	Dire Whelk		x		
Calyptraeidae	*Crepidula onyx* SF, YBI	Onyx Slippersnail		x		
Calyptraeidae	*Crepidula* spp. (small white: *C. convexa, C. plana*) I, YBI	Typical Slippersnails	x	x		
Columbellidae	*Alia carinata* YBI	Carinate Dovesnail		x		
Columbellidae	*Amphissa columbiana* YBI	Wrinkled Amphissa	x			
Columbellidae	*Amphissa versicolor* YBI	Variegate Amphissa		x		
Columbellidae	*Mitrella gausapata* YBI		x			
Littorinidae	*Lacuna* spp. YBI	Lacuna Snails				x
Littorinidae	*Littorina keenae* YBI	Eroded Periwinkle	x	x		
Littorinidae	*Littorina littorea* I, YBI	Common Periwinkle	x			
Littorinidae	*Littorina scutulata* YBI	Checkered Periwinkle	x			
Littorinidae	*Littorina* spp.	Periwinkles		x		
Muricidae	*Acanthinucella spirata*	Angular Unicorn		x		
Muricidae	*Nucella lamellosa* YBI	Wrinkled Purple	x*	x*		
Muricidae	*Nucella ostrina* YBI	Striped Dogwinkle		x		

Table 3 (continued)

Family	Species	Common Name	CC & EYBI	WYBI	TI Marina	ETI
Olividae	*Callianax biplicata*	Purple Olive Snail		x*		
	Patellogastropoda – True Limpets					
Acmaeidae	*Acmaea mitra* [YBI]	Whitecap Limpet	x*			
Lottiidae	*Lottia asmi* [YBI]	Black Limpet	x			
Lottiidae	*Lottia digitalis*	Fingered Limpet	x	x		
Lottiidae	*Lottia gigantea* [YBI]	Owl Limpet	x	x		
Lottiidae	*Lottia limatula*	File Limpet	x	x		
Lottiidae	*Lottia paradigitalis* [YBI]	Boreal limpet	x*			
Lottiidae	*Lottia pelta*	Shield Limpet		x		
Lottiidae	*Lottia scabra*	Rough Limpet	x	x		
Lottiidae	*Lottia scutum* [YBI]	Plate Limpet	x	x		
Lottiidae	*Lottia* spp.	Lottia Limpets		x	x	
	Vetigastropoda – Slit and Top Snails					
Calliostomatidae	*Calliostoma canaliculatum* [YBI]	Channeled Topsnail		x		
Calliostomatidae	*Calliostoma gloriosum* [SF,YBI]	Glorious Topsnail		x		
Tegulidae	*Tegula funebralis*	Black Tegula	x	x		
	Heterobranchia – Heterobranchs					
Aplysiidae	*Phyllaplysia taylori* [YBI]	Taylor's Seahare				x
Discodorididae	*Diaulula sandiegensis* [YBI]	San Diego Dorid	x	x		
Discodorididae	*Rostanga pulchra* [YBI]	Red Dorid	x			
Doridiidae	*Doris montereyensis* [YBI]	Monterey Doris	x	x		
Facelinidae	*Sakuraeolis enosimensis* [I]	Enosima Aeolid			x	
Myrrhinidae	*Hermissenda opalescens* [YBI]	Opalescent Nudibranch		x		
Onchidorididae	*Acanthodoris rhodoceras* [YBI]	Black-tipped Spiny Dorid	x	x		
Polyceridae	*Polycera hedgpethi*	Hedgpeth's Dorid			x	
	Bivalva – Bivalves					
Anomiidae	*Pododesmus macrochisma*	Green Falsejingle	x*			
Cardiidae	*Clinocardium nuttallii* [YBI]	Nuttall's Cockle		x*		
Hiatellidae	*Hiatella arctica*	Wrinkled Rock Borer		x		
Mactridae	*Tresus nuttallii* [YBI]	Pacific Gaper		x*		
Myidae	*Cryptomya californica* [YBI]	California Softshell	x*			
Myidae	*Mya arenaria* [I]	Soft-shelled Clam	x*			
Mytilidae	*Arcuatula senhousia* [I]	Asian Date Mussel			x	

Table 3 (continued)

Family	Species	Common Name	CC & EYBI	WYBI	TI Marina	ETI
Mytilidae	*Mytilus californianus*	California Mussel	x	x		
Mytilidae	*Mytilus* spp.[I] (*M. galloprovincialis, M. trossulus*)	Blue Mussel Complex	x	x	x	
Ostreidae	Subfamily Crassostreinae spp.[I] (does not include *Ostrea*)	True Oysters	x			
Ostreidae	*Ostrea lurida*	Olympia Oyster	x	x		
Pectinidae	*Crassadoma gigantea* [YBI]	Giant Rock Scallop	x	x		
Pholadidae	*Pholadidae* spp.	Piddocks and Angelwings		x*		
Tellinidae	*Macoma nasuta* [YBI]	Bent-nosed Clam	x*			
Veneridae	*Leukoma staminea*	Pacific Littleneck Clam		x*		
Veneridae	*Ruditapes philippinarum* [I]	Japanese Littleneck	x*	x*		
BRYOZOA – BRYOZOANS						
Bugulidae	*Bugula* spp.[I]		x	x	x	
Cryptosulidae	*Cryptosula pallasiana* [I]		x			
Membraniporidae	*Membranipora membranacea* [YBI]	Kelp Lace Bryozoan	x			
Membraniporidae	*Membranipora* sp.	Lacy Crust Bryozoans			x	
Watersiporidae	*Watersipora* spp.[I]	Red-rust Bryozoans	x	x	x	
ECHINODERMATA – ECHINODERMS						
Ophiuroidea – Brittle Stars						
Amphiuridae	*Amphiodia occidentalis* [YBI]	Long-armed Brittle Star		x		
Amphiuridae	*Amphipholis* sp.[YBI]			x		
Hemieuryalidae	*Ophioplocus esmarki* [SF,YBI]	Esmark's Brittle Star		x		
CHORDATA – CHORDATES						
Ascidiacea – Tunicates						
Ascidiidae	*Ascidia zara* [I]				x	
Cionidae	*Ciona intestinalis* [I]	Sea Vase			x	
Cionidae	*Ciona robusta* [I,YBI]				x	
Cionidae	*Ciona savignyi* [I]				x	
Corellidae	Corellidae sp.		x*	x		
Didemnidae	*Didemnum* sp.[I]	Wrinkled Sea Mats			x	
Didemnidae	*Diplosoma listerianum* [I]	Jelly Crust Tunicate			x	
Molgulidae	*Molgula manhattensis* [I]	Northern Sea Squirt	x			
Styelidae	*Botrylloides diegensis*	San Diego Sea Squirt	x		x	

