Journal of Ecosystem Sciences and Eco-Governance (JESEG)
www.jeseg.carsu.edu.ph

Vol. 4, No. 2 | December 2022
PRINT ISSN 2704 4394 | ONLINE ISSN 2782 8522
DOI: https://doi.org/10.54610/jeseg/4.2.2022.004

Marine Benthic Macrophytes Diversity and Concentration of Heavy Metals in *Thalassia hemprichii* Near Mining Area of Claver, Surigao del Norte, Philippines

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Received: July 8, 2022
Revised: October 19, 2022
Accepted: December 26, 2022
Available Online: December 30, 2022

Cite this article: Orboc, D.R.F, Jumawan, J.C., Ombat, L.A., Capangpangan, R.Y., & Seronay, R.A., (2022). Marine Benthic Macrophytes Diversity and Concentration of Heavy Metals in *Thalassia hemprichii* Near Mining Area of Claver, Surigao Del Norte, Philippines, *Journal of Ecosystem Science and Eco-Governance*, **4**(2):29-39.

ABSTRACT

Marine benthic macrophytes are a good indicator of heavy metal contamination along coastal ecosystems. Heavy metal contamination in the aquatic environment is one of the major environmental issues these days. The study aimed to assess the diversity of marine benthic macrophytes, quantify, compare, and correlate heavy metal concentration in terms of Iron (Fe), Lead (Pb), Cadmium (Cd), Chromium (Cr), and Nickel (Ni) present in *Thalassia hemprichii* among selected sampling stations in Cagdianao, Claver, Surigao del Norte, Philippines. Triplicate samples were collected from the six marine sampling stations and analyzed using Atomic Absorption Spectrophotometer. Thirty-seven species of submerged marine benthic macrophytes belonging to 15 families were recorded. The results of the heavy metal analysis revealed that accumulations of heavy metal in the above-ground tissues of *T. hemprichii* (leaves) were much higher than in below-ground tissues (rhizomes). Iron, Nickel, and Chromium concentrations were significantly different in every location, both in leaves and in rhizomes. Generally, the heavy metal uptake sequence in *T. hemprichii* leaves, and rhizomes were Iron>Nickel>Chromium>Lead>Cadmium. Also, there was no particular pattern of accumulation of each heavy metal being analyzed across study stations. Concentration patterns of heavy metals in *T. hemprichii* significantly differed depending on plant tissue and sampling sites. These findings suggest that further studies should be conducted to know the source of trace elements, especially for Chromium in the seagrass tissues.

Keywords: *Bioaccumulation, Heavy metal concentration, Macrophytes, Mineral Uptake, Thalassia hemprichii*

1 Introduction

Environmental contamination threatens a lot of marine organisms. It affects the ecosystems directly through industrial waste (Marcovecchio et al. 1994), mining, and smelting of metalliferous ores (Peng et al. 2008). Plants usually absorb elements from the soil, some are significant, but others are toxic even at low concentrations (Videa et al. 2009). Since plants form the baseline of the food chain, that is, by making their food through photosynthesis, it is vital to give attention to the possibility that specific toxic elements might be transported to higher strata of the food chain.

Seagrasses are marine flowering plants capable of reproducing even when submerged completely in seawater (Govindasamy et al. 2010; Orth et al. 2006). Globally there are 50-60 species of 12 genera and four families (Al-Bader et al. 2014; Larkum et al. 2006; Green and Short 2003). In the Philippines, 16 seagrass species were identified, 7 of these species are common (Vermaat et al. 1995), and among these species, *Thalassia hemprichii* were highly distributed throughout the Philippines (Rollon et al. 2001). Marine macrophytes were not just critical elements in coastal nutrient cycling in coastal areas. Sometimes, they also increased the availability of toxic substances to consumers of higher trophic levels, such as sea turtles and cows (Hoenlinger and Schlacher 1998; Thangaradjou et al. 2010).

Heavy metal contamination in the aquatic environment is one of the significant environmental problems in developing countries, knowing their effect on the health and reproductive capability of many organisms, including marine benthic macrophytes and invertebrates (Factor and Chavez 2012). By definition, heavy metals refer to any metallic element with a relatively high density and are toxic or poisonous even at low concentrations (Lenntech 2004; Duruibe et al. 2007). It occurs naturally in the earth's crust and common environmental contaminants because they cannot be degraded or destroyed (Duruibe et al. 2007). Environmental pollutants, such as heavy metals, are very prominent in mining areas. These metals were eventually leached out in sloppy areas, carrying acid water downstream and running off to the sea. Thus, it threatens the economically crucial marine biodiversity. Losses of living organisms in freshwater and marine environments, including seagrass, have been recorded in recent years (Alberto et al. 2015). Accordingly, this is due to natural circumstances such as floods, cyclones, high-energy storms, or disease. In most cases, it is also linked to anthropogenic inputs like industrial and agricultural runoffs, oil spills, mining, coastal aquaculture, and boating activity in the local community (Duruibe et al. 2007; Alberto et al. 2015).

