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“Assessment of the displacement of mangrove species Avicennia sp. on mud clam Polymesoda erosa (Solander, 1876) in planted Rhizosphora mangroves.”

TRABAJO FINAL DE CARRERA

Autor/es:**Joan Pérez Cremades**

Director/es:**Severino G. Salmo III**

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Assessment of the displacement of mangrove species *Avicennia sp*. on mud clam *Polymesoda erosa* (Solander, 1876) in planted *Rhizosphora* mangroves.

Environmental sciences department

Tutor: Severino G. Salmo III
Author: Joan Pérez Cremades

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ABSTRACT

The mangrove ecosystem in the Philippines consists of 35-40 mangrove species. Mangroves use to grow on soft muddy substrate, commonly in estuaries where they can find sheltered and shallow coasts, and they can also grow in more salty waters on island shores and tidal flats

The substrate is one of the most important aspects that determine mangrove distribution, and the macrofauna is one of the things which affect the substrate composition. In this study we will focus on the study of macro-invertebrate fauna (mollusc), and its ecological relationship with the mangrove species.

We are going to study if the lack of plant biodiversity affect to the faunal biodiversity and the ecological quality of mangroves, and our hypothesis are that the monospecific reforestation of mangroves entails the loss of vegetal biodiversity, which is the ecological support of many other fauna and flora species.

To find scientific data and references that endorse those statements, our main aim will be to statistically relate the distribution and abundance of plant and faunal biodiversity. In order to make that tangled task reachable we will focus on a few species. Those are the mangrove species Avicennia sp. and Rhyzophora sp. and the mud clam Polymesoda erosa (Solander, 1876) among other molluscs.

Keywords: Mangrove, Molluscs, *Polymesoda erosa*, *Avicennia sp*., *Rhyzophora sp*..

INTRODUCTION

Background:

- **Mangrove biology/ecology**

The mangrove ecosystem in the Philippines consists of 35-40 mangrove species in 16 families, including 20-30 species of shrubs and vines (The Philippine Biodiversity Conservation Priorities 2002). Mangroves use to grow on soft muddy substrate, commonly in estuaries where they can find sheltered and shallow coasts, an average water temperature of 20 ºC and a variation of 10 ºC due to season fluctuation. Mangrove vegetation can also grow in more salty waters on island shores and tidal flats. This is possible due to an exclusively mangrove adaptation, the expel of the extra salt through roots and leaves. Another characteristic of this kind of vegetation are the root pneumatophores, which allow mangroves to adapt to the altering effects of desiccation and inundation. These pneumatophores are pores in roots that allow oxygen to pass through. Some of these trees also have the adaptation to manage tidal fluctuation by germinating seeds while they are still attached to the tree (Catibog-Sinha CS, Heaney LR. 2006, Philippine biodiversity: Principles and practise).

As we can deduce from that, the substrate is one of the most important aspects that determine mangrove distribution. And one of the things which affect the most the substrate composition is the macrofauna that lives in. In this study we will focus on the study of macro-invertebrate fauna (mollusc), and its ecological relationship with the mangrove species.

The gastropods for example, within the rest of animals that compose the macro benthos, are closely related with the bottom substrate by modifying it in many physical and chemical ways. They live in the mud, bury and hide in it and even ingest it within the organically particles they feed from. That mixes the different soil layers, makes holes and structures on the plain mud, and brings oxygen to the anoxic bottom layers.

Macrofauna also affect the mangrove distribution directly. For instance, crabs and gastropods are considered two of the major seed predators of mangrove tree species, and by that they can really determine the plant community structure.

The parameters that determine the distribution of gastropod species and mangrove forest besides the substrate type are light, tidal exposure and salinity. This framework forms the different niches of the mangrove ecosystem for gastropods. According to the study carried out by I. Nagelkerken, S.J.M. Blaber, S. Bouillonc, P. Green, M. Haywood, L.G. Kirton, J.O. Meynecke, J. Pawlik, H.M. Penrose, A. Sasekumar, P.J. Somerfield 2007 “mangrove invertebrates often show marked zonation patterns, and colonise a variety of specific micro-environments. While some species dwell on the sediment surface or reside in burrows, others live on pneumatophores and lower tree trunks or prop-roots, burrow in decaying wood, or can even be found in the tree canopies”.

On the other hand some biological groups can have a wide-spread distribution through different niches, or even change their behaviour and distribution depending on the part of the world where they live. For example bivalves are often considered to be confined to a narrow seaward zone, due to larval settlement and feeding restrictions. Nevertheless in Southeast Asia, *Polymesoda erosa*, is adapted to a partially terrestrial environment; the high shores just reached occasionally by high tides.

