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Assessment of marine macrofouling community in Cebu International Port, Mactan Channel, Visayas, Philippines

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ABSTRACT

Port environments are the primary sites for biological invasions, with maritime transport being the main contributor to their increased frequency. Ports are anthropized areas characterized by altered environmental conditions and contain artificial structures that harbor introduced organisms that can become invasive over time. Cebu International Port in Mactan Channel in the Visayas region is an area of concern, being one of the largest international ports in the Philippines, and having no record of a biological baseline. This study surveyed five sampling sites in the port where PICES fouler collectors with modifications were deployed and retrieved after a period ranging from 45 to 65 days, from March to October 2021. There were four sampling collections. Retrieved organisms were identified through morphological characterization, and diversity indices were computed. Groups of identified foulers include polychaetes, barnacles, molluscs, ophiuroids, tunicates and bryozoans. The community composition shows a reef community, with polychaetes as dominant organisms. Non-indigenous species were detected, namely polychaetes *Hydroides elegans* and *Pseudopotamilla oligophthalmos,* as well as bryozoans *Amathia verticillata* and *Tricellaria* sp. *H. elegans* and *A. verticillata* are known to be highly invasive species. Index values peaked in August 2021 (southwest monsoon season). The baseline is essential in crafting policies that the community can use to prevent the spread of potentially invasive species. Monitoring species composition for the long-term a as it can be an effective tool for prevention and control of biological invasions.

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INTRODUCTION

Anthropogenic activities have drastically changed the composition of communities in marine ecosystems, with maritime transport being a key contributor. Maritime transport is the major vector for the spread of non-indigenous species (NIS). Although most of these organisms will not survive after arrival in the recipient environment, the small fraction that do may establish populations and become invasive.

Biological invasions have negative effects on the ecosystems they enter. One effect is the alteration in the trophic structure and food web dynamics of the community where the invasion occurs. For example, the Asian clam *Potamocorbula amurensis*, a native of Russia to southern China, consumed high amounts of phytoplankton when it invaded San Francisco Bay, USA (Carlton et al. 1990). This had impacts on invertebrate, fish and bird populations in the area, as phytoplankton serves as the base of the food chain (Greene et al. 2011). The European green crab *Carcinus maenas,* which was also an introduced species in San Francisco

Bay, became a predator of younger crabs. It competed with the food sources of native fowl and crabs as well (Grosholz and Ruiz 1996). Similarly, the Asian crab *Hemigrapsus sanguineus* showed an invasive's competitive effect on a recipient area when it was introduced in the United States. It had been observed to occupy the burrows of the indigenous fiddler crabs in Connecticut to compete for space and resources (Brosseau 2003).

Invasive species can also change a habitat physically or chemically, acting as ecosystem engineers. *Ficopomatus enigmaticus* is a brackish water serpulid tubeworm that builds calcareous tubes and lives in them. In optimum conditions it can grow massive reef-like structures in recipient areas, resulting in altered physical and water conditions within its vicinity (Costa et al. 2017). Other invading engineer species have been responsible for habitat destruction. *Littorina littorea*, a salt marsh gastropod that was introduced in the US, can erode sediment from hard substrate and change the condition of its surface to a generally soft one (Tillin and Hill 2016). This change in the consistency of the benthic substrate determines which other invertebrates will be successful in inhabiting it. Some invasives bring parasites to native species (Chalkowski et al. 2018); others causes changes in water quality (Costa et al. 2017).

Both the frequency and impact of biological invasions have increased in recent years. Therefore, early detection of NIS is necessary, along with policies to manage existing invasions and prevent new introductions.

Ports should be a primary focus for implementing such policies and management guidelines. Ports, which serve as the interface between the land and the sea, are susceptible to bioinvasions (Natalio et al. 2022, Wang et al. 2018). They receive marine vessels carrying NIS via hull fouling or ballast water. Ports are where ships dock and release these organisms (Chan et al. 2015). Moreover, port construction and expansion have altered coastlines and caused habitat degradation (Madon et al. 2023). These changes displace native species and make available space for other organisms to occupy. Port activities also produce pollution that further alters native marine conditions, which contribute to an environment becoming conducive for an invader (Goulielmos 2000).

Surveys that inventory both indigenous and non-indigenous species in a port are essential. Species inventory recognizing indigenous and non-indigenous species is important to regulatory agencies. Guidelines in port management regarding invasive species and ship docking requirements can be specified and implemented. More effective strategies in preventing and/or slowing the spread of potentially invasive species can be enforced. For example, pre-border biosecurity interventions can be done to ships prior to arrival to the port of destination, or border inspection can be implemented upon arrival (Epanchin-Niell et al. 2021).