Removal of heavy metals from water and soil could be done using some plant species or ‘bioindicator species' found in contaminated areas (Vardanyan et al., 2008; Pajevic et al., 2003). The unique morphological and physiological characteristic of plants makes them a good indicator in studying heavy metal concentration (Pajevic et al. 2003; Govindasamy et al. 2010). Seagrass, as a bio-indicator, has high phytoremediation potential, is plant-based, and is an environment-friendly solution to heavy metal contamination (Alberto et al. 2015).

The Philippines is considered one of the world's wealthiest countries regarding mineral deposition like nickel, gold, and copper (Aytin 2014). Metal mining and processing activities inevitably increase the risk of toxic heavy metal contamination in the marine environment (Davis et al. 2000). Assessment of heavy metal concentration in the marine environment was possible by using specific indicators such as seagrass or algae (Thangaradjou et al. 2010). Seagrass bed and heavy metal pollution in coastal areas have been studied well, but little is known about heavy metal accumulation in seagrass along Claver, Surigao del Norte, Philippines. Claver, on the northeast coast of the Caraga Region in Mindanao, lies a large mining reservation area because of its potential in mineral deposits like nickel and iron. It is primarily a mining town making it one of the primary sources of livelihood aside from fishing, farming, and trading among residents.

2 Materials and Methods

Description of Study Area

The municipality of Claver is located in the northeast part of the Caraga Region (Figure 1). It is approximately 200 kilometers away from Butuan City, the region's capital. Claver is a first-class municipality in Surigao del Norte with a total land area of 323 km². Claver belongs to climatic type II, which has no pronounced dry season with a maximum rain period from November to March.

Triplicate samples were collected from the six sampling stations in Cagdianao, Claver Surigao del Norte, Philippines. The first study station was located about 10 km far from the community with visibly disturbed water due to coastal runoffs such as silts. Study station 2 was characterized by rocky, rubble to fine sediment. This station was slightly away from the local community and somewhat isolated. Station 3 was 300m away from Station 4 with rubble to fine sediment. Station 4 was located near the community and river opening. Portions were affected by boating activities. This station

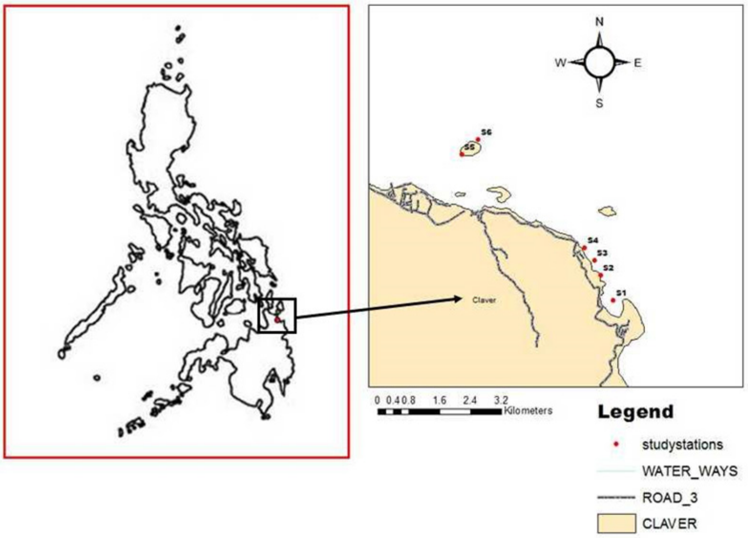


Figure 1. Map showing the six study stations in Cagdianao, Claver, Surigao del Norte, Philippines.

also has sandy substrate and moderate water current since this area receives direct runoff from upstream. Stations 5 and 6 were located at White Sand Island in Taganito, Claver, Surigao del Norte. Generally, Cagdianao bay was characterized by rocky, rubble to fine sediment, and some portions were accumulated with silt, especially at the study station 1 area. Data collection was done using goggles and snorkeling. All marine plants gathered in the field were preserved temporarily in an ice chest.