- **Description of Polymesoda sp.**

Polymesoda is a small genus of molluscs in the family *CORBICULIDAE*. It belongs to the Order Veneroida of the bivals. In Southeast Asian mangroves, *Polymesoda* (*Geloina*) *erosa* (Solander, 1786), is one of the most common of this genus. It is widely distributed on the landward fridge and in the small water pools that are formed at the bases of the mangrove trees. It is founded also buried in the mud that is only reached by water on the high tides, usually hided in between the mangroves roots. This genus is characterized by having separate sexes.

A good physical description of the diagnostic characters can be found on “A review of *Polymesoda* (Geloina) Gray 1842 (Bivalvia: *CORBICULACEA*) from Indo-Pacific mangroves.” by Morton, B. 1984. “The shells of these marsh clams are equivalve, very thick and generally not gaping. Umbones prosogyrate, nearly at or in front of the midline of valves. No lunule or escutcheon.Sculpture, when developed, mainly concentric. Periostracum conspicuous, often fibrous. Ligament external, a thick arched band behind the umbones. Hinge with 3 diverging cardinal teeth in each valve, and strong anterior and posterior lateral teeth which may be transversally striate. Interior of shellporcelaneous. Two subequal,rounded adductor muscle scars. Pallial sinus reduced or absent. Internal margins smooth. Gills of eulamellibranchiate type, fused to each other behind the foot; outer demibranch with or without an expansion above the axis. Foot generally grooved and hatchet-shaped. Mantle broadly open ventrally. Siphons short.”

- **Ecological and socio-economic importance of mangroves**

Seafood has been traditionally, on the mangrove coastal zones of Southeast Asia, one of the main food sources for the native population. That is because mangrove conditions are suitable for the recruitment of a wide variety of edible species. Among them are mainly fishes, shrimps and many other invertebrate species such as shells.

Mangroves naturally trap runoffs from the land ecosystems and the agricultural areas, and that runoffs contain sediment and organic material used as food for mainly fish and crustaceans among others.

About 80 to 90% of the demersal fisheries are dependent, directly and indirectly, on mangroves for food and shelter. The sustained productivity of mangroves also depends on the ecological integrity of the mangrove forest itself. For instance, it was documented that near-shore fish and shrimp catches are directly correlated with the presence/abundance of mangroves (Camacho and Bagarinao 1987 in Primavera 1998)

Mangroves also provide the perfect environment for aquaculture production what is one of the activities that is lately increasing the national economy and even for the protection of the natural stocks. So the governments are starting to be concerned about the restoration and conservation of those ecosystems.

Aquaculture in second-growth and rehabilitated mangrove forests may be allowed under the existing regulations set by the local government. Fish and shrimp in aqua-ponds contribute to the national economy and provide one-third of the protein requirements of Filipinos (Primavera 1991, 2000; Jansen and Padilla 1997).

Other important services provided by mangroves, that make them worthy of this care, have been recorded on the the FAO report of “The world’s mangroves 1985-2005”:

- Fishermen, farmers and other rural populations depend on them as a source of wood (e.g. timber, poles, posts, fuelwood, charcoal) and non-wood forest products (food, thatch – especially from nipa palm – fodder, alcohol, sugar, medicine and honey).

- Mangroves support the conservation of biological diversity by providing habitats, spawning grounds, nurseries and nutrients for a number of animals.
- Mangrove ecosystems are also used for aquaculture, both as open-water estuarine mariculture (e.g. oysters and mussels) and as pond culture (mainly for shrimps).
- The increasing popularity of ecotourism activities also represents a potentially valuable and sustainable source of income for many local populations, especially where the forests are easy accessible.
- Mangroves also help protect coral reefs, sea-grass beds and shipping lanes by entrapping upland runoff sediments. This is a key function in preventing and reducing coastal erosion and provides nearby communities with protection against the effects of wind, waves and water currents.

- **Mangrove statistics in the Philippines**

Mangroves have been considered, despite their many services and benefits provided, as wastelands or even unhealthy environments on the last centuries. As a result, the high population has pressured this ecosystems leading to the conversion into areas for urban development, fish and shrimp farming, agriculture and salt production.

Mangroves have also been fragmented and degraded through overexploitation for wood forest products and pollution. And also natural disasters, such as cyclones, typhoons and strong winds can damage and uproot trees situated in those shore lines.

