Comparing the Impacts of Human Disturbance and Marine Preserve Status in the Intertidal Community

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Abstract

Exploring the impacts of human disturbance on the rocky intertidal community has implications for how human interaction can affect community composition, organism abundance, diversity, and species richness. The efficacy of marine protected areas' role in preserving biodiversity has been widely debated. We found that areas of increased human disturbance lacking protective status appear to be less biodiverse. This finding provides context for implementing future marine preserves. We performed quadrat and abundance surveys on Yellow Island, a marine preserve in the Salish Sea to characterize the biodiversity of the intertidal. Utilizing community science data that used equivalent survey methods to ours from the Multi-agency Rocky Intertidal Network (MARINe) for two urban intertidal sites in the Salish Sea with intermediate and higher disturbance, we aim to answer the question of how protected status and human disturbance level impact community composition. Statistical analysis of meiofauna percent-cover and phyla counts reveals that the intermediate and higher disturbance areas have lower total phyla presence compared to the marine preserve low disturbance site. Increased disturbance sites are dominated by algal cover while the marine preserve site has increased non-algal phyla and algal phyla. With further research in eDNA and other biological traits, we can get a fuller picture of how disturbance and protection status impact the intertidal community. This work highlights the importance of long-term monitoring projects in the marine environment.

Introduction

In marine ecosystems, the intertidal ecosystem is the area that experiences varied amounts of time in and out of water based on the tides. The intertidal is divided into four parts, the splash zone, high zone, mid zone, and the low tide zone. After the tide fully recedes, the area where the water pools is referred to as a tide pool (Black in Marine Science, 2021). In the Pacific Northwest, the habitat area is defined as the rocky intertidal, which is identified by the occurrence of specific physical conditions like large boulders, pebble beaches, and other rocky substrate types found in places like Washington, Oregon, California, and British Columbia, Canada. The Salish Sea is an inland sea consisting of Washington state and British Columbia waters including Puget Sound, the San Juan Islands, the Strait of Juan de Fuca, B.C's Gulf Islands, and the Strait of Georgia (*Washington | MARINe*, n.d.).

Yellow Island is an 11-acre terrestrial and marine preserve part of the San Juan Islands archipelago. The Washington Department of Fish and Wildlife has designated Yellow Island as a marine preserve, with all tidelands and bedlands within three-hundred yards of the island holding protected status. Commercial fishing of herring is allowed but the area is no-take for any other species (*Yellow and Low Islands Marine Preserve | Washington Department of Fish & Wildlife*, n.d.). Yellow Island was purchased by the Dodd family in 1945, naturalists who constructed the only built structures on the island. The main cabin, which is still standing today, was made to be rustic yet habitable, evidenced by the multiple land stewards who have resided on Yellow Island since The Nature Conservancy purchased it in 1980. Yellow Island is managed by The Nature Conservancy which has owned it and conducted research and restoration projects on it since its acquisition. Yellow Island was desirable for conservation purposes to The Nature Conservancy for its unique amalgamation of native and non-native plant species. Yellow Island holds space for a unique terrestrial and intertidal habitat due to a lack of disturbance of its ecological environment from human activity (The Nature Conservancy, n.d).

Over twenty years of logging of the terrestrial environment has occurred on Yellow Island. However, there is much less data existing for the marine environment aside from the 1980, 2004, and 2021 intertidal monitoring projects conducted by Friday Harbor Laboratories students and other researchers (Gelow, 2004). Marine monitoring projects are crucial to document intertidal composition, abundance, and biodiversity as a marker of Salish Sea health. The Indigenous history of Yellow Island persists through the stewardship, management, and livelihood of the Coast Salish people. Through learning and applying Indigenous stewardship, Yellow Island has been uniquely shaped to reflect Indigenous traditions. Many of the plants on Yellow Island, like the Camas plant, are essential to Indigenous traditions. The management of the ecosystem through Indigenous practices has allowed for continued harvest and upholds cultural practices that are integral to the community and identity of peoples Indigenous to the San Juan Islands and surrounding regions of the Pacific Northwest.