In the Philippines, there is a paucity of literature in port studies. Biological surveys have been done in some areas of the Port of Manila, but not in other Philippine harbors or marinas. Cebu International Port, an international port located in Mactan Channel in the Visayas, is an area of concern. It is one of the country's largest international ports, and is also considered the country's largest domestic port. This facility connects vessels from all over the country, principally serving ships from the Visayas and Mindanao islands. Marine traffic in this area has been increasing for the fourth consecutive year since the pandemic, with the Cebu Port Authority logging an overall cargo increase of 10.7 percent in 2024 (Codis 2024). In the same year, domestic ship calls had a 7.3 percent increase, while foreign ship calls had a 12.3 percent increase (Codis 2024). While the port's growth benefits the economy, its ecological impacts should also be assessed. This study assessed the macrofouling community of the port, and identified non-indigenous and invasive species in the area, along with their possible ecological role in the community. The results of the study will provide a reliable information source for administrative decision-making to address any arising ecological and /or environmental concern in the port. The baseline generated can also be used for comparison to succeeding monitoring studies.

MATERIALS AND METHODS

The methods of the study had limitations due to the circumstances brought about by the COVID-19 pandemic. At the peak of the pandemic in 2021, acquisition of the water quality parameter meter was extensively delayed. The only instrument available for water quality parameter measurement was the thermometer for temperature. Hence, this was the only environmental factor measured during the study's duration. The intervals of the retrievals were uneven and could not follow the sixty or ninety-day intervals as the scheduling of field work depended on the level or type of community quarantine Cebu was in, as well as personnel and site availability for field work. Laboratories were also of limited accessibility.

Sampling sites and deployment of fouler collectors

Five sampling sites were selected in Cebu International Port (Table 1 and Figures 1–2). The criteria in site selection include accessibility to researchers and the presence of railings where fouler collectors can be attached.

Table 1: Coordinates of the sampling sites at the Cebu International Port.

Sampling site	Coordinates
1	10.306950, 123.921583
2	10.307933, 123.922800
3	10.308933, 123.923950
4	10.309350, 123.924683
5	10.309467, 123.926183

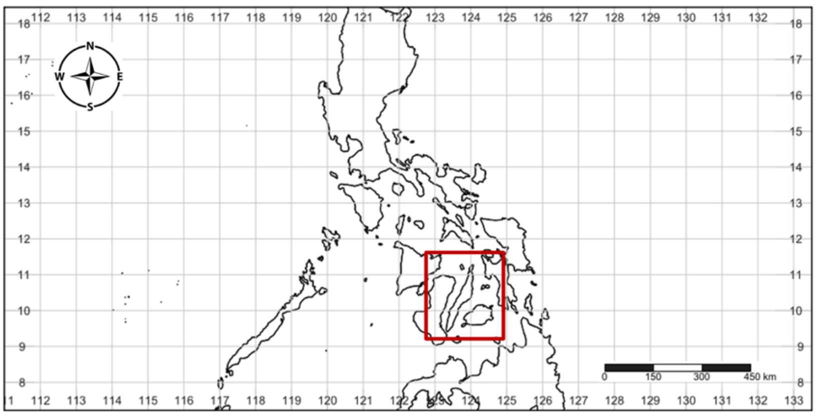

Figure 1: Location of Cebu International Port in the Philippines (map generated from simplemappr.net)