Despite the efforts of the conservation organizations and the slowly change of viewpoint of the government, the rate of mangrove destruction have not been stopped. “In the Philippines, natural resources, such as mangrove forests, are owned by the state, but because of weak state institutions and lax implementation of laws, a de facto open-access situation persists.” (Ronald J. Maliao, Bernice B. Polohan, 2007). The next table can show how hectares of mangrove loss are decreasing, but the total percentage of mangrove loss remains. This means that the efforts are not enough and the mangroves are still a very endangered ecosystem.

	most recent reliable estimate		1980	1990	Annual change 1980-1990		2000	Annual change 1990-2000		2005	Annual change 2000-2005	
Country	ha	Ref year	ha	ha	ha	%	ha	ha	%	ha	ha	%
Philippines	247 362	2003	295 000	273 000	-2200	-0,8	250 000	-2300	-0,9	240 000	-2000	-0,8

Table 1. Status and trends on mangrove area. Source the FAO report “The world’s mangroves 1985-2005”

- **Consequences of mangrove loss**

The importance of the mangroves have been already highlighted, and by consequence the effects that their lack would mean.

The effects of the biodiversity crisis in the Philippines are now felt more than ever whenever floods and landslides wreak havoc on our daily lives. The costs attributed to the biodiversity crisis range from the billions of pesos lost in the destruction of crops and fisheries, homes, roads and bridges, to the actual loss of human lives. The impact of the reckless pursuit of economic development at the expense of the environment and biodiversity, and a rapidly expanding population that requires more and more natural resources to meet their needs and demands further exacerbates the pervasive poverty among the Filipino people.

The development paradigm of the last 20th century has been destructive to the environment yet it never alleviated or eradicated poverty. Only when the environment, particularly biodiversity conservation, is included in the development equation, will poverty eradication programs have long lasting impacts and be sustainable. (The Philippine Biodiversity Conservation Priorities 2002).

- **Mangrove restoration**

The need of mangrove restoration started around 100 years ago "in 1918" (Brown and Fischer 1920), when those plantations were made in order to produce wood and alcohol. Afterwards some regions in of the Philippines started planting with the aim of protect themselves from storms and typhoons "1930s–1950s for community initiatives in Negros, Bohol and the Visayas. This was followed by government-initiated projects in the 1970s and international development assistance programs […] in the 1980s." (J. H. Primavera, J. M. A. Esteban, 2008). Nevertheless, over the last two decades the mangrove restoration objectives have changed. Other objectives and needs have appeared as people have started to understand the mangrove ecology and have started to be aware of the services that mangroves provide, locally (ex. increasing of fish catches, tourism) and worldwide (ex. Biodiversity conservation, CO_2 retention).

The protection of mangroves is embodied in the Philippine Agenda 21, which defines the government strategies towards a sustainable development. On this article the mangrove restoration program should have 3 main objectives:

1. The value of products and services generated (economic efficiency);

2. The distribution of these values across the various stakeholders (equity);

3. Sustainability of the type of use (environmental quality).

In order to succeed on this national project it has to be used an approach which combines a cost-benefit analysis and a multicriteria analysis. Decision makers have to count on the benefits all services that mangroves provide, so they can elaborate reliable studies of the national income and wealth due to conservation. But they also have to work within the different approaches of their society, which means, individual interests (for ex. owners and workers of the fishponds) and the local government interests (for ex. local employment) Distribution of income is a central political issue, especially in developing countries. “Benefits from fisheries are received by local, usually poor, fishermen. Benefits from fishponds, due to their high investment costs, accrue to distant, rich investors. Conversion of mangroves to fishponds therefore results in an unfavourable change in income distribution which is not reflected in total value. It also creates areas that are no longer accessible to the local population.”(Ron Janssen and Jose E. Padilla, 1999).

Other objective, based on the studies of several scientific that work on this field, would be in order to preserve an ecological health and environmental sustainability, to have surface relation mangrove covering- fish ponds of at least 1:1. Nowadays the relation do not even reaches 0.5:1.

Last initiatives have reached some of the objectives, or at least are helping to. New mangroves provide food, shelter and environmental protection for marine organisms and in consequence to humans living in seashore areas. Also the branches of mangrove trees provide nesting areas for other kind of organisms, like birds, which also feed from marine resources.

The main peculiarity of this ecosystem is the root system that the trees develop. It provides oxygen to the anoxic mud, changing physical and chemical characteristics of the soil. It also provides shelter against strong winds and waves during tropical storms and typhoons. As well these root systems hold the soil and protect the shoreline reducing the erosion process.

On the other hand the efforts for increasing the mangrove coverage where made through planting a single mangrove tree specie, *Rhizophora sp*.. Moreover those replanting projects took place “converting mudflats, sandflats, and seagrass meadows into often monospecific mangrove forests, making the ecological gains of such efforts highly uncertain.”(Maricar S. Samson and Rene N. Rollon, 2008), as the natural mangrove areas are now occupied by fish ponds. All of that controvert highly the main objectives mentioned above.