In contrast, the urban intertidal is where the intertidal ecosystem is adjacent to urbanized coastal areas and more accessible to human interaction. Due to its location as the boundary between land and the sea, the intertidal is highly susceptible to terrestrial and marine disturbances. The urban intertidal can consist of higher boat and ship traffic, waterway changes, dredging, pollution, shoreline hardening, and trampling. Human disturbance of the intertidal exists on a gradient. Research, exploration, aquaria, food collection, and recreation are all forms of human interaction with the intertidal that occur in urban intertidal areas (Thompson et al., 2002).

In order to compare Yellow Island to areas with increased levels of human use of similar species composition, we have selected two sites in the Salish Sea that are part of MARINe's network of long-term intertidal monitoring sites. The Washington Salish Sea intertidal is incredibly diverse and abundant in species, however, in recent years Washington sites and other intertidal communities have been threatened by industrial and urban pollution sources, habitat decline, and oil (*Washington | MARINe*, n.d.). The stress that the Washington intertidal is facing is reflected in declines of signature marine species like Orcas, salmon, rockfish, marine birds and shellfish that are essential to the areas tourism, fisheries, and recreational industries.

Post Point, in Bellingham Bay, receives a "moderate" amount of tidepoolers and human interaction during low tides. However, the intertidal area itself is 1km away from the closest access point providing it some protection from high levels of human interaction (*Post Point | MARINe*, n.d.). Manchester State Park; Central Puget Sound is located near Port Orchard, WA across from Bainbridge Island and has an accessible shoreline for kayaking, boating, swimming, camping, and other recreational activities. It is also home to a former military fort that stood for roughly a decade intended to fortify Puget Sound in the case of maritime conflict. As a state park, the site is managed by Washington State Parks and it is open year-round from 8 a.m. to dusk. Licenses are required for fishing. Activities that may damage the park or propose a hazard to wildlife such as littering are prohibited (*Manchester State Park | Washington State Parks and Recreation Commission*, n.d.).

Yellow Island, in comparison, is only open from 10-4 PM, and no dogs, food, or camping is allowed on the island (The Nature Conservancy, n.d). Boat landing is also only allowed on one side of the island and in general, boat traffic is much less than it is in more urban areas. The top human disturbance on Yellow is intermittent kayakers and boaters.

The intention of this survey is to conduct a holistic study of community composition on Yellow Island in order to compare it as an intertidal habitat with marine protected status and low levels of human disturbance to urban unprotected intertidal habitats of Washington that experience more frequent and historical human disturbance. This is in order to shed light on how historical human disturbance of an area or lack of disturbance affects the intertidal habitat. Based on previous literature, a set of characteristics have been selected that could reveal potential variations due to the scale of disturbance (Povey & Keough, 1991), (Addessi, 1994), (Stevčić et al., 2018). We expect to see differences in composition between the urban intertidal and a less disturbed environment like Yellow Island.

The major questions we propose are: how is the species richness, abundance, and diversity different between the urban intertidal and Yellow Island? As well as, are there differences between traits like organism size between the two intertidal ecosystems seen in specific organisms? We anticipate that the less disturbed area will have increased biodiversity. Beauchamp and Gowing (1982), found that density and diversity of organisms were higher in less human trampled sites. Threshold effects, or small changes in human disturbance intensity that lead to larger ecosystem response were seen in reference to *Mazzaella splendens* (Splendid Iridescent Seaweed) in which population density changes between counties where specimens were collected reflected a decline in species size over time for urban areas with high population density that was not found in areas with lower population density (Gilbert, 2021).

The major question of this study is to determine if there is unique community composition or organismal traits on Yellow Island that are different from urban intertidal environments impacted by varied levels of human disturbance. Due to reduced human disturbance on Yellow Island, we believe that organism traits and community composition will vary from comparable species found in urban intertidal areas. It is essential to compare urbanized ecosystems impacted by human disturbance to protected areas like Yellow Island with low levels of urbanization to rate the effectiveness of marine protected areas in preserving intertidal habitats. As urbanization expands in coastal zones, there is potential for more habitats to succumb to increased human interaction and disturbance. Measuring the comparison between protected areas and unprotected ones can highlight important or unique ecological factors that may encourage the creation of more protected areas with enforcement and education about human disturbance impact.

