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Research article

ASSESSING DIVERSITY AND PHYTOREMEDIATION POTENTIAL OF SEAGRASS IN TROPICAL REGION

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ABSTRACT: Seagrass ecosystem is one of the most important resources in the coastal areas. Seagrasses support and provide habitats for many coastal organisms in tropical region. Seagrasses are specialized marine flowering plants that have adapted to the nearshore environment with heterogeneous landscape structures of shallow-water estuarine/marine ecosystems. This unique feature of seagrass has rendered it to have high phytoremediation potential. Phytoremediation is a cost-effective plant-based approach and environmentally friendly solution for heavy-metal contaminated sites. The main objectives of the study were to determine the current status and diversity of seagrass ecosystem and to assess the phytoremediation potential of seagrass for lead and chromium in tropical region. Diversity of seagrass species in the study area was relatively low and only a few number of species and only a few number of individual per species were present due to environmental degradation caused by natural and human activities. Using the Shannon Diversity Index, the seagrass beds at Candelaria site had a diversity mean value of 1.6 while the Masinloc site had an average diversity value of 1.1, which indicate that both sites have very low diversity of seagrasses. Phytoremendiation efficacy of seagrass varied among coastal substrates and seagrass beds. While lead and chromium were not present in water, chromium was present in the sediment of the seagrass ecosystem in Candelaria and Masinloc, Zambales and lead was present only in the sediment of Masinloc, Zambales. *Cymodocea rotundata* was found to be a good phytoremediator for lead due to high amount of lead absorbed in both seagrass ecosystems. Chromium was not absorbed by *C. rotundata*, *T. hemprichii* and *S. isoetifolium* in both seagrass ecosystems.

Key words: Phytoremediation, Sea grass, tropics, lead, chromium, Shannon Diversity Index

INTRODUCTION

Seagrass ecosystem is one of the most important resources in the coastal areas and of significant importance to fisheries industry. It comprises some of the most heterogeneous landscape structures of shallow-water estuarine/marine ecosystems [1]. Seagrasses are specialized marine flowering plants that have adapted to the nearshore environment of most of the world's continents [2]. These marine flowering plants can produce pollen, fruits and seeds under water that have adapted to the nearshore environment. Most seagrass specie are entirely marine, although some species cannot reproduce unless emergent at low tide or subject to fresh water inflow.

Some seagrasses can survive in a range of conditions encompassing fresh water, estuarine, marine, or hypersaline [3]. Seagrasses support and provide habitats for many coastal organisms. Important fish species such as rabbit fishes (siganids) rely completely upon seagrasses.

Shrimps, sea cucumber, sea urchins, seahorses, crabs, scallops, mussels and snails are economically important and abundant. Many resident and transient species also use the seagrass for refuge, spawning and nursery activities. Moreover, seagrass could be utilized as sewage filters, coastal stabilizers, paper, fertilizer and fodder, food and medicine for man [4].

Seagrasses are made of less than 0.02% of the angiosperm flora, representing a surprisingly small number of species [5]. There are relatively few species globally (about 60%) and are grouped into just 13 genera and five families [2, 6]. In the Philippines, there are 16 taxa [4] and considered to be the second highest number of seagrass species in the world, next to Australia which has 19 species [7]. Despite of their limited diversity, they have a significant ecological and economical function. These plants support numerous herbivore and detrivore-based food chains, and are considered as very productive pasture areas of the sea [6]. They also produce sediments and interact with coral reefs and mangroves in reducing wave energy and regulating water flow [4]. Losses of living organisms in fresh and marine environment including seagrass have been reported from most part of the world due to natural causes such as cyclones, floods, high energy storms, or wasting disease or due to human influences such as land reclamation and changes in land use, agriculture runoff, industrial runoff, oil spills [6]. In the Philippines, a significant portion of the coastal habitats is at high risk of being lost in the next decade [8]. Increased human settlements along coastal areas fringed by seagrass beds, mining, coastal aquaculture, deforestation and blast fishing [4] are also causes of seagrass loss. Contaminated water caused by natural and human influences may be partially solved by the emerging phytoremediation technology. Phytoremediation is a cost-effective plant-based approach and environmentally friendly solution for heavy-metal–contaminated sites. This cost-effective plant-based approach to remediation takes advantage of the remarkable ability of plants to concentrate elements and compounds from the environment and to metabolize various molecules in their tissues. Toxic heavy metals and organic pollutants are the major targets for phytoremediation [9].