Diversity of Marine Benthic Macrophytes

Species list, distribution and estimated abundance of marine benthic macrophytes were obtained from the four shallow stations in Cagdianao, Claver, Surigao del Norte, Philippines. Data were collected following the Aquatic Plant Monitoring and Assessment Methods of AERF by Madsen and Wersal (2012) with some modifications. Identification of seaweeds was made using taxonomic references such as Zawawi et. al. (2015), Silva et al. (1987), Verbruggen et al. (2005), Ganzon-Fortes (2012), Trono (1988), Hurtado-Ponce et. al. (1992).

Heavy Metal Analysis in Thalassia hemprichii tissue

Thalassia hemprichii is the most abundant seagrass species in Claver Bay. Hence, it was chosen for heavy metal analysis. Healthy and mature seagrass were collected from the coastal areas of the four sampling stations. Samples were placed separately in sealed polythene bags and transported to the laboratory, keeping them in an icebox. Samples were washed with distilled water and separated above-ground tissues (leaves) and below-ground tissues (rhizomes and roots). It was then oven-dried at 105°C and pulverized using mortar and pestle.

Moreover, 250mg of pulverized seagrass samples were digested with 2M HNO_3 (Say et al. 1990; Govindasamy et al. 2010). Samples were filtered, added with distilled water made up to 25ml, and stored in a clean polythene bottle. Heavy metal concentrations were analyzed using Perkin-Elmer (Model 373) Atomic Absorption Spectrophotometer results were expressed as µg metal g-1 for seagrass tissues.

Statistical Analysis

Two-way ANOVA and Tukey's multiple comparisons tests (Graphpad PRISM 7) were done to analyze the significant difference between the heavy metal concentration of *Thalassia hemprichii* tissues and the study stations where it was collected. Standard deviations were expressed by using Graphpad PRISM 7 and Paleontological Statistics Software (PAST). Diversity indices (dominance, Shannon-Weiner index, and evenness) were also calculated using PAST.

3 Results and Discussion

Marine Benthic Macrophytes Diversity

Thirty-seven species of submerged marine benthic macrophytes belonging to fifteen families were recorded from selected shallow waters of Cagdianao, Claver, Surigao del Norte, Philippines (Table 1 and 2). Most of the collected seaweeds were from Division Chlorophyta, while eight species were collected from Division Rhodophyta. The least number of seaweeds were from Division Phaeophyta. For seagrass from phylum Tracheophyta, five out of nine collected species were under the family Cymodoceaceae.

The most ubiquitous species were *Thalassia hemprichii* and *Padina sp.*, which are present in all stations (Table 3). *Dictyosphaeria* sp., *Udotea geppi*, and *Halophila minor* were the least frequent species. In comparison, data collected shows an increase in diversity indices in year two. In all study sites, the distribution of marine benthic macrophytes has yet to be fully documented. These species' diversity, abundance, and survival highly depended on the degree of fluctuation of environmental conditions in the coastal zone (Al-Bader et al. 2014). The Cagdianao coast was generally shallow due to its flat and rocky topography; evaporation plays a significant role in salinity fluctuations.

Table 1. Division, Family, and Species of seaweeds collected from shallow coastal areas of Cagdianao, Claver, Surigao Del Norte, Philippines

Division	Family	Species
Chlorophyta		
	Udoteaceae	*Avrainvillea erecta* (Berkeley) A. and E.S. Gepp, 1911
		Udotea geppii Yamada, 1930
	Halimedaceae	*Halimeda macroloba* Decaisne, 1841
		Halimeda opuntia (Linneaus) Lamouroux, 1816
		Neomeris sp.
	Dasycladales	*Bornetella sphaerica* (Zanard.) Solms-Laubach, 1892
	Ulvaceae	*Enteromorpha clathrata* (Roth) Greville, 1830
		Ulva intestinalis Linnaeus , 1753
	Cladophoraceae	*Chaetomorpha linum* (O.F.Muller) Kutzing, 1845
		Boergesenia forbesii (Harvey) J. Feldmann
	Siphonocladaceae	*Dictyosphaeria* sp.
Phaeophyta	Dictyotaceae	*Padina minor* Yamada, 1925
		Padina sp.
	Sargassaceae	*Sargassum cristaefolium* C. Agardh, 1820
		Sargassum paniculatum J. G. Agardh, 1824
		Sargassum polycystum C. Agardh, 1824
		Sargassum sp.
		Dictyopteris jamaicencis W. R. Taylor, 1960
		Dictyota dichotoma
Rhodophyta	Solieriaceae	*Eucheuma denticulatum* (Burman) Collins and Hervey, 1917
		Kappaphycus alvarezii (Doty) Doty, 1988
	Gracilariaceae	*Gracilaria salicornia* (C. Agardh) Dawson, 1854
		Gracilaria sp. 1
		Gracilaria sp. 2
	Rhodomelaceae	*Laurencia papillosa* (Forsskal) Greville, 1839)
	Corallinaceae	*Amphiroa foliacea* J.V. Lamouroux, 1824
	Lomentariaceae	*Ceratodictyon spongiosum* Zanardini, 1878