Methods

Both qualitative and quantitative methods were used to survey organism's presence, abundance, and diversity on Yellow Island, and the urban site data is pulled from publicly available community science sources provided by the Multi-Agency Rocky Intertidal Network, hereafter referred to as 'MARINe'. Through taking a full inventory of species from the high, mid, and low tidal zones across the island in teams of students using species ID guides and survey tables we were able to capture a picture of the entirety of the intertidal community on Yellow Island. Species were identified to the level of highest confidence, particularly with regards to the various algal types found. Survey data was supplemented with mechanical methods of quadrat and transect survey data and the eventual addition of molecular tools (eDNA) to round out the community composition data.

Quadrat data was collected on Yellow Island between June 30th, 2023 and July 21st, 2023, during the minimums of the tidal range for the year. Half-meter by half-meter quadrats were collected from eight sections on Yellow Island (Fig 1).

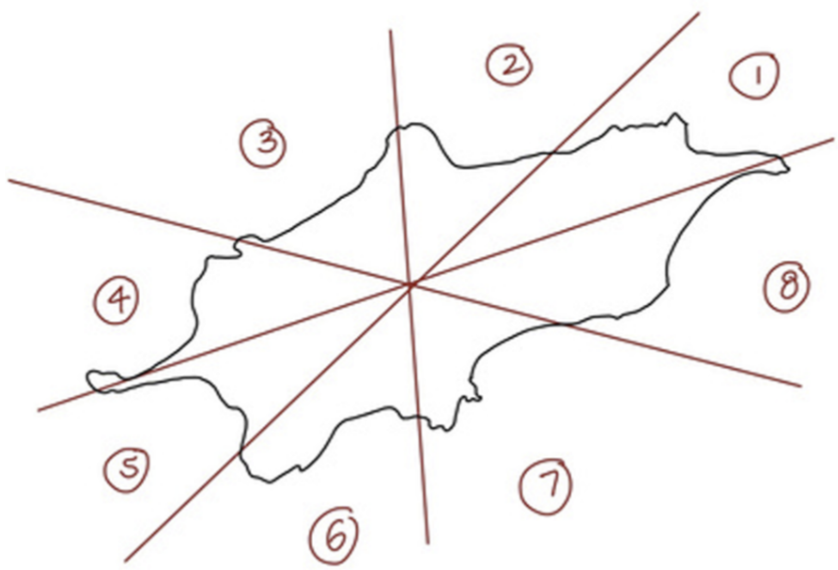

Fig. 1. Map of sections on Yellow Island

We broke the intertidal into three zones, upper, middle, and lower with each detonated by characteristic changes in algal species. Ulva spp. (Sea Lettuce) abundance was used to denote the lower intertidal, Fucus distichus (Rockweed) abundance to denote the middle, and Endocladia muricata (Turfweed), bare rock, and Chthamalus/Balanus spp. and Semibalanus spp. (Thatched and Acorn Barnacles) to denote the upper (MBNMS Site Characterization: Rocky Intertidal Habitats - III. Distribution Patterns, n.d.). All quadrats were taken for two layers of quantification: surface percent cover composition of foundational species and one layer beneath of percent cover and individual species counts, to include the temporary removal of rocks for complete surveying but no digging into the sediment. Non-percent cover and other characteristic intertidal organisms like sea stars, anemones, crabs, urchins, etc. were counted and documented to fully characterize the underlayer of the quadrat. We took approximately twenty quadrats of data per intertidal zone, totaling approximately sixty quadrats across all three zones per each of the eight sites. Almost five-hundred quadrats were collected across the entirety of the island. Quadrat data was then condensed into phylum level classifications for ease of visualization, synthesis, and negating potential errors in species classification in data collection.

Washington intertidal data comes from long-term monitoring and biodiversity surveys conducted by the Multi-Agency Rocky Intertidal Network (MARINe). Monitoring methods from MARINe are comparable to those used on Yellow Island through Quadrat and Transect surveys. MARINe plots, however, are selected for targeted assemblages and are long-term permanent plots that were originally chosen for their high abundance of a foundational species. Percent cover of other organisms are included in MARINe data along with the foundational species. Data from the two MARINe sites comes from the 2022 year of monitoring.

Results

We found that the community composition of Yellow Island consisted of twelve total phyla, nine of them being non-algal phyla. The sections varied for the amount of each phyla found but generally, the top three phyla on the island were Mollusca, Arthropoda, and Echinodermata (Fig 2).