Phytoremediation is a promising cost-effective and environmentally friendly technology and has gained increasing attention over the past ten years. Phytoremediation uses different plant processes and mechanisms normally involved in the accumulation, complexation, volatilization, and degradation of organic and inorganic pollutants [10] and is comprised of two components, one by the root colonizing microbes and the other by plants themselves, which degrade the toxic compounds to further non-toxic metabolites [11]. Due to the presence of many contaminants in the coastal environments, it is very imperative that plants should be used for phytoremediation of contamination hence, this study was conducted. The main objectives of the study were: (1) to determine the current status of the seagrass ecosystem to provide baseline information for seagrass ecosystems in two municipalities of Zambales (Candelaria and Masinloc); and (2) to determine the phytoremediation potential of the seagrass species present in the area on lead and chromium.

MATERIALS AND METHODS

Diversity Assessment of Sea grasses

Sampling Location

The study was conducted along the coast line of Masinloc and Candelaria, Zambales. Zambales is a province of the Philippines located in the Central Luzon region (Figure 1). Zambales has 13 municipalities, (North to South) namely, Sta. Cruz, Candaleria, Palauig, Masinloc, Iba, Botolan, Cabangan, San Felipe, San Narciso, San Antonio, San Marcelino, Castillejos, Subic and one city, Olongapo. Zambales, the second largest among the six provinces of Central Luzon is boarded by the South China Sea on the west and the Zambales mountains on the east, with a land area of about 3,700 square kilometers and 173 kilometers of coastline. It has a population density of 170 people per square kilometer, one of the lowest in the country. The main sources of income in Zambales are fishing and agriculture. Figure 1 shows the map of the two study sites: Candelaria (15^0 40’ 631” N, 119^0 55’ 207” E) and Masinloc (15^0 33’ 360” N, 119^0 56’ 234” E).

Site Selection

Prior to physical selection of the different study sites, locals (*i.e.* boatmen or fisherfolks) were requested to pinpoint areas where they have observed occurrences of seagrasses. Based on the initial information from the locals, ocular survey through snorkeling was done in the selected areas of Zambales. The following criteria were followed and considered in selecting a sampling site: (1) only seagrasses that formed continuous meadows were considered as transect sites; (2) seagrass patches were not a part of the in-depth survey but their occurrence in specific coastal areas of Zambales were noted; (3) seagrass beds with poor water visibility were not considered as suitable sampling sites; and (4) seagrass associates, seaweeds and benthic fauna (*e.g.* sea urchin and sea cucumber), which were found only within the quadrats sampled in each site were considered. Identification of the associated flora and fauna was up to the genus level only.

Figure 1. Map of Zambales and study sites (★ Study Site) [35].

Transect Survey

Seagrass sites that formed a continous bed with good water visibility and represented the overall condition of seagrass beds in Zambales (*e.g.* located within a cove, near a residential area, or close to mangrove forest or coral reef, etc.) were considered for the transect survey. The transect survey was done only in Masinloc and Candelaria, Zambales. Data on seagrass was collected inside a 1m x 1m quadrat placed on every 25 meters along the transect line, that was laid perpendicular to the shore up to 100 meters (Figure 1). Transect line was replicated three times in each sampling site. For the study area located in the municipality of Candelaria, the distance between each transect line was approximately 150 meters while the distance between each transect line in Masinloc was approximately 200 meters away from each other (Figure 1). The general status of Candelaria and Masinloc, Zambales seagrass ecosystem was further described based on the scheme by which indicated the following categories:

- **Pristine** or those with high or low diversity of species, bordering land masses far removed from human habitation, disturbed only by the normal intensity of natural elements;
- **Disturbed** or those of high or low diversity beds occupying bays and coves, near human habitation, and are the constant victims of man's activities, suffering from the destructive effects of domestic and industrial discharges;
- **Altered** or those areas of low diversity, permanently and completely changed or converted to other coastal uses like "Salinas" (salt marsh) and fish or shrimp ponds; and
- **Emergent** or those of low species diversity largely controlled by extreme physico-chemical conditions.