Table 3 (continued)

Family	Species	Common Name	CC & EYBI	WYBI	TI Marina	ETI
Styelidae	*Botrylloides violaceus* [I]	Chain tunicate	x	x	x	x
Styelidae	*Botryllus schlosseri* [I]	Star Tunicate	x		x	
Styelidae	*Styela clava* [I]	Stalked Sea Squirt	x	x	x	
Actinopterygii – Ray-finned Fishes						
–	Actinopterygii sp.	Ray-finned Fishes (eggs)		x		
Elasmobranchii – Elasmobranchs (Sharks, Rays, Skates, etc.)						
Myliobatidae	*Myliobatis californica*	Bat Ray	x			
Triakidae	*Triakis semifasciata*	Leopard Shark	x			
Mammalia – Mammals						
Phocidae	*Phoca vitulina*	Harbor Seal		x		
Procyonidae	*Procyon lotor*	Common Raccoon	x			

[I] = introduced species in San Francisco Bay
[SF] = first known record in San Francisco Bay
[YBI] = first known record on/around YBI
* = only found washed up and/or dead

Table 4. List of kelps, algae, and plants found in this study. An 'x' indicates that species was found at that site. CC & EYBI = Clipper Cove and Eastern Yerba Buena Island, WYBI = Western Yerba Buena Island, TI Marina = Treasure Island Marina, ETI = Eastern Treasure Island.

KELPS, ALGAE, AND PLANTS FOUND IN SURVEYS			SITE			
Family	Species	Common Name	CC & EYBI	WYBI	TI Marina	ETI
CHROMISTA - KELPS, DIATOMS, BROWN ALGAE						
Alariaceae	*Egregia menziesii*	Feather Boa Kelp		x		
Chordariaceae	*Leathesia marina* [YBI]	Sea Cauliflower	x			
Fucaceae	*Fucus distichus*	Rockweed	x	x		x
Fucaceae	*Pelvetiopsis limitata* [YBI]	Little Rockweed		x		
Lessoniaceae	*Macrocystis pyrifera* [YBI]	Giant Kelp		x*		
Sargassaceae	*Sargassum muticum* [I]	Japanese Wireweed	x*	x		x
Sargassaceae	*Stephanocystis osmundacea* [YBI]	Chain Bladder Kelp		x*		
–	Order Bacillariophyceae sp.	Diatom mat	x			
RHODOPHYTA – RED ALGAE						
Ceramiaceae	*Microcladia coulteri*	Delicate Sea Lace	x	x		
Delesseriaceae	*Cryptopleura ruprechtiana*	Grape Tongue		x		
Delesseriaceae	*Cryptopleura* sp.			x		
Delesseriaceae	*Polyneura latissima*	Crisscross Network	x	x		x

Table 4 (continued)

Family	Species	Common Name	CC & EYBI	WYBI	TI Marina	ETI
Dumontiaceae	*Cryptosiphonia woodii* [YBI]	Bleached Brunette		x		
Dumontiaceae	*Pikea californica*			x		
Endocladiaceae	*Endocladia muricata*	Scouring-pad Alga	x			
Erythrotrichiaceae	*Smithora naiadum* [SF,YBI]	Seagrass Laver				x
Gelidiaceae	*Gelidium* sp.		x			
Gigartinaceae	*Chondracanthus exasperatus*	Turkish Towel	x	x	x*	
Gigartinaceae	*Chondracanthus* sp.		x	x		
Gigartinaceae	*Mazzaella splendens* [YBI]	Splendid Iridescent Seaweed		x		x
Gigartinaceae	*Mazzaella* spp.	Iridescent Algae		x		
Gracilariaceae	*Gracilariopsis andersonii* [YBI]	Red Sea Spaghetti		x		
Gracilariaceae	*Gracilariopsis* sp.[YBI]	Sea Spaghettis	x			
Halymeniaceae	*Prionitis* sp.			x		
Liagoraceae	*Cumagloia andersonii* [YBI]			x		
Phyllophoraceae	*Mastocarpus jardinii* [YBI]	Bushy Turkish Washcloth	x	x		
Phyllophoraceae	*Mastocarpus papillatus*	Turkish Washcloth	x	x		
Phyllophoraceae	*Mastocarpus* spp.	Encrusting Red Algae	x	x		
Rhodomelaceae	*Polysiphonia* sp.			x		
Solieriaceae	*Sarcodiotheca* sp.[YBI]		x			
–	Order Gigartinales spp.			x		
CHLOROPHYTA – GREEN ALGAE						
Bryopsidaceae	*Bryopsis* sp.[YBI]				x	
Trentepohliaceae	*Trentepohlia aurea* [YBI]		x			
Ulvaceae	*Ulva intestinalis* [YBI]	Gutweed		x		
Ulvaceae	*Ulva lactuca* [YBI]	Broadleaf Sea Lettuce	x		x	x
Ulvaceae	*Ulva* spp.	Sea Lettuces		x		
TRACHEOPHYTA – VASCULAR PLANTS						
Zosteraceae	*Zostera marina*	Eelgrass	x*	x*		x

[I] = introduced species in San Francisco Bay
[SF] = first known record in San Francisco Bay
[YBI] = first known record on/around YBI
* = only found washed up and/or dead

Comparison between and across regions found that every area contained unique species, but every area also had species in common with other areas (see Figure 4). Unsurprisingly, across the four survey regions, Western YBI and Clipper Cove/Eastern YBI had the most species in common, with 50 found at

both sites. Clipper Cove/Eastern YBI had 18 species in common with the Treasure Island Marina, while Western YBI had 14 in common.