Table 2. Phylum, Family, Species and IUCN status of seagrass collected from shallow coastal areas of Cagdianao, Claver, Surigao Del Norte, Philippines

Phylum	Family	Species	IUCN status	Current Population Trend
Tracheophyta	Cymodoceaceae	*Cymodocea rotundata*	least concern	stable
		Cymodocea serrulata	least concern	stable
		Halodule pinifolia	least concern	decreasing
		Halodule uninervis	least concern	stable
		Syringodium isoetifolium	least concern	stable
Tracheophyta	Hydrocharitaceae	*Enhalus acoroides*	least concern	decreasing
		Halophila minor	least concern	unknown
		Halophila ovalis	least concern	stable
		Thalassia hemprichii	least concern	stable

Table 3. Distribution of seagrass by location. Species code: CR= *Cymodocea rotundata*, CS= *Cymodocea serrulata,* HP= *Halodule pinifolia*, HU= *Halodule uninervis,* SI= *Syringodium isoetifolium*, EA= *Enhalus acoroides*, HM= *Halophila minor*, HO= *Halophila ovales*, TH= *Thalassia hemprichii.*

Year	Location	FAMILY/SPECIES								
		Cymodoceaceae					Hydrocharitaceae			
2015		CR	CS	HP	HU	SI	EA	HM	HO	TH
	Panyug	/	*	/	/	/	/	*	/	/
	Cagdianao	/	*	*	*	/	/	*	*	/
	Station 3	*	/	*	/	*	*	/	*	/
	Sabang	/	*	/	*	/	/	*	/	/
2016										
	Panyug	/	/	/	/	/	/	/	/	/
	Cagdianao	*	*	*	*	*	*	*	*	/
	Station 3	/	/	/	/	/	/	*	/	/
	Sabang	/	/	/	/	/	/	/	/	/

Legend: / present; * absent

The exposure of seagrass beds in Panyug was less where the intertidal area was enclosed in a steep cove; hence low tide does not expose large areas. Destruction by temperature, salinity, and evapotranspiration may affect the diversity and shoot density, particularly in Cagdianao. Topography, sediment type, and the constant influx of freshwater from river opening in Sabang influence the increase of diversity and abundance of marine benthic macrophytes. Seagrass rhizomes and roots prefer penetrating in sandy sediments creating more pore spaces (Al-Bader et al. 2014). The presence of rocky substrate at Cagdianao appears unfavorable for other seagrass species' growth, reproduction, and development.

Anthropogenic inputs such as deforestation in the mainland, mangrove destruction, road construction, mining operations, sediment discharge anchorage, and other boat activities are some major threats in Claver, Surigao del Norte, Philippines. As a result of these activities, sediment loads near the seagrass beds, especially in Panyug, increases; thus, the amount of light reduces because of siltation. Samples from six study stations were analyzed for the levels of Nickel (Ni), Lead (Pb), Cadmium (Cd), Chromium (Cr), and Iron (Fe). The concentrations of these heavy metals were determined in above-ground tissues (leaves) and below-ground tissues (rhizomes & roots) at each site (Figure 4). Levels of heavy metals in leaves and rhizomes vary among stations. The highest recorded heavy metal concentrations in plant tissue were measured in above-ground tissue (2855±470.65 mg/kg DW Iron). Fe was the highest contaminant, followed by Ni 79.5±6.39 mg/kg DW, Cr 34.6±8.78 mg/kg DW, Pb 5.4±2.40 mg/kg DW and Cd with

3.07±0.933 mg/kg DW respectively. Results showed that study station 1 got the highest level of Fe, Ni, and Cd among all areas. All were from above-ground tissues. For the accumulation of Pb, it was observed that study station 3 was the highest. In the case of Cr, leaves from study station 4 showed the highest values. Different patterns were observed between leaves and rhizomes in all heavy metals studied. The metal content of the rhizomes was almost always lower in every station and metal analyzed.

Iron, Nickel, and Chromium concentrations were significantly different in every location, both in leaves and in rhizomes (Table 5. coefficient variation of 95%). Two-way ANOVA revealed no significant difference in Pb and Cd in different study stations. The lowest Cd accumulations in rhizomes (1.45±0.33mg/kg DW) was recorded from study station 5. Tukey's multiple comparison tests in Fe showed a significant difference between leaves in station 1 and leaves in station 5 ($p<0.01$; 0.0097), leaves in station 1 and rhizomes in station 5 ($p<0.01$; 0.0072), leaves in station 1 and rhizomes in station 6 ($p<0.01$; 0.0036), leaves in station 4 and leaves in station 5 ($p<0.01$; 0.0351), leaves in station 4 and rhizomes in station 5 ($p<0.01$; 0.0264), and leaves in station 4 and rhizomes in station 5 ($p<0.01$; 0.0137), respectively.