Identification of Seagrass Species

The identification of seagrass was based on: a) field guide identification of East Asian seagrass [12]; b) ttropical seagrass identification [13]; and c) atlas of seagrasses in the ASEAN region [4]. All seagrass species that were collected and identified were verified at the National Museum of the Philippines. However, the seagrass associates, seaweeds and benthic fauna (*e.g.* sea urchin and sea cucumber) found within the quadrats sampled were identified based on the Field Guide and Atlas of the Seaweed Resources of the Philippines [14] and thru the assistance of the National Museum of the Philippines.

Phytoremediation Potential of Sea grass

Collection and Sampling Protocol for Water Samples for Lead and Chromium Analysis

The presence of lead and chromium in water was analyzed in every sampling site. Water samples were collected using a one-liter capacity plastic collecting bottles. Water samples were stored in ice chest to maintain the temperature of less than 4^oC. Water samples were brougth to CRL Laboratory, at CRL Environmental Corporation Bldg., Berthaphil Ind'l Park, CFZ, Clarkfield Pampanga, Philippines for chemical analysis.

Collection and Sampling Protocol for Sediment Samples for Lead and Chromium Analysis

Sample sediment was scooped using a spatula. Scoop was pushed firmly downward into the sediment and then lifted upward. Samples was quickly raised out of the water in an effort to reduce the amount of fine-grained sediment lost due to water current. Collected grab sample were transfered directly into a labelled zip-lock plastic bag. Sample labels were attached properly to every plastic bags and placed them immediately in a cooler packed with ice. Samples were also brought to CRL laboratory for chemical analyses.

Collection and Sampling Protocol for Seagrass Samples for Lead and Chromium Analysis

To identify which seagrass species is the most active phytoremediator, the seagrass tissues were analyzed for the presence of lead and chromium. Collection of seagrass specimen was done in every site selected. Three dominant seagrass species per site were collected and analyzed. Collected seagrass was preserved prior to analysis following the steps. Gloves were wore during plant collections. Gloves were changed between the collection of each sample.

The collected plant parts such as the leaves and roots of the seagrass were washed with 0.1 – 0.3% phosphate free detergent then rinsed it with de-ionized water. Root samples were washed and dipped repeatedly in a bucket of de-ionized water. The samples were sundried for three days. The dried plant was grounded to a fine powder (about 100 g per species) and labeled properly. Chemical analysis of the plants for the presence of lead and chromium was done at CRL Environmental Corporation, Bldg., Berthaphil Industrial Park, CFZ, Clarkfield, Pampanga, Philippines.

RESULTS

Seagrass Diversity in Candelaria and Masinloc

In Potipot Island, Candelaria, Zambales, three species of seagrass were found namely: *Cymodocea rotundata* (smooth ribbon seagrass), *Thalasia hemprichi*i (sickle seagrass) and *Syringodium isoetifolium* (name noodle segrass). *Cymodocea rotundata* and *Syringodium isoetifolium* belong to Family Cymodoceacea while *Thalasia hemprichii* belongs to Family Hydrocharitaceae.

On the other hand, five seagrass species were found in Oyon Bay, Masinloc, Zambales, namely: *Cymodocea rotundata*, *Enhalus acoroides*, *Halophilla ovalis*, *Thalasia hemprichi*i and *Syringodium isoetifolium. Enhalus acoroides* (tape grass) and *Halophilla ovalis* (spoon grass) also belong to Family Hydrocharitaceae.

The different species of seagrass that were observed and identified in Candelaria and Masinloc, Zambales are shown in Figures 2- 6.