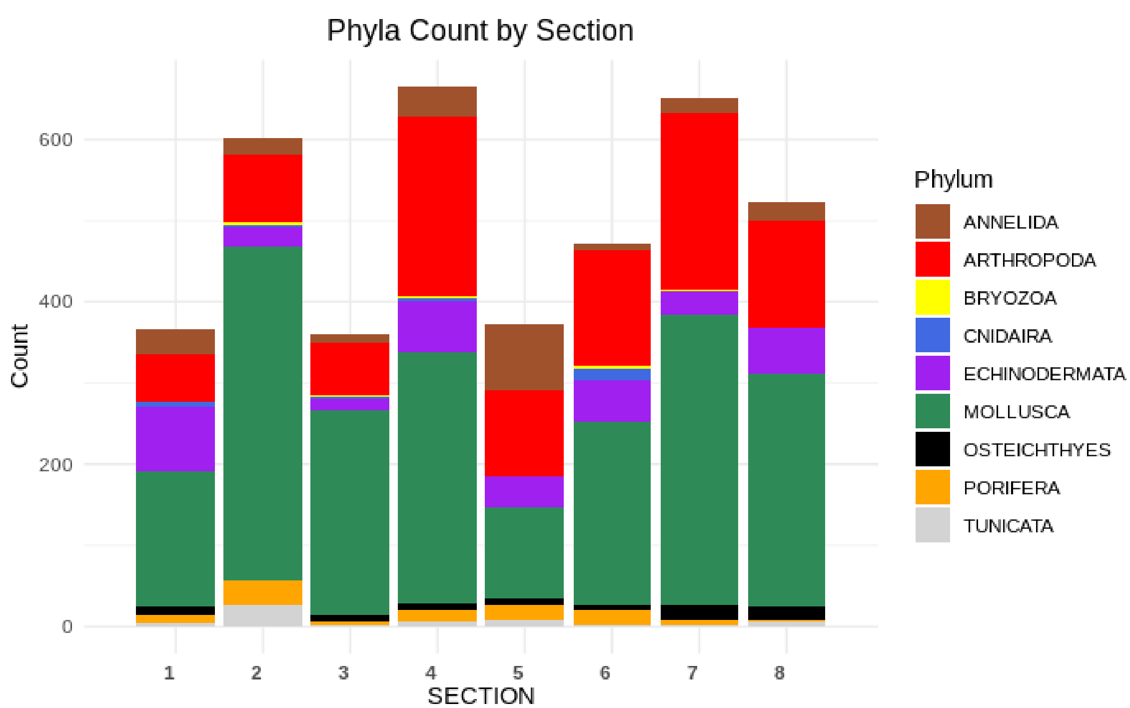

Fig. 2. Yellow Island Phyla count by section stacked bar chart

Section one consisted of the highest total number of organisms within Echinodermata and no documented organisms within Bryozoa. Section two has the largest number of organisms within Porifera, Mollusca and Tunicata, and no documented organisms within Osteichthyes. Section three has the lowest total phyla count out of all eight sections. Section four has the highest total phyla count out of all eight sections. Section five has the highest total number of organisms within Annelida and no documented organisms within Bryozoa or Cnidaria. Section six has the least number of organisms within Annelida and the highest number of organisms within Cnidaria. Section seven has the highest total number of organisms within Osteichthyes and no organisms within Cnidaria. Section eight has no documented organisms within Bryozoa or Cnidaria. The phyla distribution between sections shows high variation and presents a picture of rich biodiversity collectively across all eight sections of Yellow Island. Due to its importance for ecosystem function, we also quantified algal diversity across Yellow Island. Algal diversity was grouped in the three major phyla categories green, red, and brown. All encrusting algae were collapsed into a category and a final category was implemented for unknown algal types. Algal cover by section of Yellow Island (Fig 3) showed that brown and green algae were most abundant across all sections.