Significant differences were also observed in Nickel utilizing Tukey's multiple comparisons

Table 4. Diversity indices values of submergent marine benthic macrophytes at the four study stations in Claver, Surigao Del Norte, Philippines.

Year	**Species Richness**	**Abundance**	**Dominance**	**Shannon_H**	**Evenness_e^H/S**
2015	19	128	0.13	2.39	0.57
	6	59	0.42	1.07	0.48
	16	154	0.14	2.21	0.57
	7	144	0.24	1.60	0.71
2016	18	183	0.07	2.73	0.85
	5	70	0.50	1.02	0.55
	12	91	0.09	2.42	0.93
	18	296	0.09	2.59	0.74

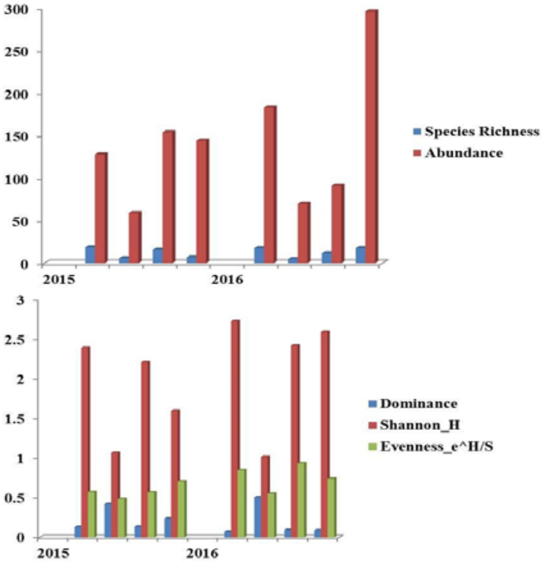


Figure 2. Diversity indices of submergent marine benthic macrophytes at the four study stations in Claver, Surigao del Norte, Philippines.

Figure 3. *Thalassia hemprichii*, Turtle grass from Claver, Surigao Del Norte, Philippines

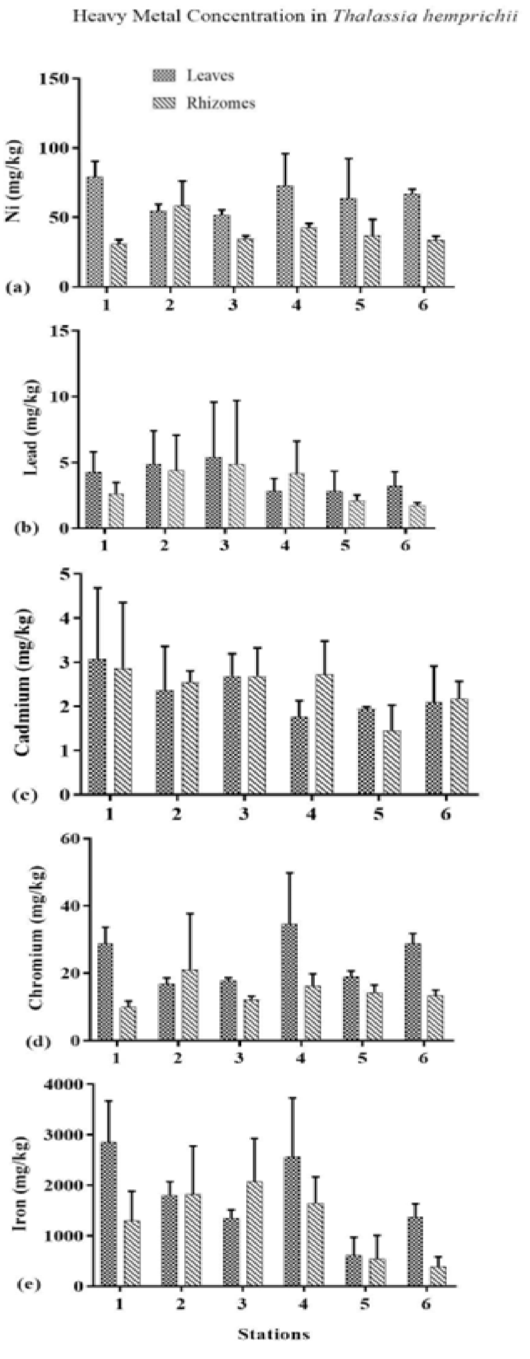


Figure 4. Heavy metal concentration in *Thalassia hemprichii* tissue (a) Nickel, (b) Lead, (c) Cadmium, (d) Chromium and (e) Iron. Error bars indicate the 95% confidence interval of the mean (n=3).

