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Assessment of the Marine Macrofouling Community in Naval Base Heracleo Alano, Cavite City

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RESEARCH ARTICLE

Abstract

Background: Ports and naval bases play a significant role in understanding marine macrofouling and the associated transport of species across boundaries. Structures on ports and piers become habitats of foulers, whether indigenous or non-indigenous. There is a paucity of literature on species composition of foulers in ports in the Philippines. Naval Base Heracleo Alano in Cavite City, formerly known as Sangley Point, is a potential habitat for non-indigenous species.

Methodology: The study assessed benthic biofoulers at four areas in close proximity at Naval Base Heracleo Alano, Cavite City, using artificial collectors. Fouler collector design was adapted from the North Pacific Marine Sciences Organization (PICES). Fouler collectors were deployed in 4 sampling points from November 2015 and retrieved in February 2016. Collected fouling organisms were identified using taxonomic keys. Species diversity (H) through Shannon Wiener Index, Species Evenness (H'/H'max), and Simpson's Index were determined.

Results and Discussion: A total of 6203 organisms belonging to 20 families was collected. Common macrofoulers were bivalves, polychaetes, decapods, amphipods, and barnacles. Shannon-Wiener index values as well as species evenness were relatively consistent. Values of the Simpson's index indicated the presence of dominant species, *Balanus sp*. The macrofouling community contained 7 non-indigenous species, namely, *Mytella charruana*, *Brachidontes*, *Mytilopsis sallei*, *Hydroides*, *Stylochus*, *Sabella*, and *Membranipora membranacea*. The macrofouling organisms present in the area may pose problems in submerged equipment and cause some financial loss to the facility; the non-indigenous could be potential threats to the local ecosystem. All seven non-indigenous species are potentially invasive, although their abundance suggests otherwise.

Conclusion: A baseline listing of species was generated and showed various species of foulers in the naval base, with *Balanus* being the dominant species, which is the same as other studies in the Asian region. Seven non-indigenous species were detected. There is a need to monitor the non-indigenous species, as *Mytilopsis sallei* (origin: Carribean) has been reported to in huge numbers in the Indo West Pacific region, particularly in Singapore, Hongkong, Thailand, India, Taiwan, China, Malaysia, Japan, and Australia; *Brachidontes* (Origin: Indo-Pacific) has spread to the Mediterranean and Red Sea.

Introduction

Biofouling is a natural process of accretion of micro- and macro-organisms on surfaces immersed on bodies of water [1]. This phenomenon poses serious impacts on ports, navy, and shore-line establishments. These areas concentrate many structures, such as buoys, wharves, concrete dikes, pilings, docks, undersea storage, offshore platforms, ships, and many others, that provide artificial substrata for biofouling assemblages. Accumulation of these organisms on these marine structures hinders maritime activities and entails economic losses. Billions of dollars are spent globally to combat negative effects of fouling [2]. Fouling settlements deteriorate ship coatings, increase fuel consumption, and damage infrastructures such as underwater sensors and heat exchangers. Moreover, as hulls and ballast water of ships act as carriers of foulers from one location to another [3], port and navy areas act as biological reservoir of non-indigenous species that can eventually turn invasive.

The introduction of invasive species is a leading threat to biodiversity globally [4,5], whether introduction is intentional or not. It is a fast-growing, and usually irreversible, environmental concern. [6]. A classic example of invasion is that of *Mytilopsis sallei* in the Indo-Pacific region. Nine countries in the Indo West Pacific Region have reported *M. sallei* introductions: India [7,8], China [9], Taiwan [10], Hong Kong [11], Japan [12], Singapore [13], Malaysia [13], Philippines [14], and Australia [15]. This has led to damage to port and marina facilities and loss in mariculture. The eradication and monitoring of this species cost the Australian government alone more than US$1.6 million [16].