Figure 2. ***Cymodocea rotundata*** **Ehrenberg and Hemprich**

Figure 3. ***Syringodium isoetifolium*** **(Ascherson)**

Figure 4. ***Thalassia hemprichii*** **(Ehrenberg) Ascherson**

Figure 5. ***Enhalus acoroides*** **(EA) (Linnaeus f.) Royle**

Figure 6. ***Halophila ovalis*** **(R. Brown) Hooker f.**

Relative Frequency (RF)%; Relative Density (RD)% and Relative Dominance (RDo)% of the various organisms observed in the Seagrass Ecosystem

Ecological parameters such as RF, RD and RDo for various species in Potipot Island is presented in Figure 7. *rotundata* and *T. hemprichii* had the highest RF values (15.07%) followed by *Amansia glomerata* (12.33%). In terms of RD and RDo, *C. rotundata* had a greater RD (34.76%) value than *T. hemprichii* (26.36%). In terms of relative dominance (RDo), *C. rotundata* had higher RDo value (53.68%) than *T. hemprichii* (30.86%). *Syringodium isoetifolium* was found to have the least computed RF, RD and RDo among the seagrass species.The creeping rhizome of *C. rotundata* and the well developed rhizome of *T. hemprichii* could be the main reason for these two seagrass species to dominate the study site although continouosly exposed to different environmental disturbances like strong waves.

In Oyon Bay, Masinloc, Zambales, *T. hemprichii* had the highest RF of 17.65% followed by *C. rotundata* (14.71%), S. *isoetifolium* (14.71%), *Neomeris annulata* (14.71%) and *E. acoroides* 11.76% (Figure 8). The RD and RDo were both higher in *S. isoetifolium with* 64.51% and 90.76%, respectively. Results indicate that *S. isoetifolium* dominated the area followed by *T. hemprichii* with RD of 16.08 and RDo of 5.64%. *C. rotundata* obtained lower RD and RDo of 11.33% and 2.80%, respectively. The higher RD and RDo of *S. isoetifolium* is probably due to the small diameter size of its shoots compared with the rest of the seagrass species. *H. ovalis* was found to be rare in the area among the seagrass species, while the two echinoderms, namely *Holothuria atra* and *Salmacis sp.* were found to be very rare among the associated species found in the sagrass ecosystem at Oyon Bay, Masinloc. It was also noted that extreme difference in the number of individuals per species could be due to their different adaptation ability to the muddy environment.

Species diversity comprise both species richness and evenness. Diversity Index is a mathematical measure of species diversity in a community, it is often use to quantify the biodiversity of a habitat. Using the Shannon Index, it revealed that the seagrass beds at Potipot Island, Barangay Uacon, Candelaria had a diversity value of 1.6 while Oyon Bay, Barangay Baloganon, Masinloc, Zambales a diversity value of 1.1 which indicate that both areas have very low diversity. This means that the seagrass ecosystems in Candelaria and Masinloc, Zambales had a very few number of species present as well as a few number of individuals per species.

Phytoremediation Potential of Seagrass

Concentration of Lead and Chromium in Water

The concentration of lead and chromium in water samples of the two sites, Potipot Island, Candelaria and Oyon Bay, Masinloc, Zambales is presented in Table 1. It was found out that lead and chromium are not present and the absence of these metals maybe due to the absorption of seagrass species present in the area.The strong wave action and occasional rain during the time of the study also contributed for the water being free from lead and chromium.