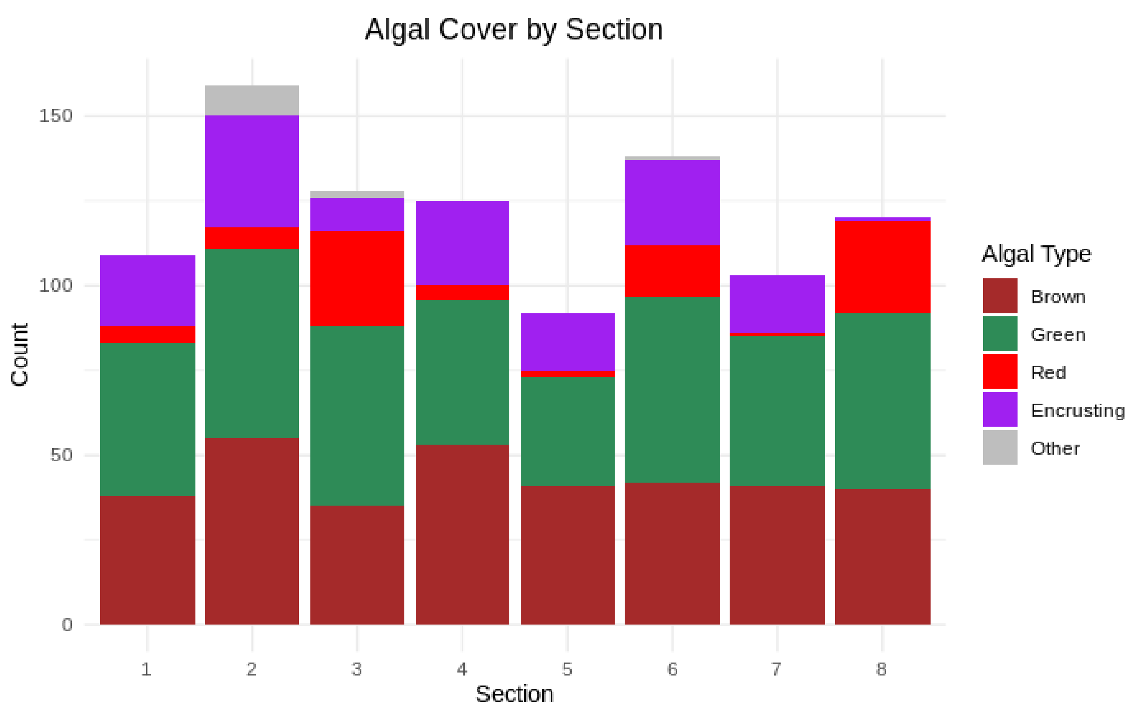

Fig. 3. Yellow Island Algal cover by section stacked bar chart

All sections of Yellow Island also showed presence of red and encrusting algae in various abundances. Section two had the highest total number of algal cover and section five had the lowest total number of algal cover.

Manchester State Park, hereafter referred to as 'Manchester' and Post Point had generally low phyla diversity, so we combined non-algal and algal phyla to characterize community composition. Of six total phyla, Arthropoda, Cnidaria, and Mollusca were the three non-algal phyla. The MARINe data was collapsed into percent cover of phyla level and divided by site and foundational species (barnacle or rockweed) (Fig 4).