The ecological effects of invasive species are as distressing as the economic effects. A study [17] has shown that invasive species can alter environmental conditions of a habitat that has impact on other organisms. Some invasives become ecosystem engineers, or habitat modifiers [18]. Their activities change species composition and trophic levels. *M. sallei*, for example, change nutrient dynamics of infested clam farms [10]. *Dreissena polymorpha*, a close kin of *M. sallei*, replaced benthic organisms and cleared plankton communities in the waters of the Great Lakes after invasion [3]. Some species can also alter a water body's physico-chemical conditions such that the water body's parameter measurements fall below standards. Hence, good environmental status cannot be achieved [19]. Moreover, displacement of species that serve as local diet will have an impact on the surrounding populace.

It is thus imperative to study the fouler composition of ports and navy fouling assemblages in order to understand the fouling community's potential in perpetuating a biological invasion. Around the world, studies of fouling on permanent port structures have been studied [20,21,22,23]. In the Philippines, there is a paucity of literature in community composition of biofoulers. In an effort to establish baseline data on these communities, studies in man-made marinas in Manila Bay have been conducted. Studies using plastic collectors deployed at different seasons of the year at South Harbor [14,24,25] have confirmed the presence of non-indigenous species in Manila Bay, such as *Mytilopsis sallei*, indigenous to the Carribeans and *Mytella charruana*, indigenous to the tropical Atlantic and Pacific coastlines of Central and South America.

The Naval Base Heracleo Alano in Cavite City, surrounded by Manila Bay at its north, and the Cañacao Bay at its southeast, is frequented by vessels from India, Brunei, Indonesia, Malaysia, Thailand, Singapore, Turkey, United States, Japan, Korea, Australia, Canada, and Vietnam. Other international and national navy ships dock in and circulate around the country for different purposes such as navy visits, expeditions, and relief operations. As such, the site has become of interest with its potential to harbor probable invasive species.

Methodology

Study Setting

Naval Base Heracleo Alano, formerly known as Sangley Point, is a military installation of the Philippine Navy located at Lat 14°28'56.5"N, Long 120°54'01.5"E, in Fort San Felipe, Cavite City, Cavite (Figure 1). It has a land area of nine hectares, surrounded by Manila Bay to its north and to its southeast Cañacao Bay. Using a watch's second hand, sampling points were randomly identified upon the researcher's glance at the second hand. Site coordinates are shown in Table 1, while dock area and specific locations of sampling sites in the map are shown in Figures 2 and 3, respectively.

The study was done during the wet season. To establish the physico-chemical conditions of the waters surrounding the port, water quality assessment was done. Measurements of the following parameters were taken *in situ* twice a week at each sampling point: temperature, pH, dissolved oxygen, salinity, total dissolved solids, and conductivity. They were taken three times and measurements were averaged. Eutech Instruments-CyberScan Series 600 Waterproof Portable Meter, Model PCD650 was used to take measurements.

The fouler collector was based on the design of the North Pacific Marine Sciences Organization (PICES) [26] (Figure 4), which was composed of a twelve-inch circular hard plastic lid. One side of the lid had four Petri dishes attached to it. One Petri dish was attached to each quadrant of the circle. The collectors were soaked in seawater for five days in the laboratory for conditioning before deployment. Deployment was done in November 2015, where two collectors were submerged at sampling point 1, and one collector each for the remaining three sampling points. They were submerged 0.5 meters below the water surface. All collectors were retrieved in February 2016. Petri dishes were placed in transparent plastic bags containing a 1:9 ratio-solution of formalin and saltwater, then stored in styrofoam containers for sorting. Petri dishes were brought to the laboratory and all specimens attached to the Petri dishes were isolated using forceps, dissecting probe, and scalpel. They were