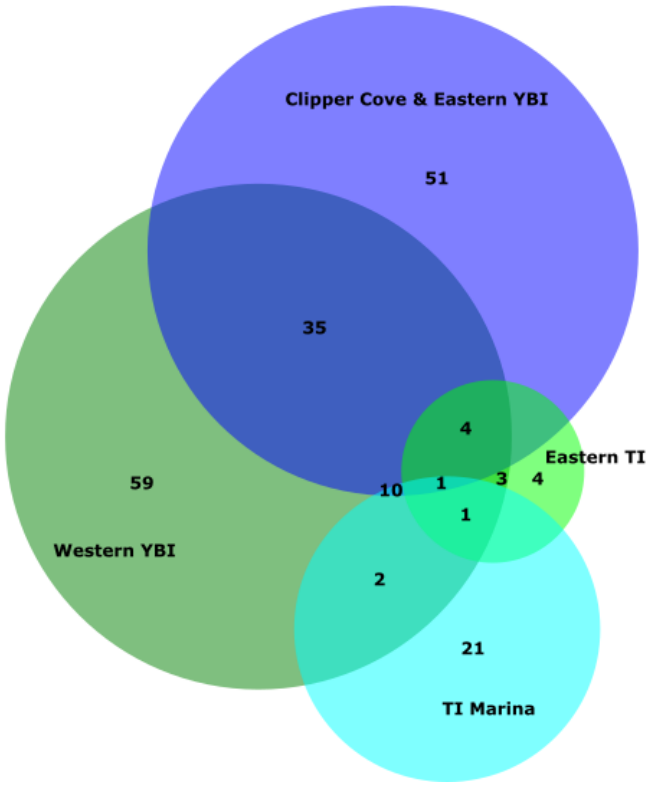


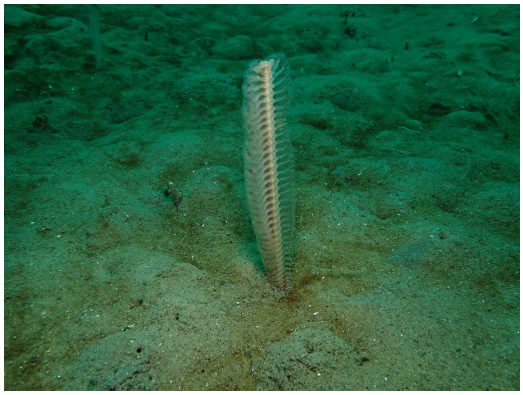
Figure 4. Venn diagram showing overlap of species between and among geographic regions. Circles are proportional to the number of species found in that region. Note that not all intersections can be displayed on a 4-circle venn diagram, and multiple numbers must be added together to understand the overlap between two regions. Refer to text and tables for a full account of species overlap. Created using DeepVenn (Hulsen *et al.* 2008).

Yerba Buena Island

Biodiversity

Focusing on Yerba Buena Island, 173 species total were documented across Western YBI and Clipper Cove/Eastern YBI. Although part of the same land mass, these two regions only had 50 species in common, while there were 65 species only found on Western YBI and 58 only found in the Clipper Cove/Eastern YBI area, indicating that the intertidal influences on these two parts of the island are quite different. Western YBI is almost directly across from the Golden Gate, approximately six miles from the opening of the Bay, and the intertidal community there very much reflects an open-ocean influence, with many species that more commonly occur on the outer coast and are adapted to wave exposure (e.g., brittle stars, many species of chiton, some species of barnacle, porcelain crabs). This visualization from Rusty Holleman shows the strong marine influence on the western side of YBI. Clipper Cove/Eastern YBI, in contrast, is much more sheltered, and the intertidal community there is more similar to those you would find at other inner Bay intertidal sites, with species that do not tolerate much wave exposure (e.g. some Cancridae crabs, coastal amphipods, some tunicates).

While not an extensive or complete biodiversity survey, the ROV surveys of Clipper Cove turned up some interesting subtidal species. The Slender Sea Pen, *Stylatula elongata*, has been documented off the east, north, and west shores of Treasure Island, but this is the first record from Clipper Cove. Sea pens are a type of octocoral, serve as a food source for some species of nudibranchs and sea stars, and can live to over 100 years. White Burrowing Anemones (*Flosmaris grandis*) have only been documented two other times in San Francisco Bay, and are understudied as a whole. The anemone attaches itself to a buried rock or shell, then extends up to 18 inches to reach the water above.



Stylatula elongata from Pacific Grove. Photo DWDaniels.

Flosmaris grandis from Alameda. Photo Chris Brown.

In both regions, we found that within sites, areas with highest biodiversity and native species richness were usually natural rocky intertidal and the rocky/cobble beaches around it, especially areas in and around places where undisturbed/unmodified island substrate and rock starts from above the shoreline, extends through the intertidal, and forms small points that reach into the subtidal (see Figure 5). These sites also typically had the most intact, native vegetation upland from the intertidal and are relatively protected from run-off.

Figure 5. Photograph illustrating examples of the rocky points and surrounding rocky intertidal areas that tended to harbor the most native biodiversity.

Comparison with 2009 intertidal study

In 2009, Applied Marine Sciences conducted a rapid, one-day assessment of the Western Yerba Buena Intertidal, via surveys at nine sites along the shoreline, as part of a larger study to characterize the intertidal of Treasure Island and Western Yerba Buena Island. While our current study and this last intertidal survey in 2009 had different methods and goals and thus should not be directly compared, examination of the species found in this study with the species list generated from the 2009 study does bring up some interesting differences. In particular, two species noted in the 2009 study were not found in our current survey: *Pisaster ochraceus* – the Ochre Star, and *Urosalpinx cinerea* – the Eastern Oyster Drill.

Pisaster ochraceus is one of the most common sea stars found along the coast of California, and is considered a keystone species and an important indicator for the health of the rocky intertidal. An outer coast species, in San Francisco Bay *Pisaster ochraceus* is only found in the open-ocean influenced areas near and directly exposed to the Golden Gate. The 2009 survey of the Western Yerba Buena Island intertidal found *Pisaster ochraceus* at four of their sites and it was listed as "present" (on a spectrum of rare–present–common–abundant) in either the mid or low intertidal at those sites. Our current study covered 2-3 of those four 2009 sites, yet we did not find any *P. ochraceus*. Due to the thoroughness of our surveys and the generally bright coloration of these sea stars, we believe we would have found them if they were present. However, one key event has occurred since that 2009 survey: the arrival of Sea Star Wasting Disease (SSWD) in 2013-2014 which led to a dramatic decrease in sea star abundance along the west coast of North America, especially for *Pisaster ochraceus*. Along the outer coast of north central California, *P. ochraceus* suffered 81% mortality (Schiebelhut *et al*. 2018). Closer to Yerba Buena Island, *P. ochraceus* at Alcatraz and at Point Bonita suffered more than 99% mortality (Miner *et al*. 2018). It's very likely that sea stars at Yerba Buena were met with a similar fate from SSWD, and have not yet recovered.