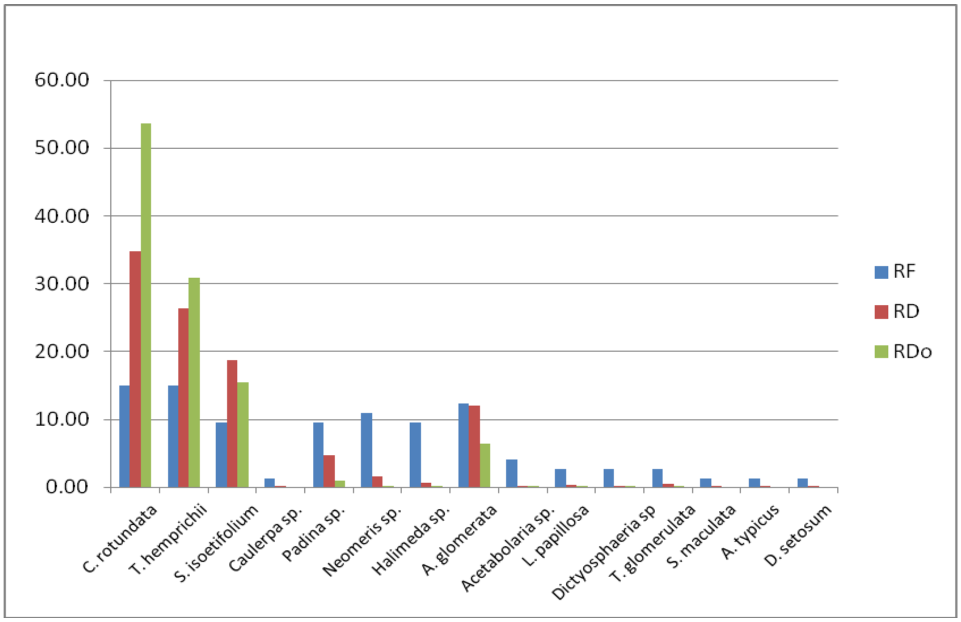

Figure 7. Relative frequency (RF), relative density (RD), and relative dominance (RDo) of seagrasses and the associated organisms in Potipot Island, Candelaria, Zambales, Philippines.

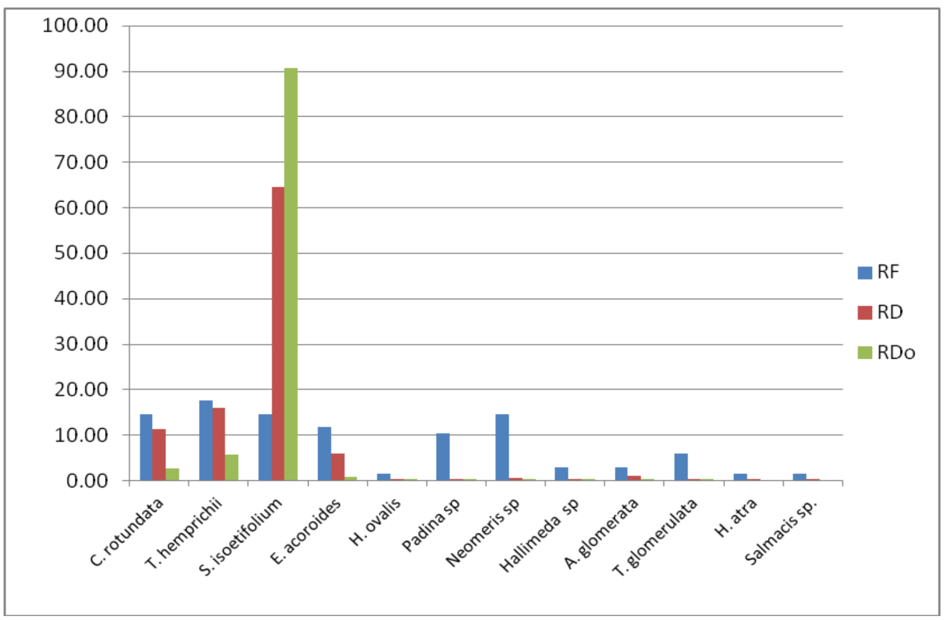

Figure 8. Relative frequency (RF), relative density (RD), and relative dominance (RDo), of seagrasses and the associated organisms in Oyon Bay, Masinloc, Zambales, Philippines.

Concentration of Lead and Chromium in Sediment

The average concentration of chromium in the sediment of the seagrass ecosystems of Potipot Island, Candelaria was about 15 mg kg^{-1} while the concentration of chromium at Oyon Bay, Masinloc, Zambales was about 10.3 mg kg^{-1} (Table 1). On the other hand, lead (119 mg kg^{-1}) was present only in the sediment of Masinloc, Zambales. The amount of lead and chromium recorded in sediment is above the effluent standard in marine water set by the Department of Environment and Natural Resources [15, 16].

Concentration of Lead and Chromium in Seagrasses

Table 2 shows that in seagrass ecosystem of Potipot Island, *Cymodocea rotundata* had an averaged concentration of 111.5 mg kg^{-1} of lead while the concentration of lead in *Thalasia hemprichii* was about 56.5 mg kg^{-1}. On the other hand, in Oyon Bay, Baloganon, Masinloc, the lead concentration of *Cymodocea rotundata* was about 82.5 mg kg^{-1}. The concentration of chromium across seagrass species was negligible.