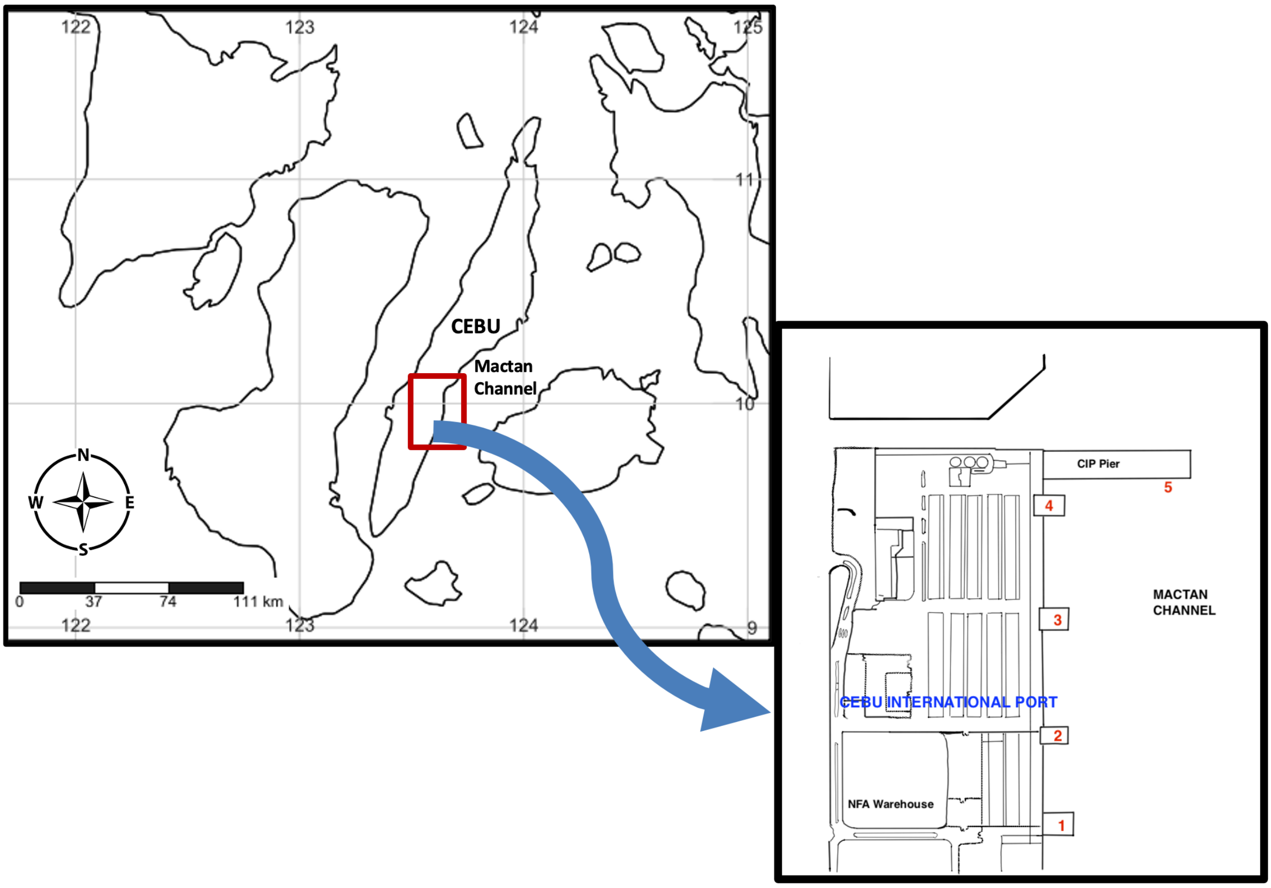

Figure 2: Map showing Cebu International Port and sampling points 1 to 5.

Fouler collectors followed the modified design of the North Pacific Marine Sciences Organization, otherwise known as PICES (Vallejo et al. 2019) (Figure 3). These collectors were used as the primary tool of the survey. A collector consists of a plastic bucket lid with a diameter of 30 cm. Each lid had four plastic Petri dishes (9 cm in diameter and 15 mm in height) attached to its underside using cable ties. The plates were positioned at equal distances from each other. The center of the bucket lid was drilled with a single hole where a nylon rope of diameter 20 mm passed through. The nylon rope should be 15 m to 25 m long, depending on the depth of the water and the height of the railing from the water.

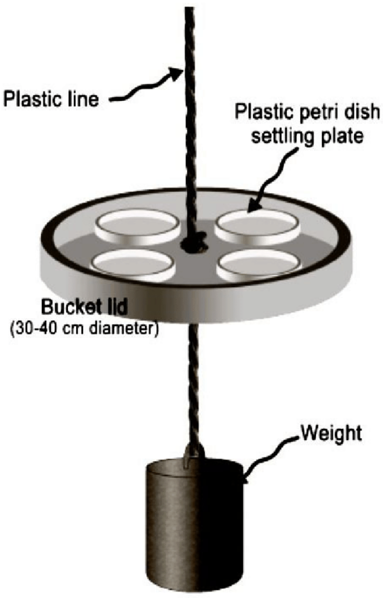

Figure 3: Design of PICES fouling collectors used in this study (based on Vallejo et al. 2019).

The collectors were soaked in sterilized salt water one week before deployment. During deployment, a collector is submerged to the water by having one end of its rope tied to the railing of the sampling site, while the other bearing a cement weight ranging from 1 kg to 2 kg. The collector is lowered 1 meter below the lowest tide level. The cement weight keeps the collector submerged in the water at all times. The lowest tide level was determined via the National Mapping and Resource Information Authority (NAMRIA) tides and currents table for 2021 (NAMRIA 2021). Nine collectors were deployed at each sampling site (45 collectors in total), with collectors spaced 1 m apart at each site. GPS coordinates of the sampling sites were taken.

Specimen collection and measurement of port water temperature

Petri plates were retrieved from the collectors every 45 to 65 days. Each plate was placed in a zipper storage bag with seawater, placed on ice in a cooler and transported to the laboratory. The temperature of the port water at the sampling sites was taken with a thermometer on a weekly basis from January to October 2021.

Species identification and biodiversity indices

The retrieved Petri plates were photodocumented and examined. Each plate was placed in a glass or ceramic bowl with seawater to allow organisms that are not adhering to the plate to be suspended in the water. Using forceps, suspended organisms such as free-living polychaetes and crustaceans were transferred to saltwater-containing Petri plates and observed under a dissecting microscope. Tube worms, molluscs, sponges and tunicates were also transferred from the bowl to separate clean Petri plates. Organisms were identified and distinguished using morphological characterization. The organisms in the retrieved Petri plates were pooled per sampling period. Published literature on marine biological invasions such as Fauchald (1977) and Vallejo et al. (2017, 2019), online databases, such as the World Register of Marine Species, Sea Life Base, and Marine Species Identification Portal, were used. Identification was then confirmed by experts from the University of the Philippines Diliman and University of the Philippines Visayas. Biodiversity index scores, specifically Shannon-Wiener's Diversity Index, Simpson's Diversity Index and Pielou's evenness index, were computed using Microsoft Excel .