(Table 5). Leaves from station 1 were significantly different when compared to rhizomes from station 1 ($p<0.01$; 0.0051), rhizomes from station 3 ($p<0.05$; 0.0120), and rhizomes from station 5 ($p<0.05$; 0.0199). Values obtained from leaves at station 4 were also significantly different when compared to rhizomes from station 1 ($p<0.05$; 0.0210), rhizomes from station 3 ($p<0.05$; 0.0471), and rhizomes from station 6 ($p<0.05$; 0.0409). For Chromium, only tissues above ground level from station 4 were known to be significantly different in comparison with the rhizomes from station 1($p<0.01$; 0.0088), rhizomes from station 3 ($p<0.05$; 0.0225) and rhizomes from station 6 ($p<0.05$; 0.0361).

The heavy metal uptake sequence in *T. hemprichii* leaves and rhizomes were Iron>Nickel>Chromium>Lead>Cadmium. The results were approximate with the study of Malea, (1994) accumulation of heavy metals in *Halophila stipulacea:* Fe>Pb>Zn>Cu>Cd. heavy metal phytotoxicity was controlled by a wide diversity of environmental conditions, including water, sediment pH, redox potential, phosphorus level, sediment cations, water temperature, salinity, and organic content (Ralph and Burchett 1998).

The accumulation of heavy metal concentration in every station is summarized from the highest down to the lowest average values, as shown in Table 6. Generally, data gathered suggest a similar trend in leaves and rhizomes from station 1 to station 6. It was always Fe> Nickel> Chromium> Lead> Cadmium, respectively, except for rhizomes in study station 6 (Fe> Ni> Cr> Cd> Pb). In contrast, the study's results also revealed that there were no particular patterns of accumulation in all study stations. The accumulation pattern of every heavy metal was as follows: Iron 1>4>2>6>3>5, Nickel 1>4>6>5>2>3, Chromium 4>6>1>5>3>2, Lead 3>2>1>6>4>5 and Cadmium 1>3>2>6>5>4. Naturally occurring Cadmium levels were extremely low, 0.01-5mg/kg-1 (Videa et al. 2009). Cadmium uptake by plants was reported to be due to the electrochemical potential gradient of the plasma membrane in the root cells. External factors such as Iron concentration can reduce the uptake of Cd (Sharma et al. 2004; Videa et al. 2009) which explains why the constant pattern of heavy metal accumulation (Fe as the highest; Cd as the lowest) was observed in every study station both in leaves and rhizomes. Videa et al. 2009 reported that Lead was considered to have low availability and solubility for plant uptake because it precipitates as sulfates and phosphates, types of chemicals found in the plant's rhizosphere. Lead was known to be inhibited in sediment when mixed with organic matter, and plants do not have a channel for Lead uptake. Principal Component Analysis (PCA) in Figure 6 showed that most of the samples were gathered on the left side of the plot. Each dot in the scatter diagram represents each sample. Different accumulations of heavy metals in leaves and rhizomes were found (Figures 5 & 6). These might be due to the various mechanisms of metal binding and regulation depending on plant species (Govindasamy et al. 2010).

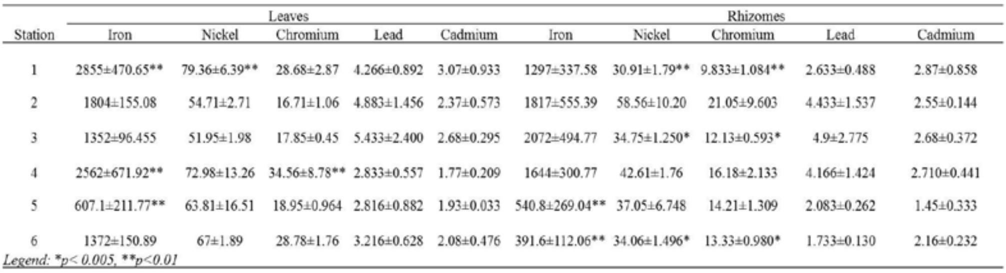
T. hemprichii were observed to have the ability to form dense, monospecific meadows and were widely distributed seagrass species along the coast of Claver, Surigao del Norte. For the record, *T. hemprichii* was known to be the dominant seagrass species on dead reef flat forms and bottom sediments with coral sand and coral rubble. In addition to that, they could also survive on muddy sand or soft mud substrate. Adaptation, through time, allows them to have well-developed rhizomes that would enable them to hold firmly in a variety of substratum. The species is morphologically suited to thrive or even recolonize disturbed areas quickly, they were also fast-growing, and their seeds were buoyant, allowing wider dispersal by water currents and wind (Alberto et al. 2015).