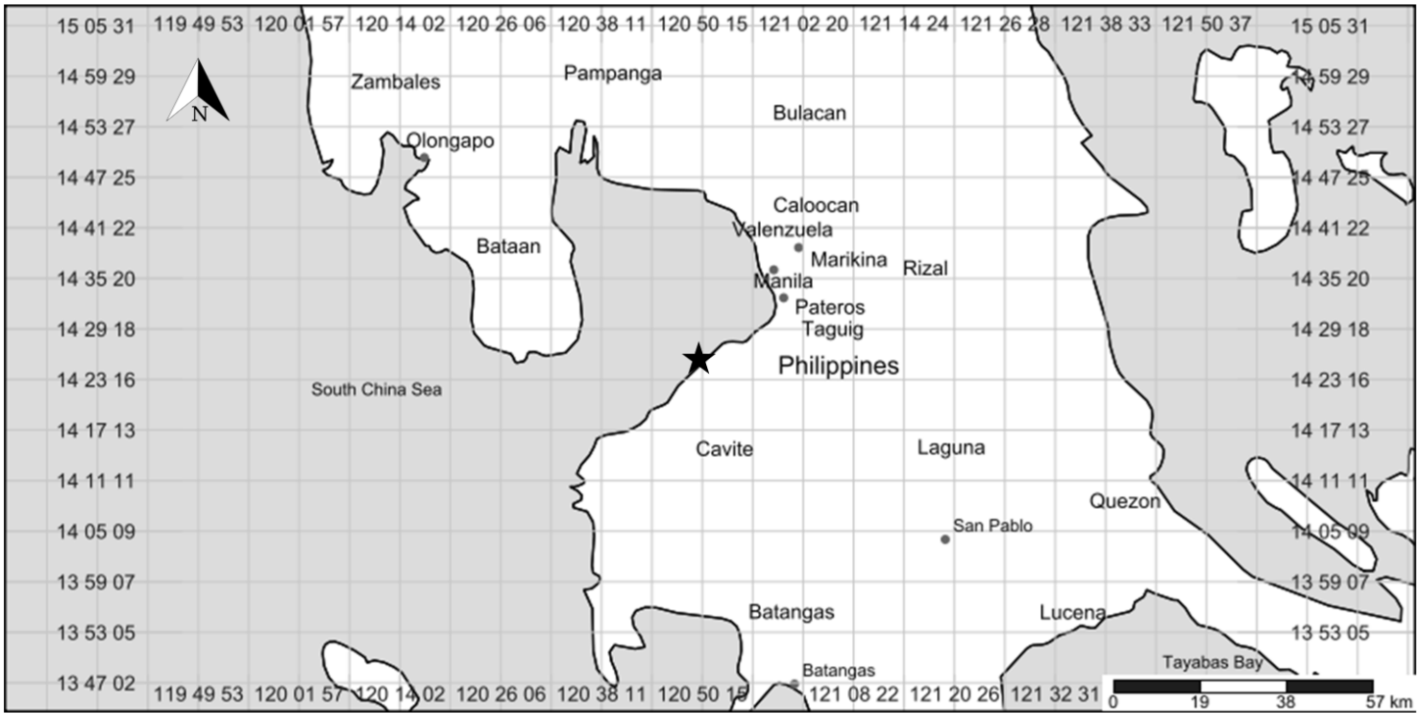

Figure 1. *Location of the study site at Cavite City, represented by the star. Map generated through SimpleMappr.*

Table 1. *Sampling points along the wooden pier in Naval Base Heracleo Alano, Cavite City.*

Sampling point	Coordinates
1	14° 29' 44.97" N | 120° 55' 1.96" E
2	14° 29' 44.86" N | 120° 55' 2.38" E
3	14° 29' 44.79" N | 120° 55' 2.15" E
4	14° 29' 44.20" N | 120° 55' 2.40" E