Urosalpinx cinerea is a predatory snail that was introduced to San Francisco Bay in the 1870s with Eastern Oyster (*Crassotrea virginica*) spat transported from the Atlantic coast for use in the Bay's commercial oyster industry. The Eastern Oyster Drill feeds on oysters, mussels, barnacles, and other shelled sessile marine organisms. Although local commercial oyster production ceased by the early 20th century, eastern drills are still found in San Francisco Bay and threaten the ongoing recovery of our native oyster species, *Ostrea lurida*, the Olympic Oyster. Present-day occurrences of *U. cinerea* in the Bay roughly correspond to areas where eastern oysters were cultivated – in particular the South Bay – although some subsequent dispersal has taken place. The 2009 survey of Western Yerba Buena Island intertidal regions found *U. cinerea* at three of their sites and listed them as either "present" or "common" in both the mid- and low-intertidal at the three sites. While two of those three sites were surveyed in this current study, we did not record the presence of Eastern Oyster Drills at either site, nor at any other of our sites along Clipper Cove/Eastern YBI. We believe there are two potential reasons for this. One possibility is that *U. cinerea* was present on Western Yerba Buena Island in 2009 but has since disappeared, which is overall a positive, though the mechanism by which they were eradicated is unknown. The other possibility is that the Eastern Oyster Drill was not actually present on Yerba Buena

Island in 2009 and was a misidentification of another species. We believe there is greater support for this possibility, as there are no other iNaturalist observations or other species occurrence records of *U. cinerea* on Yerba Buena or Treasure Islands. The closest recent observation comes from Toll Plaza Beach, east of YBI, in 2019, and all the observations of *U. cinerea* on iNaturalist are from regions of the Bay with very little open-ocean influence, which would make Western YBI an unlikely habitat. Furthermore, two snail species that we found regularly at our sites on Western Yerba Buena Island, *Acanthinucella spirata* and *Nucella ostrina*, look similar in appearance to *U. cinerea* and were not listed as being found in the 2009 survey. Regardless of the reason for the discrepancy between the 2009 study and this one, not finding the Eastern Oyster Drill in these surveys is positive news for the health of the island's intertidal ecosystem.

Introduced Species

While *Urosalpinx cinerea* was not found in this study, there were 27 other species introduced to San Francisco Bay that were found (see Table 5). Of those 27 species, 18 of them were found along Clipper Cove/Eastern YBI (16.7% of all species found in that area), 10 along Western Yerba Buena Island (8.7% of all species found in that area), 17 on the Treasure Island Marina docks (40.5% of species found there), and two found offshore of Eastern Treasure Island (13.3% of species found there).

Table 5. List of introduced species found in this study. An 'x' indicates that species was found at that site. CC & EYBI = Clipper Cove and Eastern Yerba Buena Island, WYBI = Western Yerba Buena Island, TI Marina = Treasure Island Marina, ETI = Eastern Treasure Island.

INTRODUCED SPECIES				**SITES FOUND AT**			
Type of Organism	**Family**	**Species**	**Common Name**	**CC & EYBI**	**WYBI**	**TI Marina**	**ETI**
Anemone	Diadumenidae	*Diadumene lineata*	Striped Green Sea Anemone	x		x	
Anemone	Diadumenidae	*Diadumene* spp. (*D. franciscana, D. leucolena)*			x		
Bivalve	Myidae	*Mya arenaria*	Soft-shelled Clam	x*			
Bivalve	Mytilidae	*Arcuatula senhousia*	Asian Date Mussel			x	
Bivalve	Mytilidae	*Mytilus* spp. (*M. galloprovincialis, M. trossulus*)	Blue Mussel Complex	x	x	x	
Bivalve	Ostreidae	Subfamily Crassostreinae spp. (does not include *Ostrea*)	True Oysters	x			
Bivalve	Veneridae	*Ruditapes philippinarum*	Japanese Littleneck	x*	x*		
Bryozoan	Bugulidae	*Bugula* spp.		x	x	x	
Bryozoan	Cryptosulidae	*Cryptosula pallasiana*		x			
Bryozoan	Watersiporidae	*Watersipora* spp.	Red-rust Bryozoans	x	x	x	
Isopod	Sphaeromatidae	*Sphaeroma quoianum*	New Zealand Burrowing Isopod	x			

Table 5 (continued)

Type of Organism	Family	Species	Common Name	CC & EYBI	WYBI	TI Marina	ETI
Kelp	Sargassaceae	*Sargassum muticum*	Japanese Wireweed	x*	x		x
Nudibranch	Facelinidae	*Sakuraeolis enosimensis*	Enosima Aeolid			x	
Polychaete	Syllidae	*Megasyllis nipponica*	Japanese Green Syllid			x	
Snail	Calyptraeidae	*Crepidula* spp. (small white: *C. convexa, C. plana*)	Typical Slippersnails	x	x		
Snail	Littorinidae	*Littorina littorea*	Common Periwinkle	x			
Sponge	Microcionidae	*Clathria prolifera*	Red Beard Sponge	x			
Sponge	Halichondriidae	*Halichondria bowerbanki*		x	x	x	
Tunicate	Ascidiidae	*Ascidia zara*				x	
Tunicate	Cionidae	*Ciona intestinalis*	Sea Vase			x	
Tunicate	Cionidae	*Ciona robusta*				x	
Tunicate	Cionidae	*Ciona savignyi*				x	
Tunicate	Didemnidae	*Didemnum* sp.	Wrinkled Sea Mats			x	
Tunicate	Didemnidae	*Diplosoma listerianum*	Jelly Crust Tunicate			x	
Tunicate	Molgulidae	*Molgula manhattensis*	Northern Sea Squirt	x			
Tunicate	Styelidae	*Botrylloides violaceus*	Chain tunicate	x	x	x	x
Tunicate	Styelidae	*Botryllus schlosseri*	Star Tunicate	x		x	
Tunicate	Styelidae	*Styela clava*	Stalked Sea Squirt	x	x	x	

* = only found washed up and/or dead

While there are very few studies of non-native species in San Francisco Bay that sample at Yerba Buena Island or Treasure Island, a 2009 study by the California Department of Fish and Wildlife of introduced species in the Bay found similar results to this study when surveying the subtidal fouling community of the Treasure Island marina and the rocky intertidal rip-rap of the Treasure Island/Yerba Buena Island causeway. The CDFW study found 40.4% of all species found at the Treasure Island marina were non-native, and 18.9% of the species found in the rocky intertidal rip-rap of the causeway were non-native.