RESULTS

The measurement of port water temperature during sampling periods is summarized in Table 2. The lowest recorded mean temperature was during the first sampling collection in May 2021 with 28.75ºC and the highest mean temperature was during the third sampling in August 2021 of 31.38ºC. The temperatures of the third and fourth sampling show a higher trend compared to the previous year's climatological measurements around the area by 2.5 to 3.18ºC (PAGASA, 2021).

Table 2: Mean temperatures during the sampling periods in 2021.

	Sampling 1 (May 2021)	Sampling 2 (July 2021)	Sampling 3 (Aug 2021)	Sampling 4 (Oct 2021)
Mean temperature (°Celsius)	28.75	29.34	31.38	30.70

Cebu International Port has phylum Annelida as the dominant fouling taxon. Table 3 shows the abundances of identified organisms at each sampling period. Overall, the dominant fouler is the sabellid fanworm *Notaulax* sp. the presence of which accounts for between 55% and 69% of total biofouler counts. *Spirorbis* sp., a serpulid, accounts for 16% of counts. The pantropical invasive *Hydroides elegans* was recorded. The polychaetes had the largest number of species present as well. The barnacle *Amphibalanus amphitrite* accounts for less than 10% of counts. Ascidians such as *Phallusia arabica* account for 7% of abundance.

The observed fouling organisms were consistently from similar groups. These included polychaetes, bryozoans, bivalves, barnacles, ascidians, and ophiuroids. Sponges appeared during the last two retrievals, which were in the southeast monsoon season. The abundance was highest during the first retrieval in May, which was the dry season, and the lowest was during the third, which coincided with the southeast monsoon season.

Shannon-Wiener, Simpson's and Pielou's evenness indices are summarized in Table 4. Shannon-Wiener diversity and evenness were highest (0.5908) were highest during the August 2021 sampling. Simpson's index values ranged from 0.118 to 0.511, showing low to moderate diversity, as a value of 0 shows absence of diversity and a value of 1 showing absolute diversity. Species evenness ranged from 0.3163 to 0.540 and is low, as shown by the number of individuals in the different sampling periods varying greatly from one species to another. Seaby & Henderson (2007) report that Shannon-Wiener values in ecological studies typically range from 1.5 to 3.5.

Table 4: Computed diversity indices during the sampling periods.

Biodiversity index	Sampling 1	Sampling 2	Sampling 3	Sampling 4
Shannon- Wiener Diversity Index	0.318	0.600	1.050	0.657
Pielou's Evenness Index	0.163	0.373	0.540	0.338
Simpson's Diversity Index	0.118	0.267	0.511	0.287

DISCUSSION

The study provides baseline documentation of the fouling community of Cebu International Port. It is essential to establish baselines and determine the community profile of marine ecosystems, as they provide a reference for monitoring may be used for monitoring ecosystem changes over time. Organisms in the Port of Cebu community include polychaetes and barnacles as major constituents; whereas bivalves, gastropods, bryozoans and poriferans were scarcely detected. These are the same groups of organisms found in port studies across Asia (Ocampo et al. 2014, Ocampo et al. 2019, Ocampo et al. 2024, Vallejo et al. 2017, Lin and Shao 2002, Ganapathy et al. 2024, Nandhini and Revathi 2016). The species belonging to these groups, though, are different from those observed in the Port of Manila in Manila Bay, Luzon, Philippines.

The assemblage identified in this study reveals a reef-like community, with both indigenous and non-indigenous species inhabiting the area. The Mactan area is known to support reef communities (Montenegro et al. 2005). The port may have originally been part of this ecosystem prior to coastal modifications for shipping. The port community may resemble nearby reef communities, possibly due to dispersal of organisms along connected habitats (Henderson et al. 2022).

Polychaetes dominated the abundance of the marine fouling community in the port during the sampling period. They were often found within the biogenic matrices created by *Amphibalanus* barnacles (Vallejo et al. 2017), which are also present in the port. Polychaetes are marine worms characterized by a well-segmented body, with the segments bearing a pair of parapodia with setae (Merz and Edwards 1998). They are particularly a dominant component of the intertidal zone, where they are considered indicator species of pollution (Dean 2008). Polychate dominance is ecologically important as they play key functional roles in marine environments.The presence of marine worm assemblages and their responses to environmental factors can be evidence of occurrence of marine pollution and/ or habitat disturbance (Diaz-Castaneda and Reish 2009).

All polychaete species that have been identified belong to families of sabellids and serpulids. These two families are where most polychaete primary reef frame-builders belong to. Sabellariidae build their tubes by cementing sand grains and shell fragments, and Serpulidae by secreting calcium carbonate (Bosence 1979, Naylor and Viles 2000). Serpulids can construct aggregations up to a km long (Ten Hove and van den Hurk 1993).