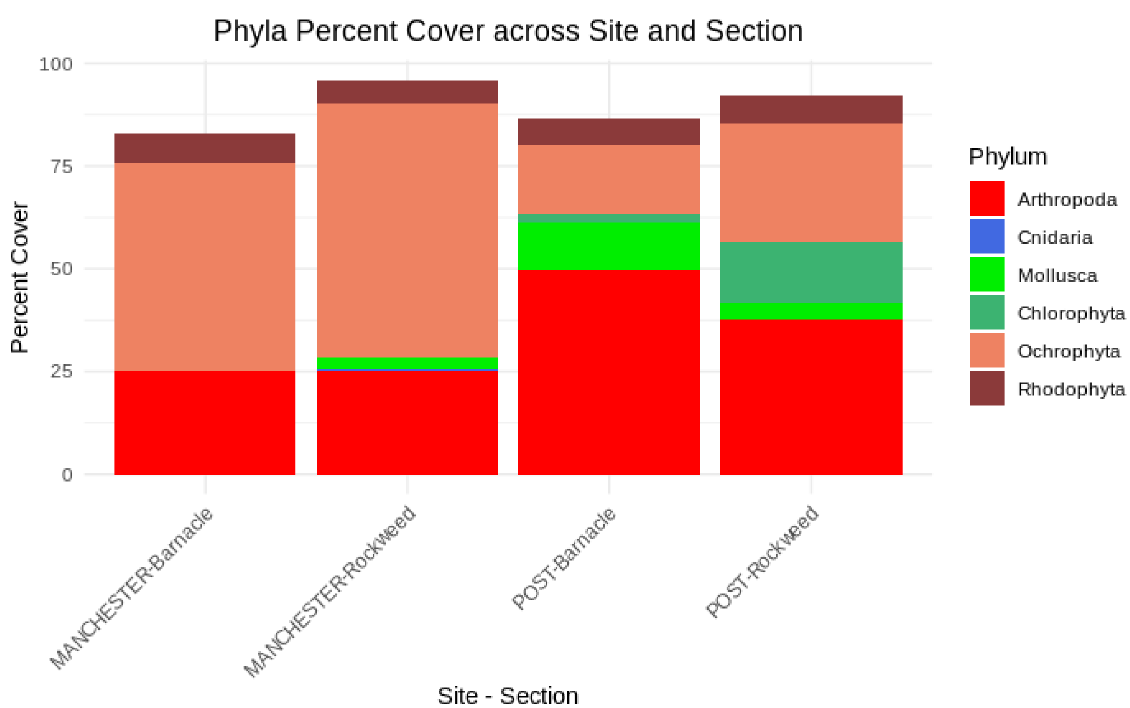

Fig. 4. Manchester & Post Point Phyla percent cover across site and section stacked bar chart

Ochrophyta (brown algae) and Arthropoda were the most abundant phyla present in both MARINe sites. Post Point had a higher percent cover for non-algal phyla such as Mollusca and Arthropoda, while Manchester was dominated by Ochrophyta as its main phyla. Post Point also had presence of Chlorophyta (green algae) while Manchester did not. Percent cover of Rhodophyta (red algae) was relatively consistent among both sites.

Discussion

The outcomes of comparing Yellow Island to the MARINe sites is consistent with our predictions. The MARINe sites have lower phyla biodiversity than Yellow Island, with Post Point, the intermediate disturbance site, having a higher percent cover of non-algal phyla than Manchester, the most disturbed site. The goal of this research was to compare protected vs unprotected intertidal areas with various levels of human disturbance to make inferences about biodiversity from the phylum level. Many studies have been conducted about the impact of human disturbance on the intertidal. The implications for human disturbance and its impact on intertidal community composition are widespread. The impacts that intertidal organisms receive from human disturbance often push them outside the disturbance ranges that they experience throughout their evolutionary history (Povey & Keough, 1991). The changes in community composition could potentially sustain throughout time, particularly with high and increasing disturbance as population grows near intertidal areas (Adressi, 1964). This research also calls into question what these results mean for marine protected area management and the creation of new protected areas. Previous studies have found that a rocky intertidal area within a marine protected area had higher species richness, diversity, and evenness when compared to sites outside of an MPA adjacent to urbanized areas (Portugal et al., 2017). In addition, the importance of increasing public awareness of marine protected areas is crucial to their existence, as disturbance can persist if enforcement isn't deterring activities like collection (Murray et al., 1999). Recovery is also an integral part of protecting intertidal habitats; suggestions have been made in previous studies to implement periods of no access and seasonal closures to allow for this recovery period (Huff, 2011). Our research is adding to the breadth of knowledge that will be useful in determining how marine protected areas impact the intertidal community and what disturbance means for these areas.

While completing data collection on Yellow Island, representative measurements were taken across three species of organism, *Pisaster ochreous* (Ochre Star), *Katharina tunicata* (Leather Chiton), and *Evasterias troschelii* (Mottled Star) to pilot the MARINe method of organism size comparison during quadrat work. This size data was collected on Yellow Island in hopes of drawing preliminary conclusions about how an impact of lack or presence of human disturbance may present itself in organismal size. This is an area for further research and work.

In future research, we will attempt to clarify how intertidal diversity may vary in a protected area like Yellow Island through using eDNA with primers that target meiofauna to support physical data collection and round out the community composition picture. The ultimate goal of this work is to make strong correlations between biodiversity health and MPA effectiveness using molecular methods. Future work also aims to mimic the work that MARINe does in setting up targeted assemblages for more data on long-lasting trends in intertidal biodiversity and continue collaboration in intertidal monitoring.

The importance of the rocky intertidal as a marine habitat is integral to the health of the marine environment, and ensuring its protection will continue to be a priority with further urbanization and global change of our oceans.

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