Further, on these areas, the new planted mangroves experienced a high mortality rate, and among the survivals it have been noted displayed stunted growth compared to the natural mangroves growth in intertidal position.

Obviously current practices and strategies on mangrove replanting and restoration in the Philippines need to be reviewed.

An ecological healthy ecosystem will provide a wider range of seafood sources, not only but the marine organisms, but in consequence also to the humans that populate those areas. It would also provide a raised amount of interesting species from the economical point of view such as fish and shrimps. Other species that can be recruited for human consumption could be the birds that inhabit those areas through a hunt regulates process.

Conceptual framework:

Does the lack of plant biodiversity affect to the faunal biodiversity and the ecological quality of mangroves? Our hypothesis is that the monospecific reforestation of mangroves entails the loss of vegetal biodiversity, which is the ecological support of many other fauna and flora species. Mud clam species *Polymesoda erosa* is believed to be associated with the *Avicennia*'s root system. So it is expected its displacement along with the *Avicennia*'s.

Awareness of the importance and value of mangrove ecosystems has been growing. This leads towards the preparation and implementation of new legislation and to better protection and management of mangrove resources. Also we can observe the increase of replantation plans in mangrove areas by the governments and some organizations.

But despite the increasing awareness, there is still much needed to be done in order to effectively conserve these vital ecosystems. Not always the governments, local people and organizations are reacting in the best way, sometimes due to lack of information.

What scientists have been observing on the replanted areas is that those repopulations are being mono-specific, threatening the biodiversity values. That means that only the mangrove species that are cheap on nursing and have higher survival expectancy are being planted. Another problem is that the natural distribution of different species is not being respected, what can affect to long term health and viability of the ecosystems.

To find scientific data and references that endorse those statements, our main aim will be to statistically relate the distribution and abundance of plant and faunal biodiversity. In order to make that tangled task reachable we will focus on a few species. Those are the mangrove species *Avicennia sp*. and *Rhyzophora sp*. and the mud clam *Polymesoda erosa (Solander, 1876)* among other molluscs.

MATERIAL AND METHODS

Experimental design

The study was performed on mono-specific planted mangroves of *Rhyzophora mucronata*. It was carried out on two different mangrove sites (Bangrin and Pilar mangroves) on which were found reminiscent scattered specimens of *Avicennia* sp. The goal of the study was to find out if there exist correlations between flora and fauna biodiversity.

With that aim on each site we delimited a zone representative of the mature mangrove. Some trees of both species of interest were selected and identified as our study plots. Then we recruited the mollusc species out of a parcel on the tree root system influence. As we need to take into account the physic-chemical parameters, those were also measured on this parcel.

The idea is to find different mollusc species on the different tree species, different abundance, and study if there is any correlation between them and the influences of the other parameters.

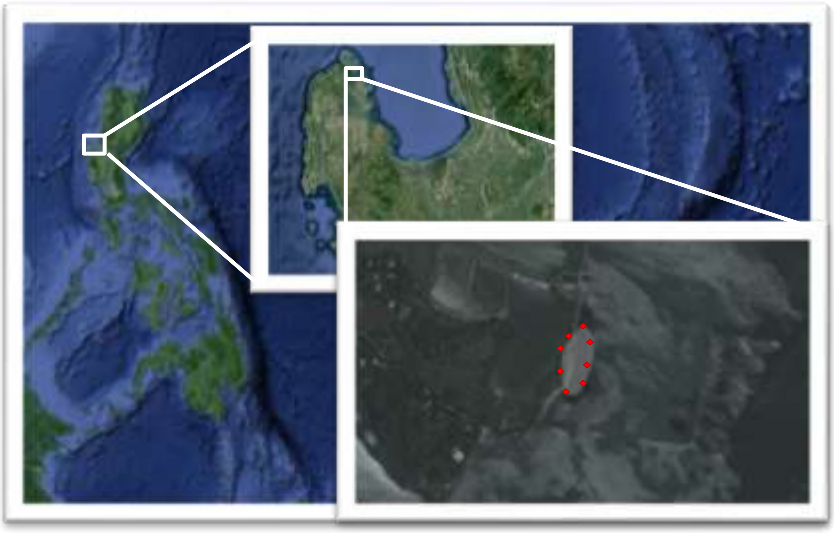
Site description

There were two different study sites, the Bangrin mangroves (Bani) and Pilar mangroves (Lucero). Both of them are mono-specific planted mangroves of *Rhyzophora mucronata* and were also affected in greater or lesser extent by recent typhoons.