Table 3: List of fouling taxa and their abundance values as mean ± standard deviation recorded from five sampling points at Cebu International Port in 2021.

Phylum	Class	Order	Family	Genus/Species	Sampling 1	Sampling 2	Sampling 3	Sampling 4
Annelida	Polychaeta	Canalipalpata	Spionidae					5.0
Annelida	Polychaeta	Eunicida	Dorvilleidae			2.0	1.0	2.0 ± 1.4
Annelida	Polychaeta	Phyllodocida	Hesionidae				1.5 ± 0.7	1.5 ± 0.7
Annelida	Polychaeta	Phyllodocida	Nereididae				2.3 ± 1.0	
Annelida	Polychaeta	Phyllodocida	Polynoidae					2.0
Annelida	Polychaeta	Sabellida	Sabellidae	*Pseudopotamilla oligophthalmos*	26.6 ± 12.0			
Annelida	Polychaeta	Sabellida	Serpulidae	*Hydroides elegans*	70.6 ± 22.7	5.3 ± 1.3	7.0 ± 3.8	11.8 ± 4.4
Annelida	Polychaeta	Sabellida	Serpulidae	*Notaulax* sp.	282.8 ± 68.2	187.0 ± 44.1	76.0 ± 10.9	157.8 ± 63.3
Annelida	Polychaeta	Sabellida	Serpulidae		1.0			
Annelida	Polychaeta	Sabellida	Serpulidae	*Spirorbis* sp.	109.0 ± 70.6	34.0 ± 27.8	15.5 ± 7.6	31.0 ± 13.9
Annelida	Polychaeta	Terebellida	Cirratulidae				1.3 ± 0.5	2.5 ± 0.7
Arthropoda	Maxillopoda	Sessilia	Balanidae	*Amphibalanus sp.*	12.2 ± 7.0	11.4 ± 2.2	19.4 ± 11.1	18.0 ± 11.7
Arthropoda	Malacostraca	Decapoda	Brachyura	Brachyuran crab	1.0	1.0	1.8 ± 0.8	1.0
Arthropoda	Malacostraca	Decapoda					2.0	
Arthropoda	Malacostraca	Decapoda	Penaeidae	*Metapenaeus* sp.	4.0			
Arthropoda	Malacostraca	Decapoda	Penaeidae		3.0		1.5 ± 0.7	1.0
Arthropoda	Malacostraca	Decapoda	Sergestidae	*Acetes erythraeus*	6.0			
Bryozoa	Gymnolaemata	Cheilostomatida	Vesiculariidae	*Amathia verticillata*	1.75 ± 0.5			
Bryozoa	Gymnolaemata	Cheilostomatida		*Bryozoan 3*	1.3 ± 0.5			
Bryozoa	Gymnolaemata	Cheilostomatida	Bugulidae	*Bugula neritina*	2.3 ± 1.0			
Bryozoa	Gymnolaemata	Cheilostomatida				2.4 ± 1.3	2.2 ± 2.2	2.0
Chordata	Ascidacea				1.0			
Chordata	Actinopterygii	Syngnathiformes	Syngnathidae	*Hippocampus sp.*	1.0			
Chordata	Ascidacea	Enterogona	Ascidiidae	*Phallusia arabica*	29.0 ± 59.8	7.0 ± 4.4	8.6 ± 2.9	7.3 ± 4.8
Echinodermata	Ophiuroidea	Ophiurida	Ophiuridae		1.0		3.0 ± 2.8	2.0 ± 1.2
Foraminifera	Globothalamea	Rotaliida	Elphidiinae	*Elphidium* sp.	3.0			
Mollusca	Bivalvia	Mytilida	Mytilidae	*Brachidontes pharaonis*	3.0 ± 2.8			
Mollusca	Bivalvia	Mytilida	Mytilidae	Modiolus sp.	2.0	2.5 ± 2.1		
Mollusca	Bivalvia	Ostreioda	Ostreidae	*Magallana billineata*	2.7 ± 0.6			

Mollusca	Bivalvia	Ostreioda	Ostreidae	-		1.5 ± 0.7		
Mollusca	Bivalvia	Ostreioda	Ostreidae	*Saccostrea cucullata*			2.0 ± 1.0	
Mollusca	Bivalvia	Pteriida	Pteriidae	*Pinctada imbricata*	3.0	2.0		
Mollusca	Bivalvia	Pteriomorpha	Placunidae	*Placuna ephippium*			1.5 ± 0.7	
Mollusca	Bivalvia	Pteriomorpha	Placunidae	-		1.0		
Mollusca	Bivalvia	Venerida	Veneridae	*Marcia hiantina*	1.0		2.0	1.0
Mollusca	Gastropoda	Neotaenioglossa	Cypraeidae					1.0
Mollusca	Gastropoda	Nudibranchia					2.0	3.5 ± 0.7
Mollusca	Gastropoda	Sorbeoconcha						1.0
Mollusca	Gatstropoda		Potamididae		2.5 ± 0.7			
Porifera	Demospongiae						1.0	1.0