Mytilus spp., *Metridium senile*, and other species (native and non-native) under the Treasure Island Marina Docks.

An aggregation of non-native *Ciona* spp. under the Treasure Island Marina docks.

Many of the non-native species found in our current study were introduced to San Francisco Bay in the late 1800s and early 1900s, like the Soft-shell Clam (*Mya arenaria*), transported to the Bay with shipments of Atlantic oysters in the 1870s, or the Striped Green Anemone (*Diadumene lineata*), native to Japan and first collected in SF Bay in 1906. Others are relatively new introductions, like the Japanese Green Syllid (*Megasyllis nipponica*), and the solitary tunicate *Ascidia zara* (native to the Northwest Pacific), both first found in the Bay in 2000.

New Species Records

This current study found 96 species that had never previously been recorded (via iNaturalist or on GBIF) on or immediately around Yerba Buena Island. While it's a large number of species, it's not altogether unsurprising given that the Yerba Buena Island intertidal is largely difficult to access and/or inaccessible for most of the shoreline beyond Clipper Cove, thus leaving it understudied via academic means and under-documented via iNaturalist users.

More surprising are the eight species found in this current study that had never been previously recorded (via iNaturalist or on GBIF) in all of San Francisco Bay, or in the case of the Onyx Slippersnail (*Crepidula onyx*), had never been previously documented *alive* in San Francisco Bay (see Table 6).

Table 6. List of species found in this study that are new records for San Francisco Bay. An 'x' indicates that species was found at that site. CC & EYBI = Clipper Cove and Eastern Yerba Buena Island, WYBI = Western Yerba Buena Island, TI Marina = Treasure Island Marina, ETI = Eastern Treasure Island.

NEW SPECIES RECORDS FOR SAN FRANCISCO BAY				SITES FOUND AT			
Type of Organism	**Family**	**Species**	**Common Name**	**CC & EYBI**	**WYBI**	**TI Marina**	**ETI**
Brittle Star	Hemieuryalidae	*Ophioplocus esmarki*	Esmark's Brittle Star		x		
Chiton	Tonicellidae	*Tonicella lokii*	Flame Lined Chiton		x		
Crab	Porcellanidae	*Petrolisthes manimaculis*	Chocolate Porcelain Crab		x		
Polychaete	Terebellidae	*Pista pacifica*	Fringed-hood Spaghetti Worm		x		
Red Algae	Erythrotrichiaceae	*Smithora naiadum*	Seagrass Laver				x
Snail	Calyptraeidae	*Crepidula onyx*	Onyx Slippersnail		x		
Snail	Calliostomatidae	*Calliostoma gloriosum*	Glorious Topsnail		x		
Sponge	Raspailiidae	Raspailiidae sp.			x		

All of these new-to-SF-Bay species were found on Western Yerba Buena Island, with the only exception being the Seagrass Laver (*Smithora naiadum*) found on the eelgrass off Eastern Treasure Island. Western YBI is likely a hotspot for these new species records due to its inaccessibility (and thus being understudied), combined with it being a site largely under open-ocean conditions thanks to its proximity to and that it directly faces the Golden Gate, making it a somewhat unique site within San Francisco Bay.

Ophioplocus esmarki found on WYBI.

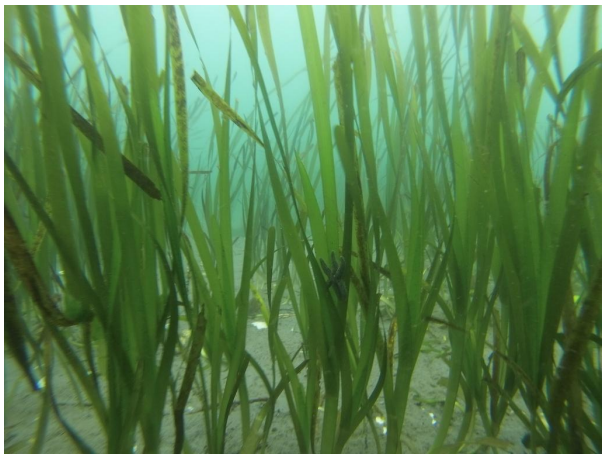
Tonicella lokii found on WYBI.

Calliostoma gloriosum found on WYBI.

Smithora naiadum is a species that is epiphytic on seagrasses (surfgrass and eelgrass), and thus it makes sense that it was found at the only site with seagrass. Although we could find no records in collections (Cal Academy, UC Berkeley Herbarium, or in GBIF) of this species, it has likely been observed by ecologists and others working on eelgrass in the San Francisco Bay. The lack of available information about this species in biodiversity databases highlights the need for ongoing collections and photo-based monitoring in the Bay and beyond. It could also be that the protected nature of the

eastern side of Treasure Island provides a unique set of conditions that allows *Smithora* to thrive. This question needs more investigation.

Eelgrass



Eelgrass (*Zostera marina*) is a native marine plant that can form extensive beds in shallow (between mean low water and ~-1.5m below mean low water) sheltered habitats with sandy or muddy bottoms. In San Francisco Bay, eelgrass beds are important habitat for invertebrates and fish – especially small species and juveniles, and serve as key foraging areas for larger fish species. Eelgrass beds also prevent erosion by slowing down wave energy and stabilizing sediment, helping to protect shorelines.