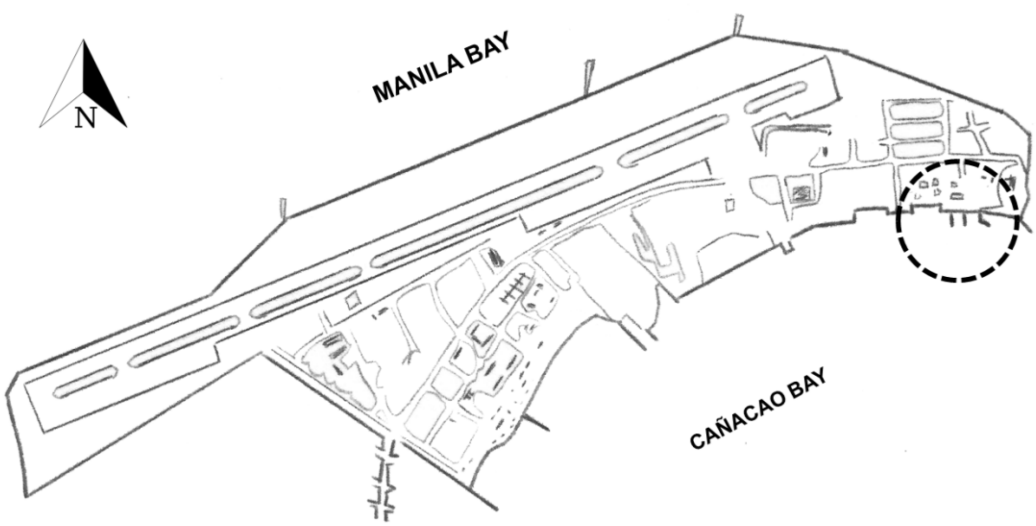

Figure 2. *Map of shipping dock at Naval Base Heracleo Alano showing sampling points.*

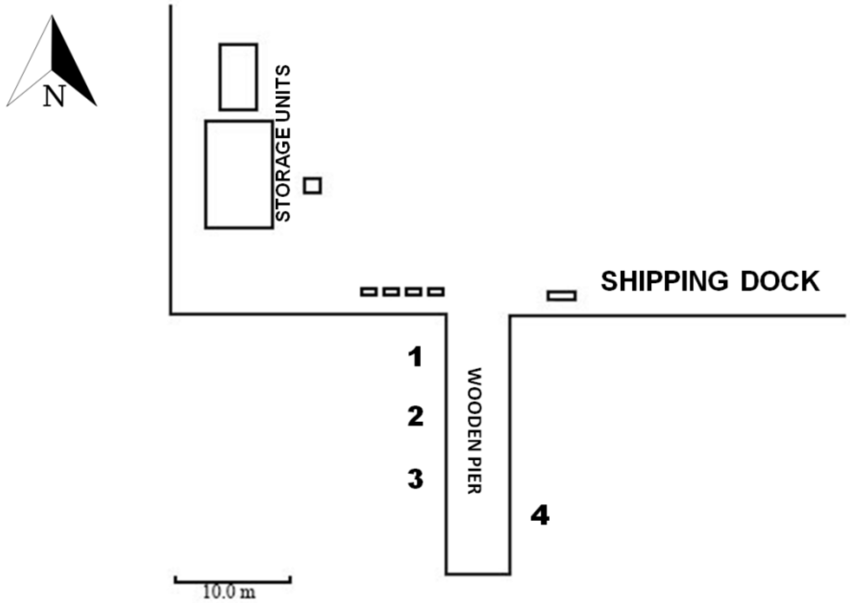

Figure 3. *Map of Naval Base Heracleo Alano showing chosen area for sampling points encircled in broken line.*

photographed under a Leica ES2 stereo microscope with a ruler for scale. Initial identification was done by using available online databases such as SeaLifeBase and Marine Species Identification Portal, and World Register of Marine Species. Further identification and verification were done with the use of taxonomic keys of Fauchald [27] and Springsteen [28]. Experts from SeaLifeBase and the Institute of Environmental Science and Meteorology of UP Diliman were also consulted for confirmation.

Biodiversity indices such as the Shannon-Wiener and Simpson's indices were determined, as well as species richness and species evenness, for each sampling point in the naval base. Measurements for water quality parameters were assessed for normal distribution. Analysis of variance at 95% confidence level was used to test for significant differences, with the IBM Statistical Package for the Social Sciences as the program used for testing.