Bangrin mangrove forest has a total surface of 42.25 hectares, being the largest of the two. This one has species of *Rhyzophora sp.* of different ages and different age groups are distributed and concentrated in patches, according to the year they were planted. The chosen study site its situated between 16º14''958 and 16º14''972N latitude; 119º55''648 and 119º55''679E longitude. This plot corresponds to the least exposed zone to tidal oscillations, near to the fish ponds which used to be the mangrove natural habitat. The study site was chosen due to the existence of scattered specimens of *Avicennia sp*. in between the *Rhyzophora* specimens, which were much more abundant.

Map 1. Bangrin mangrove protected area and study site 1. (red spots)

Pilar mangrove has a surface of just 1 hectare, being much smaller than the first one. This site has a mature central forest of Rhyzophora sp. surrounded by new plantings. As in Bangrin, it is limited in the intertidal zone by fishponds. In the strip that separates the fish ponds from the new plantations some *Avicennia sp*. specimens are found. Those are thought to be reminiscent from the natural mangrove that used to be. Some of this few *Avicennia sp*. trees were slightly higher than the rest of the mangrove. The study site matches the mature tree zone with the following coordinates: 16º22''265 - 16º22''316N latitude; 119º57''821 - 119º57''839E longitude.



Map 2. Pilar mangrove protected area and study site 2. (red spots)

Sampling

In order to simplify and homogenize the obtained data, we have chosen representative plots of the mangroves studied. Those plots shared the same tide level and were on the mature part of the mangroves. On each site 4 examples of *Avicennia sp.* and 4 of *Rhyzophora sp.* were chosen, and bivalves and gastropods were recruited on a parcel of 1 m^2, 5 meters around the trees. Biological samples were categorized according to 3 categories: Tree fauna, Epifauna and clams. Specimens sampled were identified, weighed and length measured *in situ*.

Besides, on each chosen tree we sampled the parameters of RedOx, EC, Luminosity, pH, Air Tº, Soil Tº and Salinity. Those parameters are thought to influence directly the distribution and abundance of fauna and even to being influenced by the same fauna.

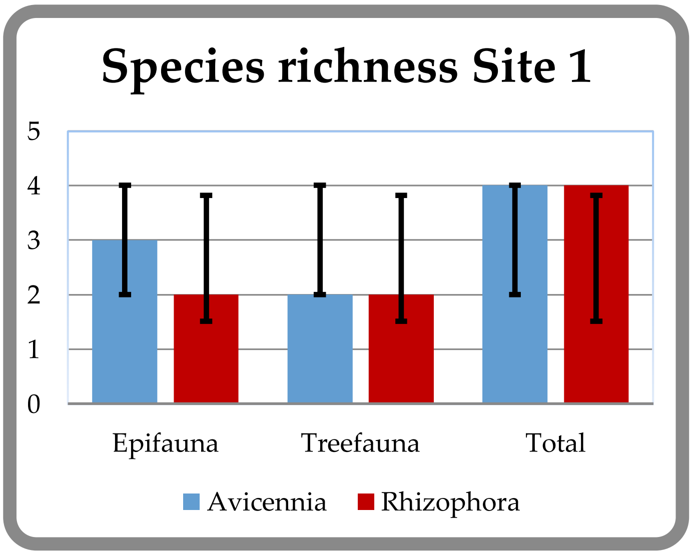
Data analyses

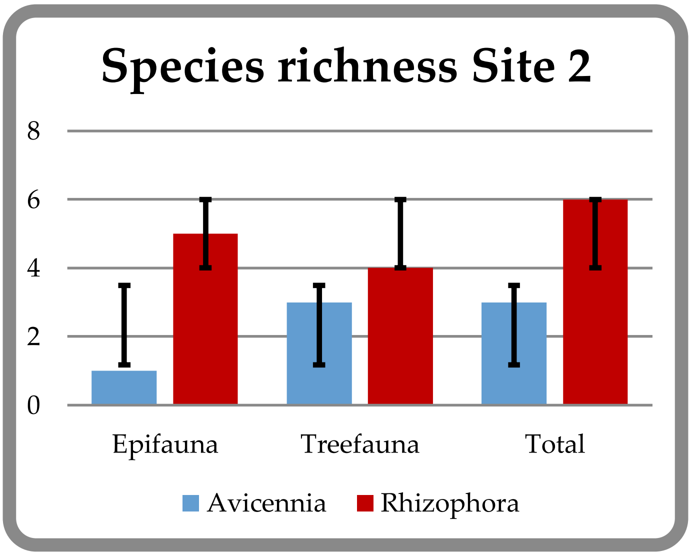
All data were then included in an Excel 2010 data base and statistically analysed with the same program. The statistical analysis was focused on four main targets: Species richness, length-weight relationship, abundance and biomass. All of them were compared among the two species of mangrove trees and between the two sampling sites.

