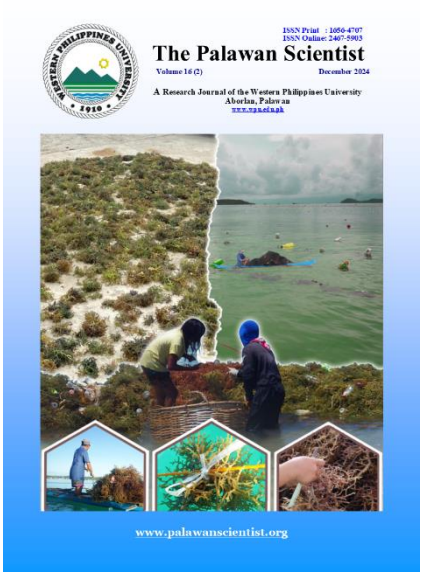
Review Paper



The ecological status and fisheries of Malampaya Sound, northwestern Palawan, Philippines

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ABSTRACT

A review of the state of the marine ecosystem and fisheries of Malampaya Sound, Palawan was undertaken. A total of 30 papers relevant to the topic were selected and reviewed. The results showed that the rich and diverse coastal waters of Malampaya Sound harbor 8 species of seagrasses, 9 species of mangroves, 262 species of fish, and various species of corals and macroinvertebrates including the rare giant clams *Tridacna* spp. The Sound plays a vital role in the local economy because the local community uses it for subsistence fishing and as a source of livelihood. It is so productive that it was termed the "fishbowl of the country" because it provides a substantial contribution to the country's fishery sector and economy. However, degradation continuously threatens it, most of which are interrelated anthropogenic issues. The declining environmental condition of the area prompted the government to close it for commercial fishing in the 1970s. Several conservation measures have been undertaken since then to preserve its remaining resources, including its declaration as a protected landscape and seascape in 2000. Despite this, if not for a slight improvement, the condition has worsened. So far, only the mangrove ecosystem has dramatically improved. Seagrass and coral reefs are still in poor to fair condition. A collective effort by the community and government agencies, with the support of the academe and non-government organizations, coupled with strict enforcement of existing laws, income diversification for the locals, monitoring of environmental parameters, and implementation of sustainable fishing practices, is necessary to achieve sustainable use of the area.

Keywords: conservation, ecoregion, fishing ground, last frontier

INTRODUCTION

Malampaya Sound is part of the larger Malampaya Sound Protected Land and Seascape. It is located at 10.8464° N, 119.3654° E, on the northwestern side of Palawan Province, Philippines (Figure 1). This rich marine area covers 24,000 ha and includes 10 barangays from the municipalities of San Vicente and Taytay. It is a protected inlet consisting of complex sheltered bays, coves, and islands, with a

marine area of approximately 240 km^2. It is an estuary system that receives water from 30 river systems. It is divided into two sections, the Inner and the Outer Sound, which are home to diverse ecosystems of seagrasses, mangroves, and corals (DENR 2001).

During the 1960s, Malampaya Sound was a significant and thriving traditional fishing ground in the Philippines. Located at the northwestern tip of Palawan Island, on the western part of the archipelago, the Sound is a popular tourist destination for diving and Irrawaddy dolphin watching. At the same time, it serves as an area for subsistence fishing for local fisherfolk. It has a rich and diverse ecosystem and was considered a fishbowl in the 1970s. However, the increasing demand for marine fish food did not spare the Sound from overexploitation. Ecological stress is brought about by degrading human activities has caused damage to corals and other marine life (McNeely et al. 1990; Deocadez and Aliño 2005). This can permanently impact ecological timelines when combined with changing climate conditions due to rising atmospheric carbon dioxide (Bindoff et al. 2005; Doney et al. 2012; Doney et al. 2016).