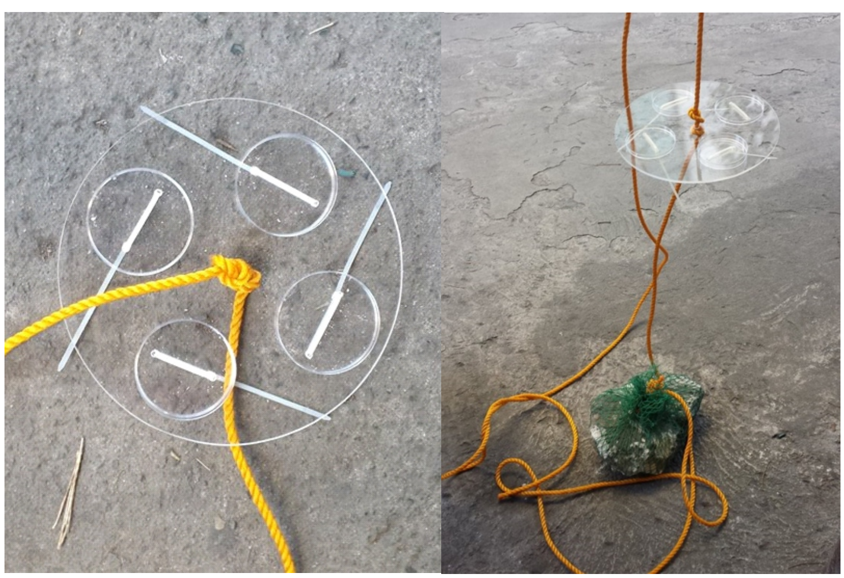

Figure 4. *Assembled fouling collector with design from PICES.*

Results

Physico-Chemical Parameters

The measured water quality parameters of the sampling points are summarized in Table 2. The mean temperature among sampling points was 26.763 ± 1.0436°C. The MeanSD pH was 7.89630.22603, slightly basic. All were within the acceptable pH range (6.0-9.0) of Philippine marine waters (DAO, 1990-34). The mean dissolved oxygen measurements among all sampling points (1.5150 ± 1.8292 mg/L to 1.5600 ± 1.9062 mg/L) were below the acceptable minimum value of 5.0 mg/L (DAO, 1990-34). MeanSD mV was -55.9259.0411, MeanSD Conductivity was 41.98690.73975mS, MeanSD TDS was 277.2374.9462 ppm, MeanSD NaCl was 75.47251.59598 ppt, MeanSD Resistance was 10.82500.19394Ω, MeanSD DO was 19.68721.2372 %, and MeanSD mDO was 1.54751.68590. Analysis of variance indicated that water temperature, pH, mV, Conductivity, TDS, NaCl, Resistance, DO, and mDO did not show significant differences among the study sites (F=0.113, P=0.951; F=1.375, P= 0.298; F=0.594, P=0.631; F=0.060, P=0.980; F=0.058, P=0.981; F=0.310, P=0.818; F=0.067, P=0.976; F=0.002, P=1.000 and F=0.001, P=1.000).

Table 2. *Water quality factors obtained from four sampling points in Naval Base Heracleo Alano,Cavite City.*

Sampling points	Water Quality Factors (Mean ± SD)				
	Temperature (°C)	pH	Dissolved Oxygen (mg/L)	Total Dissolved Solids (ppm)	Conductivity (mS/cm)
1	27.0500 ± 1.5927	7.7050 ± 0.3671	1.5150 ± 1.8292	276.4250 ± 5.3860	41.8725 ± 0.7999
2	26.6500 ± 0.9539	7.9725 ± 0.1597	1.5575 ± 1.9013	276.9750 ± 5.9377	41.9325 ± 0.8954
3	26.6500 ± 0.9539	7.9550 ± 0.0957	1.5575 ± 1.9013	277.8250 ± 5.3131	42.0700 ± 0.8002
4	26.7000 ± 0.9695	7.9525 ± 0.1438	1.5600 ± 1.9062	277.7250 ± 5.2993	42.0725 ± 0.7835

Table 3. *Total abundance of fouling organisms observed at each sampling point in Naval Base Heracleo Alano, Cavite City.*