RESULTS

Species richness:

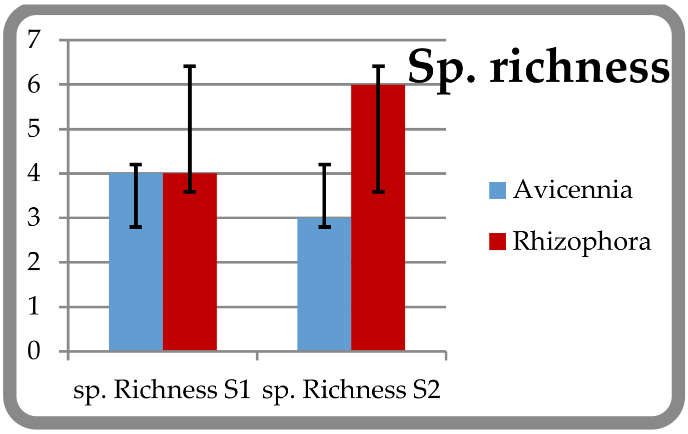
A total of 9 species were found within the two mangrove sites. Those were: *Cerithidea sp., Gafrarium pectinatum, Isogriomon ephippium, Nassarius arcularius, Nerita phanospira, Perna viridis, Polymesoda erosa, Terebralia sulcata* and *Telescopium telescopium*.





Graphic 1. Specie richness on sites 1 and 2.

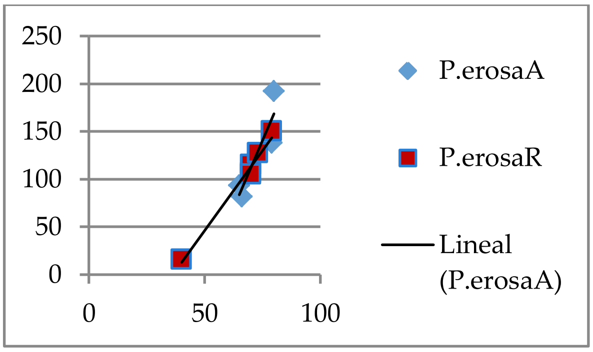
On site 1 the number of different species was almost the same among epifauna, treefauna and in the total area of study of each tree. Nevertheless on site 2 the difference its remarkable. The epifauna on *Avicennia* influence area consisted on one unique specie; *Cerithidea sp*., while on *Rhyzophora* were found up to 5 different species. In the total account of site 2, *Rhyzophora* has double of species (6) than *Avicennia* (3).



Graphic 2. Total specie richness comparison between sites 1 and 2.

Length-Weight relationship

In order to study the Length-Weight relationship we applied to the disperse graphs tendency lines. In all epifauna species the result was the same but in *Polymesoda erosa.* The disperse graphs shown the length-weight points for *Avicennia* and for *Rhyzophora*, and their tendency lines, that were in all cases close enough. But for *Polymesoda sp*. the lines were crossing.