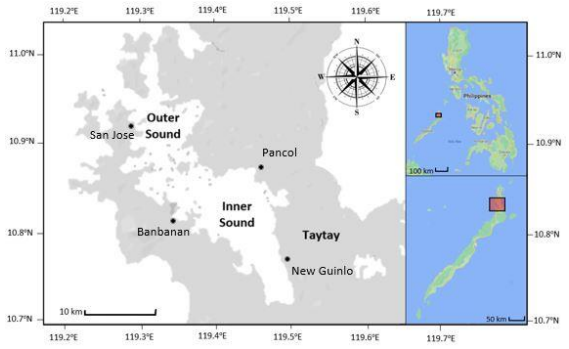

Figure 1. The Malampaya Sound Protected Landscape and Seascape, Taytay, Palawan is located in the northwestern sector of Palawan province, Philippines.

Fish stocks cannot sustain their population due to the compounding effects of natural and anthropogenic causes, resulting in the depletion of marine species (Pauly et al. 2002, 2005). The area was closed for commercial fishing activities in 1973 because it was already heavily overfished (Ronquillo and Llana 1987). In 1986, stricter conservation measures were implemented, allowing only municipal fishing boats (3 GT or less) to use handline, spear, crab hook, cover pot, fish trap, fish pot, pole and line, gill net for fish, and shrimps, fish corral, and beach seine for fishing in the area. To further conserve the remaining marine resources, ensure continuity and sustainability of species, replenish fish stocks, and increase the biodiversity of flora and fauna in the area, it was declared a protected landscape and seascape in 2000.

This paper does not generate new field data; instead, it uses existing literature to answer the research question, "What are the current ecological conditions and trends in Malampaya Sound?" This research question focuses on the environment and fisheries within the context of Malampaya Sound. It investigates the status of the ecosystem including aspects of biodiversity, and habitat health. Moreover, described the fishery resources and activities. The degrading ecological conditions of Malampaya Sound, mainly due to anthropogenic activities, lead to a decline in biodiversity and habitat quality. As a result, it negatively impacts the productivity and sustainability of its fishery resources by reducing fish stocks and altering species composition. In effect, it decreases economic opportunities for local fishing communities. The implementation of applicable conservation measures and restoration activities is vital to achieving ecological resilience and sustainable fisheries.

THE REVIEW PROCESS

This study describes the current conditions of major coastal ecosystems in Malampaya Sound, including seagrass, mangroves, and coral reefs. It also presents information on area utilization and fisheries. It also identified the factors affecting the area and ascertained the threats, problems, and resource issues.

A review was undertaken on the state of the marine environment of Malampaya Sound, Palawan. A thorough search was done on Google Scholar for literature in April 2024. The probe revealed that there have been very few studies conducted on Malampaya Sound. From the year 2000, only an average of 2 articles every year were published in scientific journals. These are mainly related to biodiversity, coastal resource management, geology, and aquaculture. Due to the scarcity of information from the published papers in journals, government reports, and other technical papers were also considered in the review.

The initial output of the search revealed a total of 452 literature (Table 1). They were screened and selected based on their titles and the relevance to the study. A total of 30 papers relevant to the topic were selected for review. Data were gathered from each article, paper, or report and were categorized and grouped into seagrass, mangroves, coral reefs, and fisheries.

CURRENT STATE OF MAJOR COASTAL ECOSYSTEMS

The Sound has a diverse coastal environment with various ecosystems, such as seagrass meadows, mangrove forests, and coral reefs that are extremely rich in biodiversity and productivity.

Seagrass

Seagrass beds serve a variety of ecological functions. They cover sandy areas of the ocean floor and serve as nursery and breeding grounds for small fish and invertebrates, not just food and shelter. In Malampaya Sound, they cover an area of about 21 km^2 (PNSS 2004), mainly in Barangay Banban, Bucal, Liminangcong, San Jose, and Tumbod (PCSD 2006; dela Peña et al. 2015b) (Table 2). There are 13 species found in the Philippines, but only eight are thriving in the Sound. These species are: *Enhalus acoroides* Royle, 1839; *Cymodocea rotundata* Asch. and Schweinf.; *Cymodocea serrulata* Ascherson and Magnus, 1870; *Halodule pinifolia* Hartog; *Halodule uninervis* Ascherson; *Halophila ovalis* Hooker, 1858; *Syringodium isoetifolium* Dandy; and *Thalassia hemprichii* Ascherson, 1871. In 2004, a baseline survey found that the outside of the Sound had a percentage cover of these species ranging from very poor to poor (8 –30%). However, the monospecific stands of *E. acoroides* thickly cover the inner Sound (PCSD 2006; dela Peña et al. 2015b).