Organisms	Total Abundance (Total No. Of Individuals) in Sampling Points			
	1	2	3	4
Mytilopsis	5	2	5	6
Mytella charruana	5	6	7	14
Pinctada	0	0	2	1
Modiolus	6	11	7	2
Brachidontes	8	9	10	8
Perna viridis	319	61	92	327
Balanus	733	396	701	233
Hydroides	106	439	0	1
Crassostrea	0	0	1	0
Amphibalanus	301	0	81	0
Pitar	3	0	0	0
Uca	1	0	0	0
Penaeus	1	0	1	0
Nerita	7	0	0	0
Stylochus	1	0	0	0
Ciona	8	0	35	0
Membranipora membranacea	0	0	0	0
Sabellastarte	2	0	0	0
Diadumene lineate	7	4	5	13
Sabellidae Family	0	0	599	210
Nereididae Family	4	0	0	11
Polynoidae Family	413	112	190	82
Spionidae Family	1	0	0	0
Actiniidae Family	0	0	1	0
Amphipods	82	220	105	169
Isopods	2	3	1	5

Macrofouling Organisms

After the three-month period, a total of 6,203 organisms classified into 20 families was collected from all four sampling points. Five families belong to Class Bivalvia, 1 from Class Gastropoda, 1 from Class Cirripedia, 5 from Class Polychaeta, 4 from Class Malacostraca, 1 from Class Rhabditophora, 1 from Class Anthozoa, 1 from Class Ascidiacea, and 1 from Class Gymnolaemata. Table 3 shows the full list of species and total abundance of macrofoulers collected from the sampling during the duration of the study.

Shannon-Wiener Index, Simpson's Index, Species evenness, and Species richness of the four sampling points are summarized in Table 4. Highest species diversity of 1.7602 and species evenness of 7 was recorded in sampling point 4. Simpson's index values ranged from 0.7376 to 0.7981, showing strong dominance of certain species in the sampling point. Species evenness ranged from 0.5605 to 0.7000.

Discussion

A significant result of the study is the documentation of the community composition of marine macrofoulers found in the naval base. The listing provides baseline information of current species composition in the naval base, and these species are the primary recipients of the impact of maritime traffic and activities. Macrofouling community composition in Naval Base Heracleo Alano included amphipods, bivalves, barnacles, button anemones, bryozoans, flatworms, gastropods, isopods, tunicates, and polychaetes, with such finding being supported by several other studies with similar results [15, 29, 30, 31].

The most abundant species observed was *Balanus*. These are euryhaline and eurythermal bivalves, and they are abundant in coasts [32]; they are widely distributed but most dominant in tropical and subtropical estuaries [33]. High numbers can be attributed to their tolerance to a wide range of salinities, especially at the attachment and settlement stages of development and a motile larva.

The second most abundant in the community was *Perna viridis*, a tropical and subtropical mussel highly distributed in rocky littoral and shallow sublittoral ecosystems [34]. They are native in the Indo-Pacific region and are commercially cultured in Malaysia, Thailand, and the Philippines [34,35,36]. They are fast growing with a high tolerance to many environmental factors making them important biofoulers [34]. *P. viridis* can adapt to a wide range of salinity from 19 ppt to 44 ppt, 30 ppt being the optimum. It can survive in water temperatures ranging from 26 °C to 32 °C. *P. viridis* has better growth in tropical areas due to constant levels of temperature and food accessibility, thus increasing larval abundance [35]. *P. viridis* has a tendency to be invasive and eventually compete with small and slow-growing native species. This was observed in Tampa Bay where the native *Crassostrea virginica* was displaced by *P. viridis* [37]. The computed Simpson's index indicates dominance of some species. *Balanus* and *P. viridis* are these dominant species.

Another important outcome of the study is the indication of non-indigenous species in the naval base. Seven species are non-indigenous, namely, *Mytella charruana*, *Brachidontes*, *Mytilopsis sallei*, *Hydroides*, *Stylochus*, *Sabella*, and *Membranipora membranacea*. *Mytella charruana* is a native species of the Atlantic coast of South America and the Pacific coast of Central and South America from Mexico to Ecuador [38]. It is considered a tropical species with a wide range of salinity tolerance [39]. *M. charruana* could survive transport via ballast water or in ship hulls [38]. *Brachidontes* was first observed in the Mediterranean Sea years after the opening of the Suez Canal. It has a preference to form populations in relatively more saline and warmer seawaters [40]. *Mytilopsis sallei* is native to the Caribbean islands and the Bay of Mexico [41,42]. It has been reported to be notoriously invasive in North America, Europe, Australia, and the Caribbean [14, 43]. It is a pollution-tolerant species capable of surviving a wide range of salinities and temperatures. *Hydroides* is native to the east coast of North America distributed along brackish waters, lagoons, and ports [44]; other species are native of Chesapeake Bay, United States [45]. The latter study showed that periodic moderately low dissolved