These indigenous polychaete genera, *Spirorbis* and *Notaulax*, are reef-associated calcareous tubeworms typically found on rocky and coral shores. Both belong to family Serpulidae. *Notaulax* species are observed embedded in living or dead massive corals such as *Porites*. *Spirorbis* species, on the other hand, can be seen associated with *Diploria*, *Porites* and *Millepora* (Hunte et al. 1990, Marsden and Meeuwig 1990). *Spirorbis* can also occur as epibionts on brown macroalgae such as *Fucus* (Ni et al. 2018). The presence of the two taxa indicates the existence of reef habitats in the area, with nearby Mactan Island indeed having significant reef habitats in Magellan Bay. A species of *Notaulux*, *Notaulax phaeotaenia*, is known from Mactan Island, Cebu (Rosito 1983).

Two others are non-indigenous. *Hydroides elegans* was recorded in this survey, and the species can commonly form dense populations in harbors and on reef flats in tropical and subtropical seas (Ten Hove 1994). In Hong Kong, for example, a study of submerged mariculture cage nets showed that they were completely covered by *H. elegans* (Jianjun and Zongguo 1993) after 30 days. In Japan, *H. elegans* is considered a mariculture pest, as the worms compete with oysters for nutrition and oxygen. Its colonization of oyster beds in Hiroshima caused economic loss as they heavily fouled local oyster aquaculture (Hirata and Akashige 2004).

It is also a primary fouler in Australian marine waters (Lewis et al. 2006) and in the Mediterranean Sea (Kocak et al. 1999), especially in Turkey's Alsancak Harbor (Çinar et al. 2008). Some studies have shown that the species can replace native species (Cinar et al. 2013, Kim and Yu 2025). Biofouling is seen as the major mode of dispersal of this marine worm (Pettengill et al. 2007).

H. elegans is a problematic invasive fouling species due to several biological characteristics. The larvae are mobile and can be transported in ballast water, hulls, and equipment (Xu et al. 2009; Lema et al. 2019). It reaches sexual maturity in as few as 9 days under tropical harbor conditions (Carpizo-Ituarte & Hadfield 1998). Its short planktonic stage allows rapid colonization of new substrates (growth up to 1.5 mm per day; Nedved & Hatfield 2009). The worm constructs tightly-adhering calcareous tubes for defense (Nedved & Hatfield 2009). As a result, *H. elegans* quickly accumulates on submerged structures, interfering with operations and damaging infrastructure, and can displace native species (Cinar 2013).

Currently, the control of *Hydroides* fouling is done via chemical coatings and physical removal methods. Antifouling coatings are sprayed on ship hulls (Cima & Ballarin 2012). Organisms can be directly removed from the hull during dry-docking with scrapers or remotely operated robots (Park et al. 2022) or via ultrasonically-activated water jets (Salta et al. 2009). However, these methods are costly. Therefore, developing more environmentally friendly and cost-effective control strategies for *H. elegans* fouling is necessary.

The other polychaete species, *Pseudopotamilla oligophthalmos* belongs to the Sabellidae. This species has been reported from Indonesia, Australia, and New Zealand (Day & Hutchings 1979; Glasby et al. 2009; Tovar-Hernández et al. 2020); its type locality is Singapore (Salazar-Vallejo et al. 2009). It is known to be associated with soft corals, sponges, and *Notaulax* sp (Tovar-Hernandez et al. 2020). This is the first report of this species in the Philippines; the only Sabellidae previously recorded in the Philippines is *P. polyophthalmos* (Salazar- Vallejo et al. 2009, Tovar-Hernandez et al. 2020).

The abundance of polychaetes in the study is different from that of the abundant species in other Philippine and Asian ports. In the Port of Manila in Manila Bay, barnacles *Amphibalanus* and *Balanus* were most numerous in several surveys from 2014 to 2019 (Ocampo et al. 2014, Vallejo et al. 2017, Vallejo et al. 2019, Trinidad et al. 2019). In this study, barnacles come second in abundance. The Port of Batangas shows gammarids as its most abundant organism (Ocampo et al. 2024). Other ports in Asia also show varying trends. In Songkhla Port in Thailand, *Balanus* spp was most abundant in a 13-month sampling period (Phuttapreecha 2018). Port structures in Karambunai Bay, Malaysia showed species of bivalves, polychaetes and maxillopods, with barnacles being present in all sampling frames (Affandy et al. 2019). In three major ports in Myanmar, namely Yangon, Myeik, and Sittway, tubeworms were the dominant organisms (Khaing 2018). The differences in dominant species can be attributed to the variability of environmental conditions and human activities in the ports (Kocak et al. 1999). The structure of fouling communities is determined by these environments (Kocak et al. 1999). Environmental factors that may shape fouling process and composition include temperature, salinity, pH, turbidity and chemical pollutants. However, the interplay of these factors and their roles in forming the biofouling surfaces and assemblages are still not fully understood, particularly in port environments, although polluted waters tend to be more vulnerable to arrival and establishment of non-indigenous species (Kocak et al. 1999).