Table 1. The search string used and the resulting literature reviewed.

Search String	("Malampaya Sound" OR "Northwestern Palawan") AND ("Coastal ecosystems" OR "Marine biodiversity" OR "Ecological status" OR "Fisheries" OR "Aquatic Biodiversity" OR "Biodiversity" OR "Habitat health" OR "Water quality" OR "Ecosystem degradation" OR "Sustainable fisheries" OR "Fish population dynamics" OR "Anthropogenic impacts" OR "Fishing communities" OR "Conservation measures" OR "Resource management" OR "Management strategies" OR "Marine protected areas" OR "Marine conservation" OR "Resource management" OR "Environmental monitoring" OR "Environmental impact")
Initial Search	452
Titles that Qualified	46
Papers Relevant to the Review	30

Table 2. The seagrasses of the Malampaya Sound, Palawan, and the Philippines. Note: Asterisks indicate sources of the literature.

Location	**Area Covered (**km^2)	**Number of Species Present**	**Status**	**Author**
Malampaya Sound	21 *	8**	8-30% in Outer Malampaya Sound, 100% in Inner Sound***	*PNSS 2004 **PCSD 2006 ***CHE-UPLB 2015
Palawan	187* (excluding Tubbataha Reefs and Spratlys)	10**		*Fortes 2004 **PCSD 2015
Philippines	978	16		World Bank 2005

Mangroves

Another critical ecosystem found in Malampaya Sound is the mangroves. These plants serve various ecological and economic functions that line the intertidal zones of the area. It was estimated to cover an area of 2500 ha in 1985 (Figure 2). A decline occurred in 1998 when excessive harvesting for charcoal and housing materials reduced the cover by half (Pilien and Walpole 2003; dela Peña et al. 2015b). However, according to a recent report, the mangrove population has dramatically improved, covering 3342 ha in 2017 (Table 3) (PSA 2020).

Based on the study conducted in 2004, there are nine mangrove species commonly found in the Sound, namely: *Rhizophora apiculata* Blume, *Rhizophora mucronata* Poir, *Xylocarpus granatum* J. Koenig, *Bruguiera cylindrica* Blume, *Ceriops tagal* C.B. Robinson, *Bruguiera gymnorrhiza* Lam,

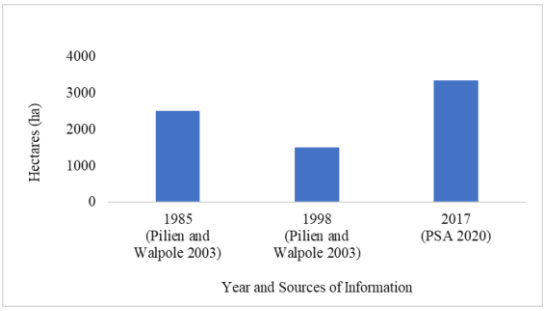

Figure 2. Temporal changes of mangrove cover in Malampaya Sound, Palawan.

Excoecaria agallocha L, *Scyphiphora hydrophyllacea* C.F.Gaertn, and *Lumnitzera littorea* Voigt (Table 4) (PCSD 2006). The percentage cover was assessed as "moderate" to "high" in several barangays, including Old and New Guinlo, Alacalian, Abongan, Banbanan,

Liminangcong, and Pancol. All areas, except San Jose, were subjected to extensive mangrove-cutting activities. It has an average density of 525 trees per hectare. However, a recent study conducted by dela Peña et al. (2015b) found that only about 46% of the area is in a healthy condition, and only Banbanan has good mangrove forest cover.

Table 3. Estimates of mangrove cover of the Malampaya Sound, Palawan, and the Philippines. Note: Asterisks indicate sources of the literature.