Table 1. Traces of lead and chromium in water and sediment at seagrass ecosystem of Potipot Island, Uacon, Candelaria and Oyon Bay, Baloganon, Masinloc, Zambales

Site/ Heavy metals	**Water**	**Sediment**	**Effluent Standard (Marine Waters)**		
			DAO#35 1990		DAO 2008-xx
			Class SC		Class SC
			OEI	NPI	
	(mg/kg)	(mg/kg)	(mg/L)	(mg/L)	(mg/L)
Candelaria		(Sandy)			
a. Chromium (total)	0	15*	0.5**	0.2**	.05***
b. Lead	0	0	1.0	0.5	.05
Masinloc		(Muddy)			
a. Chromium (total)	0	10.3*	0.5**	0.2**	.05***
b. Lead	0	119*	1.0	0.5	.05

OEI: Old or Existing Industry;
NPI: New/Proposed Industry or waste/water treatment plants to be constructed.
* Average readings
**Chromium (hexavalent),
***Chromium (Cr^{+6})

Table 2. Amount of lead and chromium in the three dominant species of seagrasses at seagrass ecosystem of Potipot Island, Uacon, Candelaria and Oyon Bay, Baloganon, Masinloc, Zambales

Site/ Heavy metals	**Site/ Heavy metals**		
	C. rotundata	***T. hemprichii***	***S. isoetifolium***
	(mg/kg)	**(mg/kg)**	**(mg/kg)**
Candelaria			
a. Chromium (total)	0	0	0
b. Lead	111.5*	56.5*	0
Masinloc			
a. Chromium (total)	0	0	0
b. Lead	82.5*	0	0

*Average readings

DISCUSSION

Generally, a total of five specie of seagrass were found within the study sites of Candelaria and Masinloc, Zambales, namely; *C. rotundata, T. hempricii, S. isoetifolium, E. acoroides* and *Halophila ovalis*. Results show that the number of seagrass species in Candelaria and Masinloc, Zambales were fewer now compared to previous studies conducted in Masinloc, Zambales. Seven species namely: *C. rotundata, T.hempricii, S, isoetifolium, E. acoroides, H. ovalis, H. uninervis,* and *H. pinifolia* were found in the survey done in eleven barangays of Masinloc by DA-BFAR in 2009 [17]. *Cymodocea rotundata* was the most dense and the most dominant in Potipot Island, Candelaria, Zambales while *S. isoetifolium* was the most dense and most dominant species at Oyon Bay, Masinloc, Zambales.

In our study, *Thallasia hemprichii* was found to be the most common seagrass species, because it was the most adapted and robust seagrass species in both environments and it was the most dispersed among the seagrasses thriving in the area. *Enhalus acoroides* and *Halophila ovalis* were found to be the least common among the seagrass species observed. These were the same species with the least percent occurence in Cagayan in the Northern Philippines [18]. *T. hemprichii* forms dense, monospecific meadows and is the dominant seagrass species on dead reef platforms and in bottom sediments composed of coral sand and coral rubble. Also, it was observed growing on muddy sand and soft mud bottoms, as well as mud covered coral banks. It has a well-developed rhizome which allows it to firmly anchor in a variety of substratum.

It is a fast growing seagrass species able to recolonize disturbed areas quickly. The seeds of this seagrass are buoyant which allow for wider dispersal facilitated by wind and currents [19]. *Cymodocea rotundata* was found to be very adapted to sandy seagrass bed of Candelaria. This seagrass species is commonly found thriving in a lower intertidal zone that is exposed during extreme low tides. They were scattered along the intertidal zone. *Syringodium isoetifolium* was found to be the most frequent, most dense and most dominant species in the muddy seagrass bed of Oyon Bay, in Masinloc. They were found densely scattered through out the study areas particularly along the 75 to 100 meters of the intertidal zone.

Species diversity comprise both species richness and evenness. Results indicate that both areas have very low diversity. This means that the seagrass ecosystems in Candelaria and Masinloc, Zambales had a very few number of species present as well as a few number of individuals per species. Generally, seagrasses are mostly adapted to live and reproduce in sheltered, soft shallow sandy-muddy soft-bottomed coastal habitats such as coastlines, estuaries and lakes [20]. There are many important factors in maintaining healthy seagrass. These include sediment quality, temperature, salinity, turbidity [20] or light gradient and depth [21], currents and hydrodynamic processes (water movement).