Clipper Cove

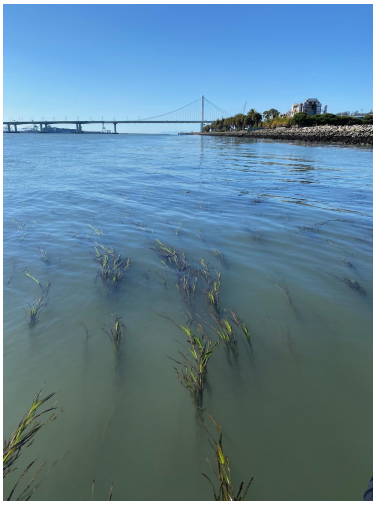
Clipper Cove has historically harbored a small (<1 ha) eelgrass bed. Eelgrass in Clipper Cove has been confined to a narrow fringe along the southern shoreline, due to the steep depth gradient offshore.

In two walking surveys in Clipper Cove during winter 2019-20, no eelgrass was found. Because eelgrass biomass can vary seasonally and tends to peak in summer in San Francisco Bay, one more walking survey was conducted in July 2020, where again, no eelgrass was detected. Previous studies of eelgrass in San Francisco Bay have determined that there is high variability year-to-year in eelgrass biomass in Clipper Cove, and that yearly weather patterns and other regional factors may be the main drivers of eelgrass there, instead of local factors (Merkel and Associates 2009, AECOM 2019), so we decided to search Clipper Cove again in 2021, this time by ROV, to visually survey for eelgrass. We conducted ROV surveys in February and June 2021, but no eelgrass was seen.

This finding is in line with other studies. Caltrans, as part of the San Francisco-Oakland Bay Bridge East Span Seismic Safety Project, has conducted surveys of eelgrass cover at Yerba Buena Island. Eelgrass at Clipper Cove has been declining over the past fifteen years, from 0.2 ha in 2007 to less than 0.1 ha in 2013, and no eelgrass was detected in Clipper Cove in the 2015-18 surveys (the most recent surveys for which there are published data). Apparently this trend has continued, with our study finding no eelgrass in 2020 and 2021. Link to Clipper Cove video footage taken by David McGuire.

Eastern Treasure Island

In contrast to Clipper Cove, the eelgrass bed offshore of eastern Treasure Island is quite extensive. This study was not designed to survey the extent of the bed, however, visually, the eastern Treasure Island bed appeared to be of similar size to what was found in previous studies, extending along almost the entire length of the eastern shoreline (offshore from 3rd Street to 13th Street). We often encountered washed up eelgrass on Clipper Cove beach. This drift eelgrass is mostly likely from the Eastern Treasure Island eelgrass bed.



The Eastern Treasure Island eelgrass bed could be an important source for reintroduction of eelgrass into Clipper Cove. While eelgrass primarily reproduces by sending up new shoots from its rhizomes, it does also produce seeds which could disperse into Clipper Cove either directly from the Eastern Treasure Island bed, or on broken stems of eelgrass that carry fertile seeds into Clipper Cove, eventually dropping into the sediment bed. Subtidal Eastern Treasure Island is also likely under similar environmental and ecological conditions as Clipper Cove, so the eelgrass bed there might also be the best place to gather rhizomes and shoots for reintroduction to Clipper Cove, if reintroduction is an option TIDA is interested in pursuing.

<u>Yerba Buena Island in the Context of San Francisco Bay</u>

Biodiversity

Of the 198 species documented in this survey and via previous iNaturalist observations, 190 of them have also been documented at least once in other parts of the San Francisco Bay. While it was outside the scope of this study to determine how similar the intertidal community on YBI is to intertidal communities found in other parts of the Bay, it is clear that the suite of species found on YBI is generally reflective of the suite of species found in the Bay on the whole.

However, YBI is likely unique in that it harbors both an open-ocean influenced intertidal community on its western shores, and a more classic sheltered bay community along Clipper Cove and next to the Torpedo Storehouse. Many of the species found on Western YBI are only found in other parts of the Bay

with strong open-ocean influences: places like Crissy Field and Aquatic Park along the north shore of San Francisco, Horseshoe Cove and the Fort Baker region of Sausalito, and the south shore of Angel Island. Some of these species include: Pubescent Porcelain Crabs (*Pachycheles pubescens*), Giant Rock Scallops (*Crassadoma gigantea*), Striped Dogwinkles (*Nucella ostrina*), California Spiny Chitons (*Nuttallina californica*), and Little Rockweed (*Pelvetiopsis limitata*). Clipper Cove / Eastern YBI, in contrast, is home to some species that only exist in sheltered intertidal environments, for example Striped Green Anemones (*Diadumene lineata*), Lugworms (*Arenicola* spp.), and New Zealand Burrowing Isopods (*Sphaeroma quoianum*). In both regions of YBI we also found "crossover" species: species generally considered more "open coast" found on the Clipper Cove/Eastern YBI shorelines (like the Northern Kelp Crab (*Pugettia producta*)), and "sheltered/bay" species found on the Western YBI shoreline (like the Fringed-hood Spaghetti Worm (*Pista pacifica*)). This highlights that, while Western YBI is most like an outer coast site, it is still within and influenced by San Francisco Bay, and Clipper Cove/Eastern YBI, while most similar to a fully sheltered Bay site, is still close enough to the Golden Gate to receive some open-ocean influence.

Rocky Intertidal

Natural rocky intertidal areas are rare in the San Francisco Bay (see Figure 6). Many of the original rocky outcrops and small islands in the Bay were destroyed in order to remove shipping hazards. In the Figure 6 map, the rocky areas of Yerba Buena Island are not included, although areas of YBI are included in maps of other habitats in the same report. If a new report is being written, it will be important to include YBI rocky areas. As mentioned above, these rocky points along the western side of YBI and between Clipper Cove and the Torpedo Storehouse harbor the most native biodiversity and generally are adjacent to intact native upland areas. Because of this rarity and high biodiversity, these areas should be protected from run-off, sedimentation, modification, and other disturbances. Introduced species and debris should be removed. They should also be celebrated and protected with interpretive signage.