Location	Area Covered (hectares)	Number of Species Present	Author
Malampaya Sound	3,342 *	9**	*PSA 2020 **PCSD 2006
Palawan	59,421*	23**	*FMB 2019 **PCSD 2004
Philippines	256,185*	65**	*Long and Giri 2011 **Garcia et al. 2013

Table 4. Estimates of mangroves around Malampaya Sound (PCSD 2006). Ra = *Rhizophora apiculata*, Rm = *Rhizophora mucronata*, Xg = *Xylocarpus granatum* Campostenum, Bc = *Bruguiera cylindrica*, Ct = *Ceriops tagal*, Bg = *Bruguiera gymnorrhiza*, Ea = *Excoecaria agallocha*, Sh = *Scyphiphora hydrophyllacea*, Ll = *Lumnitzera littorea*.

Barangay	Trees ha.$^{-1}$	Stand Volume (m3 ha^{-1})	SV Class	Species Present
Old Guinlo	1037	361.44	High	Ct, Bc
New Guinlo	696	127.15	Moderate	Ct, Ra, Rm
Alacalian	702	367.8	High	Ct, Ra, Rm, Xg, Bg, Bc, Ll, Sh
Abongan	429	388.18	High	Bs, Ra, Ct, Xg, Bg, Ea
Banbanan	329	274.41	High	Bg, Ra
San Jose	116	120.59	Logged-over to High	Bg, Ra, Rm
Liminangcong	322	278.38	Moderate to High	Ct, Ra, Rm
Pancol	566	184.56	Moderate to High	Ct, Ra, Rm
Mean	524.63	262.81	High	

Coral reefs

Coral reefs are built by a hermatypic group of anthozoan corals belonging to the Order Scleractinia (Alcala 2001). They are important sources of food, valuable pharmaceuticals, and chemicals of importance to industry. They regulate global climate, serve as research and recreation areas, and help prevent land erosion. Unfortunately, the reefs that remain in excellent condition in the Philippines make up only 1.9% in the 1990s (Wilkinson 2000). In the Sound, the fringing reefs are found in the outer portion, in Barangays Liminangcong, Tumbod, San Jose, and Bambanan. There has been no published report on how many species of corals are present in the area; however, it was reported in 2004 that coral cover ranges from 30 to 75% (CHE-UPLB 2015). A similar report was published by the PCSD (2004, 2006), accounting for the coral reefs from fair to good condition. However, the latest published surveys revealed that the condition in the Sound worsened from poor to fair (Matillano et al. 2014; dela Peña et al. 2015a), except in areas on the Outer Sound like Liminancong where corals remained in excellent condition (Matillano et al. 2014).

Associated reef fish are also found to be abundant in the Sound. There are 262 species of fish recorded (Balisco et al. 2014; Dolorosa and Matillano 2014), of which 101 were target species, 97 were indicator species, and 64 were major species. Pomacentrids and chaetodontids mostly dominate the fish population. Comparatively, the Sound harbors more fish species than the reefs found in the adjacent Taytay, Turtle, Binunsalian, and Bacuit Bays. It is estimated that the reefs have a high productivity that can yield fish biomass of 59.94 t.km^2.

Macroinvertebrates also inhabit the area, with 10 species recorded, including the rare *Tridacna* spp. Bruguière, 1797, and *Conus* spp. Linnaeus, 1758 (Dolorosa and Matillano 2014). Sightings of the destructive *Acanthaster plancii* Linnaeus, 1758, were also noted.

Over the years, deterioration has been observed among the reefs around the Sound. This can mainly be attributed to siltation and destructive fishing practices such as dynamite and cyanide fishing (dela Peña et al. 2015b). The rampant use of inappropriate fishing gear, such as beach seine and Danish seine, makes recovery challenging as well. In 2015, the remaining corals were in either poor or fair condition (PCSD 2006; Matillano et al. 2014; dela Peña et al. 2015b).