The presence of tunicate *Phallusia* suggests that the Cebu International Port has reef-related conditions but also reflects anthropogenic disturbance. *Phallusia* is an indicator of human impact on coral reef-associated habitats by its propensity to dominate disturbed and artificial habitats such as ports and harbors (Shenkar et al. 2022). Heavy metal bioaccumulation was observed in the tissues of *Phallusia nigra* in a bay in Brazil, where human activities have high impact (Martinez 2023). *Phallusia arabica*, detected in this study, is a major ship biofouler that can attach to both ship hull and sediment (Monniot and Monniot 2001).

The port is also characterized by the presence of brittle stars (class Ophiuroidea). Ophioroids were not reported in any of the surveys in the Port of Manila (Ocampo et al. 2014, Vallejo et al. 2017, Vallejo et al. 2019, Trinidad et al. 2019) and Port of Batangas (Ocampo et al. 2024). These organisms are part of a coral community, usually associated with other fauna and flora groups (Lawley et al. 2018, Baroliya 2018). They often co-occur with sponges such as *Haliclona* and *Spheciospongia*, which provide shelter and enhance local currents for feeding (Baroliya 2018).

Two species of bryozoans are also non-indigenous. *Tricellaria* sp. is widely distributed in the North and North East Pacific region, Northeast Atlantic and Canada (Dyrynda et al. 2000, Sirenko et al. 2004, Roy et al. 2014); there is no known species in the Philippines. The spaghetti bryozoan, *Amathia verticillata,* on the other hand, is a non-indigenous species whose native range may include the Mediterranean (Cranfield et al. 1998) or the Caribbean (Galil and Gevili 2014). It is distributed in the tropical and temperate regions, where it is an extensive fouler and is considered invasive (Minchin 2012). It is a highly invasive bryozoan and its success is due to its reproductive and physiological capabilities. It can reproduce sexually and asexually through fragmentation and budding (Marchini et al. 2015). It also shows high regeneration abilities hence can grow rapidly, and is hermaphroditic (Furfaro et al. 2025). Colonies can release viable larvae that have high dispersal potential, and can reproduce continuously when conditions are conducive (Micael et al. 2018). It is a generalist and habitat provider that can survive in a wide range of conditions (Humara-Gil and Cruz-Gomez 2019). It can also adhere persistently to a different kinds of substrates, including smooth surfaces, allowing it to survive in highly hydrodynamic conditions. This makes it highly adaptable to hull fouling (Minchin 2012, Marchini 2015). Like other invasives, the species infests vessels and fouls commercial fishing gears and equipment. It can form shades over native algae and seagrasses that can lead to mass mortality

(Williams 2007). It can also facilitate introduction of other non-indigenous species due to its ability to host associated community (Marchini et al. 2015). Hence, *A. verticillata* poses a significant threat to the Port of Cebu. In other countries, management of the organism focuses on prevention, monitoring, and rapid response, as eradication is difficult (Ackland et al. 2025).

Molluscs and malacostracans were observed during the sampling period. The presence of crabs and shrimps may be due to availability of food in the collectors, as these organisms are predators of molluscs and polychaetes (Choy 1986, Cartes 1993). Molluscs were composed of gastropods and bivalves. The gastropod families such as nudibranchs and cowries are carnivorous, feeding on bryozoans, tunicates and polychaetes that were present in the plates. Bivalves, on the other hand, are filter feeders. Their larvae occupy port structures as they achieve metamorphic competency, and eventually become their habitat for development and settlement. *Marcia hiantina* and oysters *Magallana bilineata*, *Saccostrea cucullata* and *Placuna ephippium* are economically important as major sources of food and livelihood in many coastal communities (Campos et al. 2022, Lebata-Ramos et al. 2023). *Pinctada imbricata* is a pearl oyster that is cultured, and *Modiolus* sp is also harvested for food (Napata and Andalecio 2011). One species is non-indigenous, *Brachidontes pharaonis*, and its native range is the Indo-Pacific region (Garaventa et al. 2012). The mollusc is also found at the Port of Manila in Manila Bay, although its abundance has remained low (Vallejo et al. 2019). Bivalves though, were not observed during the fourth sample collection. The physical conditions of the port and its waters could have prevented these organisms from settling, as waste disposal materials and their composition as well as toxic materials from port activities could have had an impact to the larvae (Mann 1988).

Temperature was the sole water quality parameter that was measured in the study due to logistic constraints brought about by the pandemic. It is, however, one of the most essential factors which affect port ecology. During the study period the temperature ranged from 28.75 to 31.38°Celsius, and these are within tolerance ranges for the native and invasive polychaetes, as well as bivalve species (Tovar-Hernandez et al. 2020, Devakie and Ali 2000). Studies have shown that fluctuations in temperature influence the abundance of macrobenthic organisms, and that it can also be the most significant factor in the abundance of macrobenthos. A study of coral reefs in the Persian Gulf concluded that rising temperature can be a source of stress that causes lower abundances especially during summer (Tavanayan et al. 2021). Temperature though, is not a limiting factor for early development and settlement of invasive *H. elegans* (Qiu and Qian 1997). On the other hand, the percent cover of another invasive, *A. verticillata,* can be correlated with temperature; the highest coverage can be observed during the warmest months at the warmest areas (Zavacki et al. 2024).