Table 4. *Diversity indices of four sampling points in Naval Base Heracleo Alano, Cavite City.*

Sampling Point	Shannon-Wiener Index (H)	Simpson's Index (D)	Species Evenness (E)	Species Richness
1	1.7346	0.7743	0.5611	21.000
2	1.5392	0.7428	0.6001	13.000
3	1.6199	0.7376	0.5605	18.000
4	1.7602	0.7981	0.7000	14.000

oxygen led to an increase in the invasive species cover of *Hydroides*. Hence, hypoxia can cause a shift of dominance of local species like that of *Balanus* cover being overcome by *Hydroides* cover. *Stylochus* is a native species in the Strait of Georgia [46]. *Sabella*, on the other hand, is a native species from different Mediterranean habitats and found thriving in polluted harbors and sewage outfalls. This species is also found on the eastern Atlantic coasts, from Portugal to northwest France, and in the Azores [47]. *Membranipora membranacea* is native to the North Pacific waters. It was first observed in the Northwest Atlantic in the Gulf of Maine in 1987 and in the Atlantic coast of Nova Scotia in 1992 [48].

The observed non-indigenous species in the sampling sites may have been brought to the local waters through ship-mediated introduction. Shipping is the major vector of transport and introduction of non-indigenous species, either through hull fouling and ballast water [6]. Ballast found at the bottom of a vessel is responsible for its stabilization. During periods of instability, large volumes of water are pumped into ballast tanks, including aquatic flora and fauna [49]. Particles and sediment included in the pumped water then settles and provide a suitable living environment for macrofoulers in different life stages [50]. There is a constant risk of non-indigenous species being carried on along the vessel's travel route [51]. Increasing ship size also increases the probability of ship-mediated introductions [52]. Commercial ships and tankers that use ballast on a regular basis have a higher probability of facilitating ship-mediated introduction than smaller vessels such as passenger ships and private boats [49].

The presence of non-indigenous species poses a threat to the local ecosystems. Following introduction, the foreign species may compete for shared resources, which, in turn, upsets the balance in the food chain [53]. Long-term effects include the reduction or loss of biodiversity or even extinction. Non-indigenous species may also be carriers of diseases that may affect marine life [54]. Moreover, non-indigenous species are potentially invasive. They can displace indigenous organisms and dominate the area. If the displaced endemic species is part of the local diet, then the surrounding populace would have to alter their nutrition source. A study in Taiwan showed that the invasion of *Mytilopsis sallei* in clam beds led to a decrease in growth of the clams, hence not meeting standards as food source [10]. If the non-indigenous specie is edible and has a capacity to retain certain harmful substances that it take in from the marine waters, then the health of the populace would be at stake. *Perna viridis* for example, is a known invasive species [55]. It has also shown a capacity to accumulate concentrations of heavy metals above the acceptable concentration for human consumption [56]. Since *P. viridis* is a source of food in areas where it is naturally found [57], it is probable that the populace of areas it invades will also turn to it as a source of food. It could then be a health hazard.

Conclusion

The macrofouling community of the Naval Base Heracleo Alano pier marina in Cavite City, Cavite was studied. A total of 6,203 organisms was observed in the settling plates which were submerged at four points in the sampling area. The most dominant organisms found in the sampling area were members of the genus *Balanus*. *Perna viridis* was second most abundant. Other organisms in the community included bivalves, bryozoans, polychaetes, anthozoans, and gastropods. Seven non-indigenous species were observed in the naval base: *Mytella charruana*, *Brachidontes*, *Mytilopsis sallei*, *Hydroides*, *Stylochus*, *Sabella*, and *Membranipora membranacea*. There is a need to monitor these species as they have the potential to be invasive, and as such, could have ecological, economic, and health impact to the communities surrounding the bay.

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