FISHERIES

Malampaya is considered the "fishbowl" of the Philippines. It provided a substantial contribution to the fisheries sector before its closure in 1973. The Sound contributed 19% to the total national 'municipal' landings (Pido et al. 1996). It was also among the top ten producers of anchovies during this time (DA-BFAR 1977). Experts estimated that the standing stock density and potential fisheries productivity of Malampaya Sound are 6.5–9.7 t.km^{-2} (Ronquillo and Llana 1987) and 2,750 mt annually (dela Peña et al. 2015a). These values are three to six times higher than other fishing grounds like Manila Bay, Bacuit Bay, and Imuran Bay (Ronquillo and Llana 1987). The mean catch rate by trawl is 1073 kg hr^{-1}, mostly demersal fish. The major species caught are *Sardinella* spp., Indo-Pacific mackerel, Spanish mackerel, and anchovies (DA-BFAR 1977). These results were further verified by Estudillo et al. (1987) through the plankton study they did in the area. They further found out that the Sound harbors a significant population of ichthyoplankton, including fish eggs, which makes it a critical breeding and nursery area.

A recent study revealed that there are 17–23fishermen per km^{-2} that rely on fishing as a source of livelihood (dela Peña et al. 2015a, 2015b). They mainly use hook and line, bottom set gillnet, and drift net (dela Peña et al. 2015b; Gonzales 2018), catching 69 commercial species of fish, shrimp, and crabs (Gonzales et al. 2017) that can reach up to 100 kg trip^{-1} (Table 5).

Table 5. Catch per unit effort using major fishing gears used in Malampaya Sound, Calamianes, and Apo Island, Philippines.

Fishing Ground/ Type of Gear	Year of Study	Hook and line	Drift Net	Gill net	Author
Malampaya Sound	April to August 2016	0.84-2.2 kg hr^{-1}	-	0.06-3.35 kg hr^{-1}	Gonzales 2013; Gonzales et al. 2017
Malampaya Sound	2010-2012	10-100 kg trip^{-1}	30-80 kg trip^{-1}	10-40 kg trip^{-1}	dela Peña et al. 2015a
Calamianes Islands	2008	5.6-12.5 kg trip^{-1}	21.5 kg trip^{-1}	9.0 kg trip^{-1}	Tupper et al. 2015
Apo Island Marine Reserve	1980-2001	1-2 kg hr^{-1}	-	-	Maypa et al. 2002

THE SOUND AT A GLANCE: THREATS, PROBLEMS AND RESOURCE ISSUES

The deteriorating state of the environment, not just in Malampaya but throughout the country, highlights the need for the government to take measures to protect the remaining resources of the Sound. Natural causes and anthropogenic activities have already impacted the fragile state of the Sound. A series of conservation measures must be implemented to achieve this, such as the periodic closure of the area for commercial fishing and the use of selected fishing gear.

Table 6 lists the issues and challenges faced by Malampaya Sound, as identified by various authors. It is worth noting that some problems arose as a result of the preceding issues. For example, the high demand for fish in the export market and the growing population led to the use of illegal and harmful fishing techniques, which caused habitat destruction and overfishing.

Several issues contribute to the problem, some of which originate on land. Poor waste disposal and agricultural run-off are two examples of activities that add to the stress. The sedimentation rate, as measured by Sombrito et al. in 2004, ranges from 0.2 to 4 cm per year. David et al. (2009) also found that the silt in the Sound is mainly siliciclastics, indicating a terrestrial-dominated source. They further emphasized that the slight increase in organic content in younger sediments reflects the rise in various anthropogenic inputs into the coastal region. Additionally, the high total coliform concentration in the Sound could be attributed to household waste/ sewage and/ or effluent run-off, making it unsuitable for recreational purposes.

An indication of eutrophication is already visible in the area due to the frequent occurrence of algal blooms (Sellner et al. 2003). According to Borja et al. (2000) and Sombrito et al. (2004), the cysts of *Pyrodinium* are responsible for causing harmful algal blooms. Such events can result in massive fish kills and even mortality in humans due to the depletion of oxygen in the water and the toxins they release (McGowan, 2016).

Anthropogenic activities reduce the ability of the Sound to recover from natural pressures like typhoons and diseases. This is evident in the current coverage of seagrass and coral, as described above. The declining fish catch and biodiversity in the area are causes for concern among the marginal fisherfolk. Immediate action is needed to address this issue and safeguard the livelihoods of the people who depend on fishing for their income and sustenance. Fishermen continue to experience a 60-80% reduction in catch (dela Peña et al. 2015b). As such, a comprehensive approach is recommended to address the identified threats and issues.