The diversity indices across the four sample collections increased from the first sampling period and peaked in the third, then decreasing in the fourth. The Shannon-Wiener index was highest in the third (southwest monsoon) sampling, reflecting increased diversity. Simpson's index ranges from 0 to 1, with 1 indicating no diversity. Simpson's index was highest (0.511) in sample 3, indicating moderate diversity (since values near 1 mean low diversity). It indicates a moderate level of diversity, which means there is a variety of species present, and that the distribution of individuals across those species is not perfectly even. The other three retrievals show lower values, indicating relatively lower degree of biodiversity. Both indices peaked at the third sampling retrieval, which was August 2021. This is within the monsoon season which generally occurs from late June to October. The peak during this time may be attributed to the significance of the flushing of seawater in maintaining a healthy habitat (Purushothaman et al. 2023), and the frequent rains of the season do this role. Flushing of seawater may increase dissolved oxygen and encourage larval settlement. The port may also be a monsoon-influenced coastal area as results show diversity peaking in the monsoon season. This can be supported by some findings in an Indian port that showed that the diversity, abundance and community structure of the macrobenthos varied with season (Velayudham et al. 2020).

Pielou's evenness index ranges from 0 to 1, 1 indicating perfect evenness. The highest value is midway between 0 and 1, showing moderate level of evenness, as there is no skewing across the different groups of organisms. The highest value amongst the sampling periods would be the third sampling period as well, at 0.54, revealing moderate evenness during the third retrieval. Low values are seen during the rest of the sampling collections, and these reconcile with the abundances showing dominating species. The presence of dominating species is a common observation in ports, as seen in several studies (Ocampo et al. 2014, Ocampo et al. 2019, Vallejo et al. 2019).

The variation in the values of the aforementioned biodiversity indices is common in biofouling organisms as they undergo seasonal variability (Marimuthu et al. 2023). Studies have shown that seasonal influences and/ or environmental conditions and pressures in the port can account for the changes in the community composition in port areas. For example, a study in Manila Bay (Trinidad et al. 2019) showed community composition changes during the northeast monsoon season. The same was observed in a study in Taiwan, where immersed plates had lower species richness during the northeast monsoon than the southwest monsoon season (Lin and Shao 2002). In Hong Kong, the dry season communities were determined by bryozoans, bivalves and macroalgae, while in the wet season they were determined by polychaetes and tunicates (Astudillo et al. 2013). A study that examined tropical and temperate fouling communities concluded that total fouling diversity is sensitive to metal pollution (Cannong-Clode et al. 2011). In a tropical bay in Brazil, organic pollution caused a change in the relative dominance of species (Mayer-Pinto and Junqueira 2003).

CONCLUSION

The species composition of Cebu International Port reveals a coral reef-associated fouling community, dominated by polychaetes in terms of abundance and number of species. Other members of the community include barnacles, bryozoans, bivalves, gastropods, sponges, tunicates and ophiuroids. The presence of ophiuroids is unique to this port. The inventory of organisms show indigenous and non-indigenous species, which reflect the human influence of the area. Non-indigenous polychaetes *Hydroides elegans*, *Pseudopotamilla oligophthalmos* and bryozoans *Amathia verticillata* and *Tricellaria* sp. were detected. *Hydroides elegans* and *Amathia verticillata* are highly invasive species. Values of biodiversity indices peaked during the third sample collection in August 2021, which may be influenced by flushing of seawater that promotes a healthy habitat. The presence of certain species is an indicator of environmental change and can be used as a basis for regulations establishing regular monitoring surveys to be done regularly. Conducting surveys for the long-term is an essential management tool for prevention and control of invasive species. These baseline data facilitate future monitoring and suggest that including additional parameters (salinity, nutrients, dissolved oxygen) could enhance understanding of port fouling ecology

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

CONTRIBUTIONS OF INDIVIDUAL AUTHORS

Conceptualization, Ocampo, Vallejo; Data curation, Manalo, Casiguran, Bacay, Marcelino; Formal analysis, Manalo, Casiguran, Bacay, Marcelino, Conejar-Espedido; Funding acquisition, Ocampo, Vallejo; Investigation, Manalo, Casiguran, Bacay, Marcelino; Methodology, Ocampo, Vallejo; Project administration, Casiguran, Ocampo; Resources Manalo, Casiguran, Bacay, Marcelino, Conejar-Espedido; Software, Conejar-Espedido; Supervision, Ocampo, Vallejo, Casiguran; Validation, Manalo, Casiguran, Bacay, Marcelino; Visualization, Ocampo, Vallejo; Writing – original draft, Ocampo; Review & editing of manuscript, Ocampo, Vallejo.

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