The very low diversity of seagrass found in Candelaria and Masinloc, Zambales can be attributed to the location of the area which were affected by various environmental problems. Factors affecting the species composition of seagrasses include the bottom type as well as the location of the seagrass beds. The seagrass bed at Oyon Bay, Brgy Baloganon, Masinloc has a muddy substrate that smothered the whole seagrass ecosystem. Sediments from flooding during typhoon and heavy rain settled at the seagrass bed could be the reason for the low species diversity of the site due to burial of the species present in the area. Moreover, mariculture activity, local fishing boats, run offs from non-point soures like households, agriculture and the power plant present in the study area could affect and hamper the coastal resources hence, could result to biodiversity loss. Duarte, quoted the causes for seagrass loss are multiple and some of them were disease [22] burial by shifting sand [5] excess nutrient inputs to coastal waters, sediment quality, excess organic supply from aquaculture and effluents, water quality deterioration by excess sediment inputs, mechanical damage from fishing activities, coastal engineering and boat activities.

In Potipot Island, only three species of seagrasses could thrive in a relatively exposed bed during low tide. Besides of its being exposed during low tide, Potipot Island is exposed to a strong wave action due to its geographic location. It was also noticed that the seagrass bed in the area was exposed during low tide. About 200 m to 300 m away from the seashore (approximate) was exposed during lowtide. Moreover, some guests from the resort disturbed the seagrass beds for curiousity, they were inquisitive with the animals thriving in the area and accidentally damaged the seagrass meadow. Seagrass exposure at low tide, wave action and associated turbidity and low salinity from fresh water inflow determine seagrass species survival at the shallow edge [23, 24]. Seagrasses survive in the intertidal zone especially in sites sheltered from wave action or where there is entrapment of water at low tide, (e.g., reef platforms and tide pools), protecting the seagrasses from exposure (to heat, drying) at low tide. Fortes also stated that extreme lowtide during daytime creates a negative effect on seagrass abundance, biomass, growth rate and production [4].

Substrate is also important for the growth of seagrass. Potipot Island has a sandy corraline bottom which are easily penetrated by seagrass roots as affirmed by Heminga and Duarte [5]. However, high mobility and constant shifting of these fine sediments, in which currrents and waves-induced bedload transport generate large sand ripples and sand waves, render them unsuitable to support plant growth[5][25]. These processes cause successive burial and erosion, which may cause seagrass mortality, depending on the size and frequency of these events relative to the life history and growth capacity of these species. Hence, highly mobile, but otherwise suitable, sandy sediments may be bare of seagrass cover [5].

Results revealed that sediments of the coastal areas in Oyon Bay and Potipot Island are both contaminated with heavy metals. The amount of lead and chromium recorded in sediment is above the effluent standard in marine waters as set by the Department of Environment and Natural Resources [15, 16]. Presence of chromium in the sediment was probably due to the huge deposits of chromite in the mountains of Masinloc. A mining company, BCI-Coto in Masinloc is presently operating in the nearby area which export monthly an average of 1-1/2 million pesos worth of chromite ore, mined from what is known as the biggest deposit of refractory ore in the world. On account of the bigger volume of shipping done here, as compared to that handled at San Fernando, La Union, Masinloc was declared a port of entry. Lead is also present in the sediment of Oyon Bay, Masinloc mainly because of the several fishing boats travelling in the coastal areas and the presence of Masinloc Power Plant near the study area. Masinloc Power Plant is reported to have haevy metals and metalloid emission such as fly ash. The heavy metals detected are arsenic, cadmium, chromium, copper, lead, mercury, nickel and zinc [26]. Seagrass ecosystem in Candelaria had a sandy coralline substrate while Masinloc seagrass ecosystem had a muddy substrate.

Chromium can be accumulated in either sandy or muddy substrate while lead can only be accumulated in a muddy fine grain substrate. Fine-grained sediments were the main carriers of heavy metals [27]. Horowitz stated that there is a strong positive correlation between increasing chemical concentration and the increasing percentage of fine-grained material [28]. One of the most significant factors controlling both suspended- and bottom-sediment capacity for retaining trace metals is grain size [28]. Fine grained fraction of sediment, namely the silt – clay fraction, facilitates the uptake of metals more so than any other grain size [28, 29]. This indicates that more heavy metals were bound in the silt and clay fractions than the sand-sized fraction of the sediment.