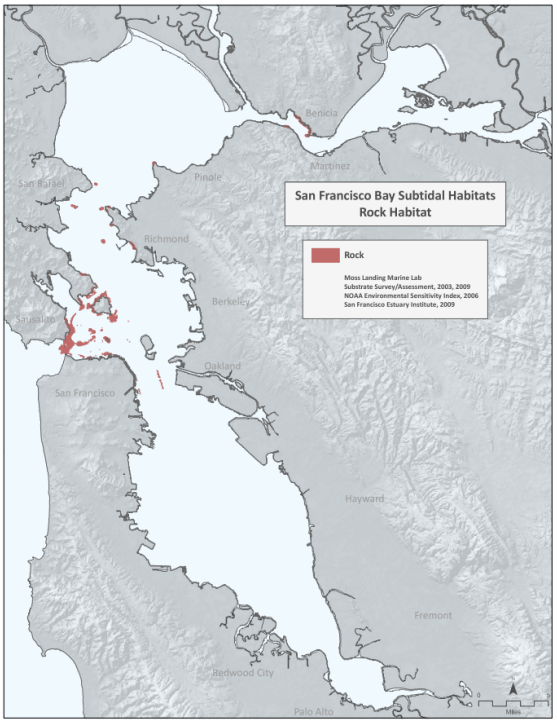


Figure 6. Distribution of rocky habitat in San Francisco Bay. Source: San Francisco Bay Subtidal Habitat Goals Report (2010).

Gaining a deeper understanding of the characteristics of these natural rock intertidal sites with intact native habitat upslope and other similar sites throughout the Bay and working to determine if this correlation is more widespread is an important area of further study. Regularly pairing upland surveys with intertidal and subtidal surveys to gain an understanding of multi-habitat interactions is rarely done

and will give us new and important insights. Identifying similar areas on YBI and throughout the Bay can allow for protection of existing sites, and finding areas with a subset of the needed characteristics will give us new insights into potential restoration areas. For example, on YBI areas with underlying natural rock, away from landslide areas and creeks that currently have riprap or other modifications, could be restored as living shorelines, modelling the restoration after adjacent intact areas.

Invasive Species

San Francisco Bay is one of the most highly invaded estuaries in the world, due primarily to intensive shipping activity and introduction of non-native species through the commercial oyster industry. There are over 250 known introduced and/or cryptogenic species currently living in San Francisco Bay. In this study, we found 27 of those introduced species in the YBI intertidal and the Treasure Island marina. While many of the non-native species in San Francisco Bay are tiny or difficult to distinguish from native species, and while not all of the introduced species in the Bay are invasive, we think it's important to note that there are some highly invasive, easy to identify introduced species in San Francisco Bay that we did not find in these surveys, yet YBI potentially has suitable habitat for (i.e., species that inhabit rocky or sandy shores, not just mudflats). Because of the size and distinguishable characteristics of these species, we believe we would have seen and documented them if they were present in the YBI intertidal or TI marina. This includes the Eastern Oyster Drill, *Urosalpinx cinerea*, which was discussed earlier. Other invasive species we believe we would have found if they were present on YBI include:

- *Carcinus maenas*, the European Green Crab: considered one of the worst invasive species in the world, *Carcinus maenas* is native to the northeastern Atlantic. It was first introduced in the U.S. on the Atlantic Coast by 1817, and was first found in San Francisco Bay along Redwood Shores in 1990. It is now found along most of the Bay shoreline from San Pablo Bay through the South Bay in sheltered intertidal and shallow subtidal habitats, but has not yet been seen on any of the Bay's major islands, based on records from GBIF and iNaturalist. This species impacts intertidal communities by preying on clams, mussels, and other crabs (like *Metacarcinus magister*, the Dungeness Crab), as well as competing with native crabs for habitat and food.
- *Busycotypus canaliculatus*, the Channeled Whelk: *Busycotypus canaliculatus* is a large (5-8") predatory snail, native to the east coast of the United States. It was first discovered in the San Francisco Bay in 1938, and is the largest snail in the Bay – how it arrived in the Bay is unknown. It inhabits oyster beds, mud, and sand flats in the intertidal to subtidal. While all recent observations are from the South Bay, the Channeled Whelk has been found north of the Bay Bridge in the past. Though it preys on bivalves, the ecological and economic impacts of *B. canaliculatus* in the San Francisco Bay are largely unknown.
- *Geukensia demissa*, the Atlantic Ribbed Mussel: native to the Atlantic coast of North America, *Geukensia demissa* was first found in San Francisco Bay in 1894, introduced with Eastern Oyster imports. It is well-distributed throughout the Bay, most commonly found in marsh habitats where it forms large beds throughout the mud, but it will also settle on rocks, wood, and other hard substrate. They cause injury or drowning in the endangered Clapper Rail by trapping their toes or feet in the valves when the mussels close, but are also an important food source for Clapper Rails as well. They also negatively impact the structure of marsh channels and dikes.

Eelgrass

In comparison to other eelgrass beds in San Francisco Bay, the beds off eastern Treasure Island and in Clipper Cove (when present) are quite small. The shallow subtidal areas of San Pablo Bay/Point Pinole and Richardson Bay consistently have the largest eelgrass beds in the Bay, together often comprising 55-72% of all the eelgrass in San Francisco Bay in any given year. In comparison, all eelgrass found around TI and YBI usually accounts for about 2% of all eelgrass in the Bay annually. While our study and other recent studies did not find eelgrass in Clipper Cove, across the entire Bay eelgrass extent fluctuates greatly year to year, with no indication of an overall increase or decrease over the past two decades. These large fluctuations across eelgrass beds throughout San Francisco Bay are hypothesized to be driven primarily by large-scale episodic events that influence sedimentation in the Bay: high flow events in wet years substantially increase sediment loading and thus sediment suspension in the water, which is slowly removed from the Bay by tidal exchange. Eelgrass is extirpated from sites of high suspended sediment and low sediment export for several years following these high-flow events. During drought conditions, sediment loading is reduced, increasing water clarity and improving conditions that support eelgrass (Merkel and Associates 2009).

Eelgrass is also affected by many other environmental and ecological factors, such as light availability, microalgae and epiphytes, salinity, pollution, water temperature, and storms. These conditions can change across San Francisco Bay as a whole (e.g., reduced salinity during wet years), or can be limited to individual sites (e.g., decreased light availability due to new construction along the shoreline shading the water). Understanding which factors have the greatest influence on the eelgrass bed in Clipper Cove could be integral to bringing that bed back naturally or to the success of eelgrass reintroduction work.