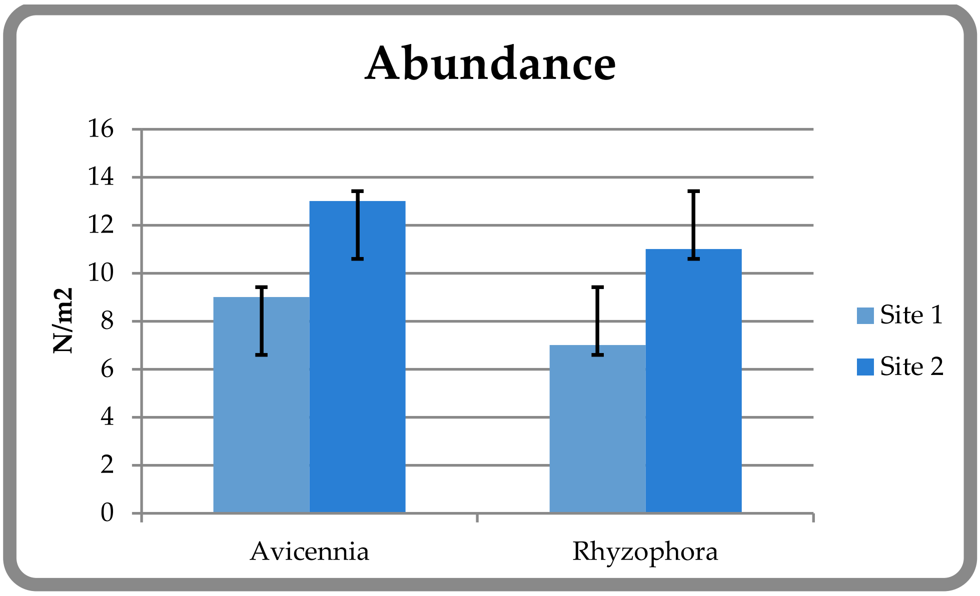


Graphic 3. Tendency lines of P. erosa weight-length relationship

A t-test study was carried out for all the species, and the result was the same for all of them. We supposed in our null hypothesis (H_0) that the length-weight relationship was equal for the 2 mangrove trees. In all cases the value for the 2 tail t-test assuming different variances was larger than 0.05. In *Polymesoda erosa's* case, t-test value was 0.39 (>0.05), bearing out our null hypothesis. So the graph tendency line could not have enough values for an accurate representation.

Abundance

In order to obtain the abundance we calculated the number of molluscs per square meter. That is the number of mollusc samples that we have on each plot, as we were sampling one square meter on the influence surface of the tree. Then we calculated the average abundance among same tree species. Next graph shows the results with the average data.

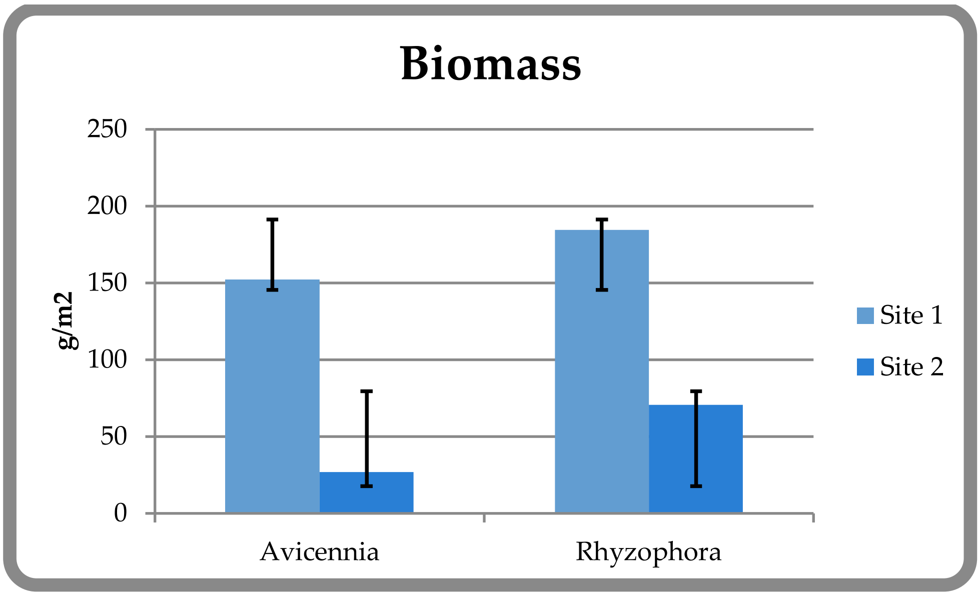


Graphic 4. Abundance on Avicennia and Rhyzophora on both sites.

As we can see the standard deviation is not so large, but we can also appreciate that in both cases (Site1, Site2) the abundance is larger on *Avicennia*'s trees than on *Rhyzophora*.

Biomass

The biomass was calculated dividing by the number of plots, the sum of all sampled molluscs weights. Obtained values are represented on the next graph.



Graphic 5. Biomass on Avicennia and Rhyzophora on both sites.

As can be seen the main difference on the biomass case is not between tree species but between sites. Both Avicennia and Rhyzophora on site 1 have a much larger biomass while on site 2 both of them have lower biomass and larger deviation.

DISCUSION AND CONCLUSION

Even though it was not possible to demonstrate a significant difference on mollusc size by the specie of tree were they live, we found other remarkable facts.

Concerning the species richness, it was almost equal for the first site, were the *Avicennia* trees were well represented among *Rhyzophora*. In the second site the mollusc species diversity was way larger on *Rhyzophora* but that could be because of the lack of *Avicennia* representation. An study should be carried out on similar sites with the same tree diversity and distribution in order to find out more reliable data.

The abundance of molluscs has not a big difference between the two kinds of trees but still it was larger on Avicennia's trees. Than can be explained by the bigger surface that provides Avicennia root system, what allows more small animals to live in.

Al last the biomass is maybe the most remarkable parameter. It was much larger on the first site (Bangrin). That could be because it is in fact a much larger mangle, what makes logical to think it could be able to hold a bigger biomass. Another reason could be that it is a healthier mangle (understanding by healthier that is more diverse on mangrove tree species and has a considerable size). But of course that hypothesis should be hold by a more focused study on biomass among different mangle sites.