Chromium is considered one of the environment's most harmful elements (Videa et al. 2009). Above-ground tissues from study station 4 showed high content of Cr (34.56±8.78 mg/kg). Plants store Chromium in their vacuoles (Shanker et al. 2005; Videa et al. 2009). Although there was no standard reference for the toxicity concentration of Chromium, data previously gathered in this study suggests that there is potential for these metals to bioaccumulation and be transported to higher tropic levels through the food web. Meanwhile, a similar observation was made in Nickel and Iron.

Study station 1 (Panyug) was located in an area where it was not exposed to strong water currents like in a cove. A muddy mix of sand and silt characterized sediment in this area. The topography, occasional rain, and metabolic rates of the leaves in the area, possibly leading to a high level of element uptake in the above-ground tissue of *T. hemprichii,* may have also contributed to the observed variations.

Heavy metal availability can be affected by water temperature, sediment cation exchange capacity, water, sediment pH, redox potential, salinity, organic concentration, and other elements (Ward 1989; Govindasamy et al. 2010). Heavy metals were accumulated in above-ground tissue than below-ground tissue. Because of the leave's vacuole (site of photosynthesis), energy from photosynthesis and oxygen can also trigger the active uptake of the element. These variations in the heavy metal accumulation in seagrass leaves and rhizomes may also be attributed to environmental and metabolic levels depending on the phonological stages of the sample (Fujiyama and Maeda 1979; Eide et al. 1980; Govindasamy et al. 2010). Concentration patterns of heavy metal in *T. hemprichii* found in the study area significantly differed depending on plant tissue, sampling time, and sampling sites.

Table 5. Mean values ± SE (n=3) of heavy metal accumulation (mg/kg DW) in six Claver, Surigao Del Norte sampling stations.



	Leaves					Rhizomes				
Station	Iron	Nickel	Chromium	Lead	Cadmium	Iron	Nickel	Chromium	Lead	Cadmium
1	2855±470.65**	79.36±6.39**	28.68±2.87	4.266±0.892	3.07±0.933	1297±337.58	30.91±1.79**	9.833±1.084**	2.633±0.488	2.87±0.858
2	1804±155.08	54.71±2.71	16.71±1.06	4.883±1.456	2.37±0.573	1817±555.39	58.56±10.20	21.05±9.603	4.433±1.537	2.55±0.144
3	1352±96.455	51.95±1.98	17.85±0.45	5.433±2.400	2.68±0.295	2072±494.77	34.75±1.250*	12.13±0.593*	4.9±2.775	2.68±0.372
4	2562±671.92**	72.98±13.26	34.56±8.78**	2.833±0.557	1.77±0.209	1644±300.77	42.61±1.76	16.18±2.133	4.166±1.424	2.710±0.441
5	607.1±211.77**	63.81±16.51	18.95±0.964	2.816±0.882	1.93±0.033	540.8±269.04**	37.05±6.748	14.21±1.309	2.083±0.262	1.45±0.333
6	1372±150.89	67±1.89	28.78±1.76	3.216±0.628	2.08±0.476	391.6±112.06**	34.06±1.496*	13.33±0.980*	1.733±0.130	2.16±0.232

*Legend: *p< 0.005, **p<0.01*

Table 6. The trend of heavy metal accumulation in *Thalassia hemprichii.*

Year	**Species Richness**	**Abundance**
1	Fe> Ni> Cr> Pb> Cd	Fe> Ni> Cr> Pb> Cd
2	Fe> Ni> Cr> Pb> Cd	Fe> Ni> Cr> Pb> Cd
3	Fe> Ni> Cr> Pb> Cd	Fe> Ni> Cr> Pb> Cd
4	Fe> Ni> Cr> Pb> Cd	Fe> Ni> Cr> Pb> Cd
5	Fe> Ni> Cr> Pb> Cd	Fe> Ni> Cr> Pb> Cd
6	Fe> Ni> Cr> Pb> Cd	Fe> Ni> Cr> Cd> Pb