Phytoremediation is an eco-friendly approach using plants [11] and their associated microbes [10] to remedy contaminated soils and water [11], sediments and groundwater. It is emerging as a cost-effective and environmentally friendly technology. Due in large part to its aesthetic appeal, this technology has gained increasing attention over the past 10 years. Phytoremediation uses different plant processes and mechanisms normally involved in the accumulation, complexation, volatilization, and degradation of organic and inorganic pollutants [11]. Salt *et al*. also stated that toxic heavy metals and organic pollutants are the major targets for phytoremediation [9]. Phytoremediation of metals is being developed as a cost-effective and environmentally friendly solution for heavy-metal–contaminated sites [30].

Hence, this phytoremediation study was undertaken due to the various anthropogenic activities that are happening in the coastal areas in Masinloc and Candelaria where the seagrass ecosystems and their biodiversity are now under severe stress from the combined impacts of human overexploitation, habitat destruction, pollution, sedimentation and general neglect. There is an urgent need to conserve and manage these habitats in the Philippines. This study could identify potential plants to absorb heavy metal contaminants in the coastal areas for soil and water conservation. Results indicate that *Cymodocea rotundata* is a good phytoremediator for lead because it has the ability to accumulate higher amount of lead in both study sites. It was also noticed that *Thalasia hemprichii* only absorbed lead in Candelaria seagrass ecosystem but not in Masinloc seagrass ecosystem. This is probably because of the different types of sediments of the two study sites. Potipot Island had a sandy coralline substrate which is coarser than the sediment in the seagrass ecosystem at Oyon Bay, Baloganon, Masinloc which had muddy substrate with fine grain sediments. The coarser grain sediment had a lesser capacity to withhold heavy metal than fine grain sediment. Hence, lead was readily available in the sandy coralline substrate for easy uptake by the seagrasses.

Aside from the difference on the type of sediment, results could also be attributed to the type of seagrass rhizome which could affect its ability to uptake heavy metal. *C. rotundata* has a fast rhizome elongation rate [31]. This characteristic of *C. rotundata* could be a reason for being a good phytoremediator of heavy metal. Findings of this study revealed that *C. rotundata* was a good phytoremediator for lead in both study sites. The hyperaccumulation of lead in *C. rotundata* maybe due to its fast rhizome elongation rate of 210 cm per year [32]. Another study showed that *H. ovalis* was found to be the strongest accumulator for Hg in Tajung, Malaysia [33] which could be due to its fast rhizome elongation rate too [32]. However, chromium was not absorbed by the three dominant seagrass species in the two study sites. Seagrass sequesters trace metals from the marine environment via both the leaf and root-rhizomes and these concentrations can be correlated with the water column and sediments, respectively [34].

CONCLUSION

The diversity of species in the seagrass ecosystem of Potipot Island, Barangay Uacon, Candelaria and Oyon Bay, Barangay Baloganon, Masinloc, Zambales is very low due to environmental degradation caused by natural and human activities. *Cymodocea rotundata* is a good phytoremediator for lead because it has the ability to accumulate higher amount of lead in Candelaria and Masinloc seagrass ecosystems. On the other hand, *Thalasia hemprichii* only absorbed lead in Candelaria seagrass ecosystem, but not in Masinloc seagrass ecosystem because of the presence of sandy coarser grain sediment which makes lead readily available for its easy uptake. Moreover, chromium was not absorbed by the three dominant seagrass species in the two study sites. It only shows in this study that *C. rotundata, T. hemprichii* and *S. isoetifolium* are not capable of up taking chromium.

RECOMMENDATIONS

Further study on the assessment of seagrass ecosystem in the coastal areas of Zambales should be conducted. More regional study on seagrass assessment distribution, protection and management should be conducted. Further study on phytoremediation potential of other seagrass species should be done. A fresh and dry plant sample should also be considered. Close monitoring of illegal dynamite or blast fishing should be done by people involved and people concerned to prevent further degradation of the seagrass meadow. Close coordination among local fishermans, traders, researchers, local government units and management implementers should be undertaken for resource sustainability.

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