REFERENCES

- Brown and Fisher. 1920. Philippine Mangrove Swamps.Minor Forest Products of the Philippines Vol. I, 22, DANR, Bureau of Forestry Bul. No. 17.

- Camacho A. S., Bagarinao T. 1986. Impact of fishpond development on the mangrove ecosystem in the Philippines, p. 383-405. in UNESCO/UNDP, Mangroves of Asia and the Pacific: status and management. (RAS/79/002) UNDP/UNESCO Research and Training Pilot Programe on Mangrove Ecosystems in Asia and the Pacific, Manila, Philippines.

- Catibog-sinha CS, Heaney LR. 2006. Philippine Biodiversity: Principles and Practice. Quezon city: Haribon Foundation for the Conservation of Natural Resources, Inc. 222-223.

- FAO 2007. The world's mangroves 1980-2005. A Thematic study prepared in the framework of the Global Forest Resources Assessment 2005. FAO forestry paper 153. Food and Agriculture Organization of the United Nations. Rome.

- Gosner, L. Kenneth. Guide to Identification of Marine and Estuarine Invertebrates. Wiley-Interscience. New Jersey, U.S.A., 1971. ISBN 0 471 31897 3.

- Jansen R., Padilla J. 1997. Valuation and Evaluation of Management Alternatives for the Pagbilao Mangrove Forest. Collaborative Research in the Economics of Environment and Development (CREED) Working Paper Series Nº9, International Institute for Environment and Development (IIED), London.

- Liberato V. Laureta. Compendium of the economically important sea shells in Panay, Philippines. The University of the Philippines Press, Diliman, Quezon City. Philippines, 2008.

- Maricar S. Samson and Rene N. Rollon. 2008. Growth Performance of Planted Mangroves in the Philippines: Revisiting Forest Management Strategies. Ambio Vol. 37, No. 4, June 2008 234-240.

- Morton, B. 1984. A review of *Polimesoda (Gelonia)* Gray 1842 (*Bivalvia: Corbiculacea*) from Indo-Pacific mangroves. Asian Marine Biology. 1: pp 77-86. Hong Kong: Department of Zoology, The University of Hong Kong.

- Nagelkerken I., Blaber S.J.M., Bouillonc S., Green P., Haywood M., Kirton L.G., Meynecke J.O., Pawlik J., Penrose H.M., Sasekumar A., Somerfield P.J.. 2007. The habitat function of mangroves for terrestrial and marine fauna: A review. Aquatic botany 89 (2008) 155-185.

- Ong, P.S., L.E. Aufang, and R.G. Rossel-Ambal (eds.) 2002. Philippine Biodiversity Conservation Priorities: A Second Iteration of the National Biodiversity Strategy and Action Plan Deparment of Enviromental and Natural Resources – Protected Areas and Wildlife Bureau, Conservation International Philippines, Biodiversity Conservation Program - University of the Philippines Center for Integrative and Development Studies, and Foundation for the Philippine Enviroment, Quezon City, Philippines.

- Philippine Agenda 21. 1992. Philippine Sustainable Development Network. http://www.psdn.org.ph/

- Primavera, J. H. 1991. Intensive prawn farming in the Philippines: ecological, social, and economic implications. Ambio, 20(1): 28-33.

- Primavera, J. H. 1998. Mangroves as nurseries: shrimp populations in mangrove and non-mangrove hábitats. Est. Coastal Shelf Sci. 46: 457-464.

- Primavera, J. H. 2000a. Development and conservation of Philippine mangroves: Institutional issues. Ecological Economics. Vol 35 p 91.

- Primavera J. H., Esteban J. M. A. 2008. A review of mangrove rehabilitation in the Philippines: successes, failures and future prospects. Wetlands Ecol Manage, DOI 10.1007/s11273-008-9101-y.

- Ronald J. Maliao, Bernice B. Polohan. 2007. Evaluating the Impacts of Mangrove Rehabilitation in Cogtong Bay, Philippines. Enviromental Assessment. Environmental Management (2008) 41:414–424 DOI 10.1007/s00267-007-9021-2.

- Ron Janssen, Jose E. Padilla. 1999. Preservation or Conversion? Valuation and Evaluation of a Mangrove Forest in the Philippines. Environmental and Resource Economics 14: 297–331.

- Tinker, W. Spencer. Pacific sea shells: a handbook of common marine molluscs of Hawaii and the south seas. Charles E. Tuttle company. Rutland, Vermont & Tokyo, Japan. 1952.