Table 6. Threats and problems observed in Malampaya Sound.

Threats and Problems	Pido 1995	Sandalo 1996	Pilien and Walpole 2003	David et al. 2009	Avillanosa et al. 2006	CHE-UPLB 2015	dela Peña et al. 2015a	Gonzales et al. 2017
Terrestrial development								+
Population increase								+
Overexploitation					+	+		
Resource conflict (use and access)			+				+	+
Habitat Destruction		+					+	
Pollution	+			+			+	
Cyanide and dynamite fishing		+					+	
Illegal fishing	+							
Organic matter and nutrient loading	+			+				
Poor waste disposal and management						+		
High export of fish supply						+		
Climate change						+		

IMPLICATION AND SOLUTION TO THE CURRENT CONDITION

It has been several decades since the government initiated the conservation of the remaining resources of the Sound. The decadal effort was already noticeable in the mangrove forests of the area. Figure 2 shows that it has already surpassed the initial coverage of the survey conducted in 1985. This suggests that environmental policies can coexist with rapid economic growth and competition for resources (Thomas and Belt, 1997). However, with the current global economic crisis and other internal problems that every nation is experiencing today, the delivery of services to the masses takes time. Given the limited capacities of the government to respond to the needs of the citizenry at the community level, non-government organizations (NGOs) are seen as vital links between the government and the people for the delivery of services (Balagot 1992). Involving and fostering partnerships with these stakeholders, including academic institutions and local communities, in conservation activities and decision-making, are encouraged to develop and implement a holistic fishery resource-based management approach.

Community involvement and empowerment are highly recommended. Javan (1999) stated that it is one of the keys to achieving sustainable development objectives. Interventions must be designed to enhance development at the community level. Environmental information and awareness are advocated to increase community participation (Thomas and Belt 1997). Promoting environmental literacy and capacity-building programs will empower local stakeholders to actively engage in conservation efforts that will further bolster long-term sustainability.

Aside from all of this, strict enforcement of the existing laws is still one of the keys to saving the remaining resources of the Sound. Monitoring of environmental resources and water quality should be regularly done too. Moreover, more scientific studies must be done to understand the ecological processes in the area. Stock assessments must be conducted, and the extent of exploitation must be determined to provide information for evaluating species vulnerability and devising management options suited for the area. Encouraging sustainable fishing practices, such as setting up catch restrictions, size limits, and closed seasons for fish species would be pivotal in mitigating overexploitation of fish stocks and safeguarding critical habitats. Moreover, exploring eco-tourism initiatives could provide alternative income sources for local communities while heightening awareness about the significance of conserving Malampaya Sound's ecosystems.

CONCLUSION

The Malampaya Sound boasts a rich and diverse ecosystem. It used to be the “fishbowl” of the Philippines during the 1970s. Its rich environment supports fisheries which is important in the livelihoods of the inhabitants. However, it is threatened by

destruction due to human-made disturbances such as poor waste disposal, high sedimentation rate, high Coliform concentration, terrestrial development, habitat destruction, pollution, illegal fishing, and overexploitation. While protective measures have been in place since the 1970s, more work is needed to achieve sustainable use of the area. The seagrass and coral cover in the area is still in poor to fair condition, indicating the need for urgent action to protect them. The mangrove population is the only one that has significantly improved. The preservation of Malampaya Sound, a vital natural resource, is only achievable through the collaboration and cooperation of the academic community, government agencies, non-government organizations, and the local community. The protection of this ecosystem requires a joint effort from all stakeholders to ensure a sustainable future for the Sound and the surrounding environment. Community involvement and empowerment, income diversification of the locals, strict enforcement of existing laws, monitoring of environmental parameters, and implementation of sustainable fishing practices will ensure long-term sustainability of marine resources.

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ETHICAL CONSIDERATION

The author declares that this work is free of plagiarism or research misconduct.

DECLARATION OF COMPETING INTEREST

The author declares no competing interests.

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