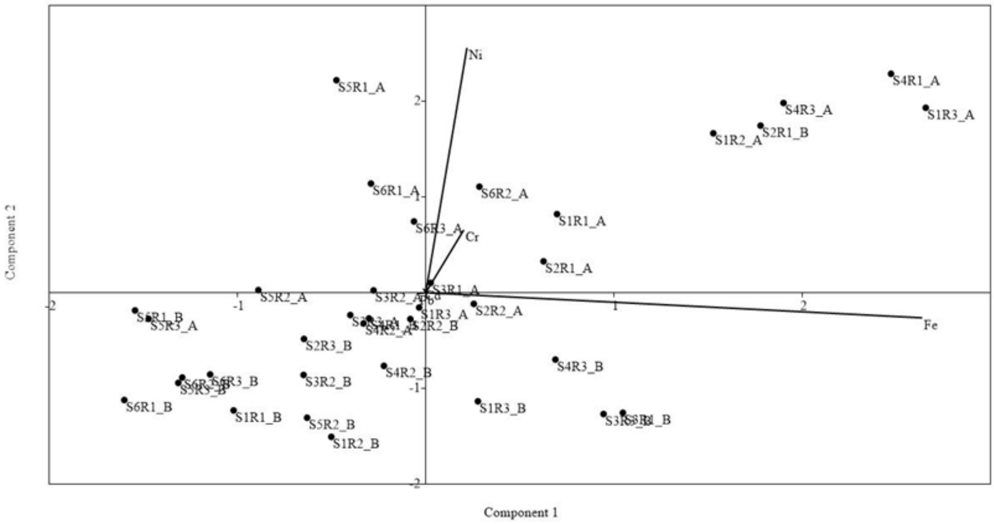


Figure 5. Principal Component Analysis (PCA) of heavy metal uptake by *T. hemprichii*

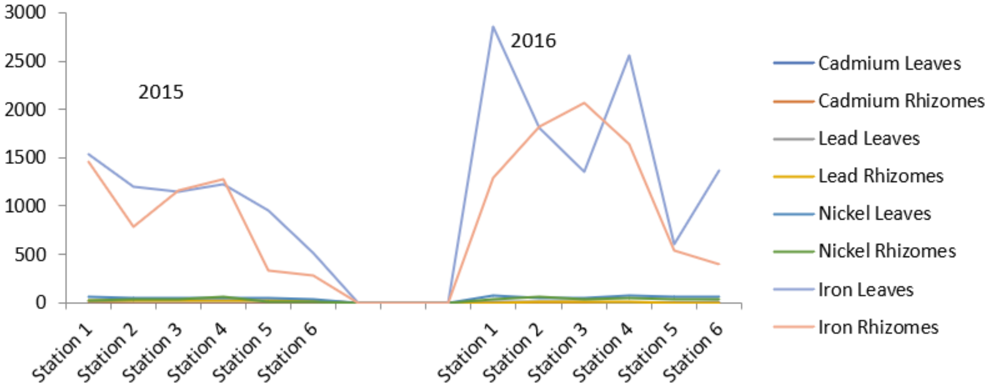


Figure 6. The trend of heavy metal uptake in *Thalassia hemprichii* leaves and rhizomes

4 Conclusion and Recommendations

The diversity of marine benthic macrophytes and heavy metal concentration in terms of Fe, Pb, Cd, Cr, and Ni present in above-ground tissue and below-ground tissue of *Thalassia hemprichii* among selected sampling stations in Cagdianao, Claver, Surigao del Norte has been determined in the present study. Thirty-seven species of submerged marine benthic macrophytes belonging to fifteen families were recorded.

Accumulations of heavy metal in *T. hemprichii* in above-ground tissues (leaves) were much higher than in below-ground tissues (rhizomes). Concentration patterns of heavy metals in *T. hemprichii* found in the study area significantly differed depending on plant tissue and sampling sites.

Further studies on trace elements such as Al, As, Mn, Co, and total Hg should be conducted as another basis for biomonitoring. Comprehensive research should also be conducted to obtain concrete results in analyzing the macrophytes as a potential indicator of heavy metals in the aquatic environment. It would also be imperative to have a map showing the concentration of heavy metals in a particular area. The present study provides two-year data on diversity, species composition, and heavy metal concentration in *T. hemprichii.* These data may help coastal resource management plan to regulate contamination from mining and other anthropogenic inputs along aquatic ecosystems of Cagdianao, Claver, and Surigao del Norte.

5 Acknowledgement

The researchers would like to thank the local officials of Cagdianao in Claver for their assistance during the sampling period. The research was supported by MS thesis grant from the Commission on Higher Education awarded to DR Orboc.

Statement of Conflict of Interest

Joycelyn C. Jumawan, the Editor-in-Chief of JESEG, abstained from the reviewing process of the article in the journal.

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