Conclusion

The intertidal habitats of Yerba Buena Island are home to hundreds of species. The diversity of the interidal matches or supasses that of any other rocky interidal site in the San Francisco Bay. Overall the species composition of the YBI intertidal is similar to that of the rest of the bay, but YBI is unique in that it has not only a suite of habitats including cobble beaches, natural rock outcrops, sandy beaches, a sheltered bay, and a marina with human-made hard substrates, but it also has a strong marine influence along its western shores and more protected conditions on the eastern side of the island. This combination of habitat types and different salinities, currents and wave action, creates a mosaic that supports many species on YBI.

Although eelgrass was not found in Clipper Cove during these surveys, regular monitoring should be conducted to track a potential return and to determine the composition of the subtidal community. Clipper Cove could be a place to focus on for eelgrass restoration once construction is finished on the island. The eelgrass bed on Eastern Treasure Island could be a candidate source population for restoration, but further research needs to be done.

Time and funding to conduct basic natural history surveys are exceedingly rare, but this type of survey is the only way to discover and document the biodiversity of a place. Regular surveys of YBI and other areas throughout the Bay will help us understand and have a record of the plants and animals in each place. These data are critical as we build new infrastructure, look to nature based solutions, and work to conserve nature in a changing world. Yerba Buena Island is an important part of the San Francisco Bay ecosystem and its diverse habitats should be protected and celebrated.

<u>Recommendations</u>

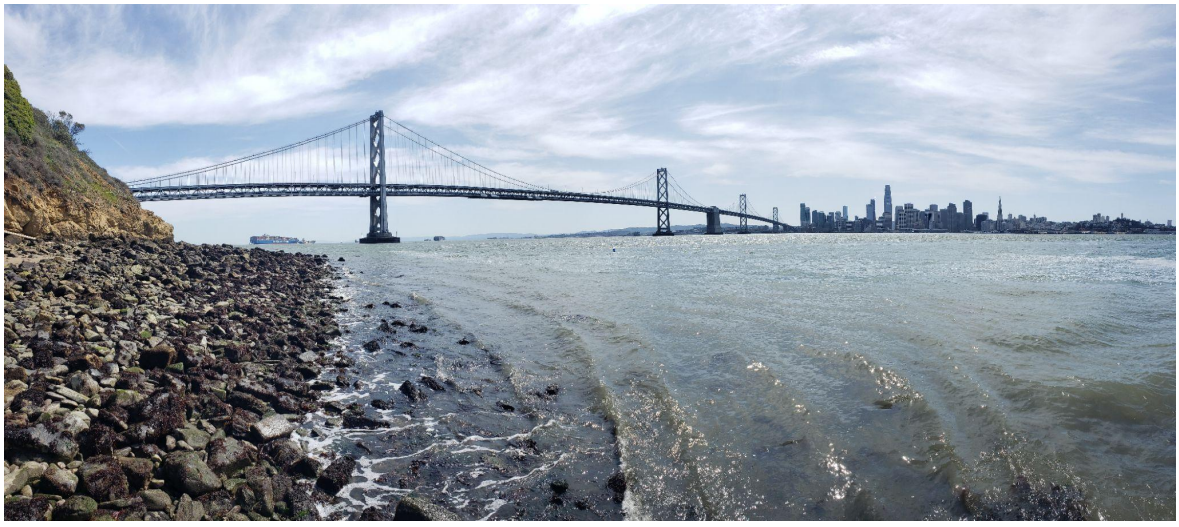
Intertidal

- Ongoing/regular monitoring of the Yerba Buena Island intertidal, for two key reasons: (1) as YBI and Treasure Island are being developed for more residential use, along with increased visitorship once the ferry terminal is built, and combined with shoreline park designation and improvements, intertidal areas, especially those along Clipper Cove and next to the Torpedo Storehouse, will experience increased human use, which can disturb habitat and in turn negatively affect species; and (2) intertidal and subtidal communities in San Francisco Bay can dramatically change composition based on environmental conditions (e.g., Chang *et al.* 2017), meaning that this current study is primarily a "snapshot" of the YBI marine community under the particular conditions of 2019-2021.
- Interpretation at Clipper Cove (via signs, kiosk, and/or a visitor center), as the main and easiest intertidal access point on YBI or TI.
- Signage and interpretation near the Torpedo Storehouse area, as another relatively easy intertidal access point.
- Continue to follow the recommendations of the 2009 Yerba Buena Island Habitat Management Plan that relate to intertidal areas and adjacent upland vegetation.

- Continued restoration and protection of upland habitats and management of run-off and sedimentation and incorporation of living shorelines.
- Follow the recommendations of the 2010 San Francisco Bay Subtidal Habitat Goals for the natural rocky outcrops and shoreline on YBI:
    - Protection 1.1 Promote preservation of rocky habitats
    - Protection 1.2 Provide access to natural rock habitats in the Bay that encourages appreciation of the habitat and its inhabitants while protecting it from human trampling
    - Restoration 1.1 Remove invasive species that may impact rocky intertidal habitats
    - Restoration 1.2 Provide funding and programs to clean up and prevent debris and upland sites adjacent to or within rocky habitat
    - Restoration 1.3 Incorporate living shoreline techniques to enhance the functions of existing natural rock.
- Continued yearly YBI bioblitzes, because: (1) the previous bioblitzes (2017-2021) produced a lot of "first records" for YBI on our species list, and (2) as more people live on TI and YBI, and as more people visit the islands, bioblitzes can be an important engagement tool to teach people about the unique biodiversity on YBI.

Eelgrass/subtidal

- A more rigorous survey of the Clipper Cove subtidal to better understand species composition.
- Regular monitoring of Clipper Cove for eelgrass and the associated ecological and environmental conditions there that affect eelgrass.
- Possible reintroduction of eelgrass at Clipper Cove if it does not return naturally during years of favorable conditions.
- Monitoring of the Eastern Treasure Island eelgrass bed and the environmental and ecological factors that affect eelgrass there as Treasure Island is redeveloped (e.g., shade stunts eelgrass – so thinking about buildings that might shade that area, increased sedimentation during construction, etc.).



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