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Evaluation of shrimp-associated species in abandoned ponds in Mati City, Philippines

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ABSTRACT

This study aimed to identify, characterize, and evaluate the biodiversity of shrimp-associated species in abandoned shrimp ponds, specifically assessing the trophic levels of bycatch species in Barangay Dahican, Mati City. Using a scoop net, researchers collected macrobenthic samples from Maitum, Lahusan, and Butuasan, finding 1,528 individuals with varying species compositions namely: *Oreochromis niloticus* (Nile tilapia), *Coenobita cavipes* (Land hermit crab), *Canarium labiatum* (Plicate conch), *Rochia nilotica* (Commercial top), *Clithon oualaniense* (Guamanian nerite), *Cerithium coralium* (Coral cerith), and *Callinectes sapidus* (Blue crab). *Cerithium coralium* was the most abundant species with 70% relative abundance, followed by Clithon oualaniense, with 29%. In contrast, the least abundant species were the *Oreochromis niloticus* and *Canarium labiatum*, with 1% relative abundance. Moreover, biodiversity indices revealed that Lahusan 1 (H' = 0.731; D = 0.46) and Butuasan (H' = 0.714; D = 0.5) had higher biodiversity, whereas Lahusan 2 had the lowest (H' = 0.318; D = 0.15). In addition, there were also significant differences in terms of species abundance (df = 6, MS = 34.18, F = 6.02, P = 0.000) and none in terms of site locations (df = 3, MS = 18.71, F = 2.08, P = 0.188). The study results showed that these associated species were mainly benthic and came from the nearby environment. Providing good management for the abandoned shrimp ponds in the area could mean reverting them to their original state to provide a habitat for other organisms.

Keywords: Aquaculture ponds, bycatch species, invasive species, Mati City, shrimp ponds

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INTRODUCTION

Greater diversity is indicated by a higher ratio of total species present and the total number of individuals of all species found in the area (Boyd, 2018). According to Mitra (2013), brackish-water pond aquaculture is expected to proliferate in the next century because it has become a significant source of seaweed, shellfish, and finfish, particularly for human food production. Hostetter (2005) wrote that with natural resources and waste creation, aquaculture and shrimp farms have direct and indirect effects on biodiversity because brackish water possesses favorable characteristics and tidal activities. Most mangrove ecosystems will be converted into aquaculture shrimp farms, and in the past, it resulted in the loss of mangrove cover, affecting water quality, biodiversity, and habitat (Macusi et al., 2022).

Mangrove ecosystems exist in the intertidal zone between sea and land, providing vital ecosystem products and services (Hanum et al., 2014). Wood (2019) says mangrove trees' thick root systems provide a natural barrier against storm surges and flooding. In the past 50 years, the mangrove ecosystems' composition and habitat complexity have been affected by urban expansion, forest product extraction, salt pond conversion, oil and gas industry, fish pond conversion, and effluents (Wang et al., 2019; Merzdorf, 2020; Hashim et al., 2021). In the Philippines, an estimated 356,000 hectares of mangrove forests, with half of the 65 total mangrove species worldwide, exist in the region (Camacho et al., 2020; Cuenca et al., 2015; Garcia et al., 2014). However, over the last century, over half of the country's mangrove areas have been converted into fishponds (Duncan, 2016). Pond effluents cause reduced primary productivity, affecting the ability of the mangrove ecosystem to do carbon storage, resilience to other environmental stressors, and efficiency as estuarine filters, biodiversity, and availability of subsistence usage of marine animals as a result of marine pollution (de Lacerda et al., 2021; Nazemroaya et al., 2009; Jickling, 2017; Ahmed et al., 2018).

Aquaculture is cultivating aquatic species in a controlled environment for food production, restoration of threatened and endangered species, and wild stock population enhancement (Herbert, 2017). Aquaculture includes growing seafood in nurseries for later harvest, and it has several benefits to the environment and humans, such as reducing pressure on wild populations of specific fish stocks, replacing invasive species with native ones, and increasing local employment (Diana, 2009). Shrimps are one of the major aquaculture species in the Philippines, with a total production of 87,700 MT in the year 2022 (Guadalquivir, 2023)

Farmed shrimps produced 55% of global trading with China, Thailand, Indonesia, India, Vietnam, Brazil, Ecuador, and Bangladesh, which were significant producers. In the United States, Europe, Japan, and other countries, farmed shrimp food exported in their markets became more accessible to a hungry, shrimp-loving populace. Profit-seeking investors have enhanced their farms using automated industrial machines and equipment, sometimes at significant environmental costs (FAO, 2020). Farm ponds can severely threaten freshwater habitats that have significantly reduced the area due to drainage schemes and agricultural intensification, according to Reyne et al. (2021).

Aquaculture pond intensification and the unattended release of water due to flooding can allow bycatch species to invade an existing farmed pond. Bycatch species are undesirable species competing with cultured species in the pond as predators or prey. These include finfish, crustaceans, mollusks, reptiles, amphibians, birds, and mammals (Kungvankij & Chua, 1986). In South-Western France, 18 invertebrate species out of 114 were found in the 36 ponds studied, indicating a high biodiversity in the study area (Céréghino et al., 2010). In 84 fish ponds studied in the Dombes region of France, Wezel et al. (2014) found that dragonflies were the most significant single contributor to regional biodiversity, accounting for 41 percent of the total biodiversity. Amphibians and macrophytes contributed 16 and 18 percent, respectively. For macroinvertebrate families and phytoplankton genera, 22 to 25 percent of regional diversity was tied to the region in which they occurred. In the Philippines, the aquaculture ponds located in Dumangas, Iloilo, Philippines, 12 species of gobies, including small-size *Acentrogobius viganensis, Pseudogobius javanicus, Mugilogobius cavifrons*, and *Gobiopterus panayensis*, were some of the most abundant fish species found in the cultured ponds. Macrocrustaceans included several penaeid and palaemonid shrimps and portunid and grapsid crabs. Mollusks in the ponds included 58 species, with *Cerithideopsilla cingulata* being the most abundant.Even though the aquaculture ponds in Dumangas, Iloilo, were designed for monoculture, the biodiversity was still high. It proves that aquaculture has a positive impact on biodiversity (Bagarinao, 2021).

Given the effects of aquaculture ponds on the local biodiversity of the area, this study aimed to investigate the shrimp-associated species found in the abandoned shrimp ponds in Mati, Davao Oriental, and to determine their level of biodiversity in Dahican, Mati City, Davao Oriental.

MATERIALS AND METHODS

Study area

The study was conducted in aquaculture shrimp ponds in Guang-Guang, Dahican, Mati City, Davao Oriental. The study site was famous for its mangrove forest that covers more than 21,000 ha. Some parts of the mangrove forest were transformed into ponds covered in this study. The aquaculture ponds were mainly less than 3 ha, with an average pond size of 4000 – 5000, operated by a maximum of two individuals per pond (Clapano et al., 2022). A total of 20 abandoned shrimp ponds were selected in the four different study sites (Maitum, Lahusan 1, Lahusan 2, Butuasan), and five ponds for every site were determined. The study area lies within 6°55’27.4 “N 12 6°16’09.6 “E. The local guide aided the selection of ponds, which were determined to be abandoned by the representative from the City Agricultures Office, and upon visitation, traces of aquaculture-related activity are non-existent in the area.

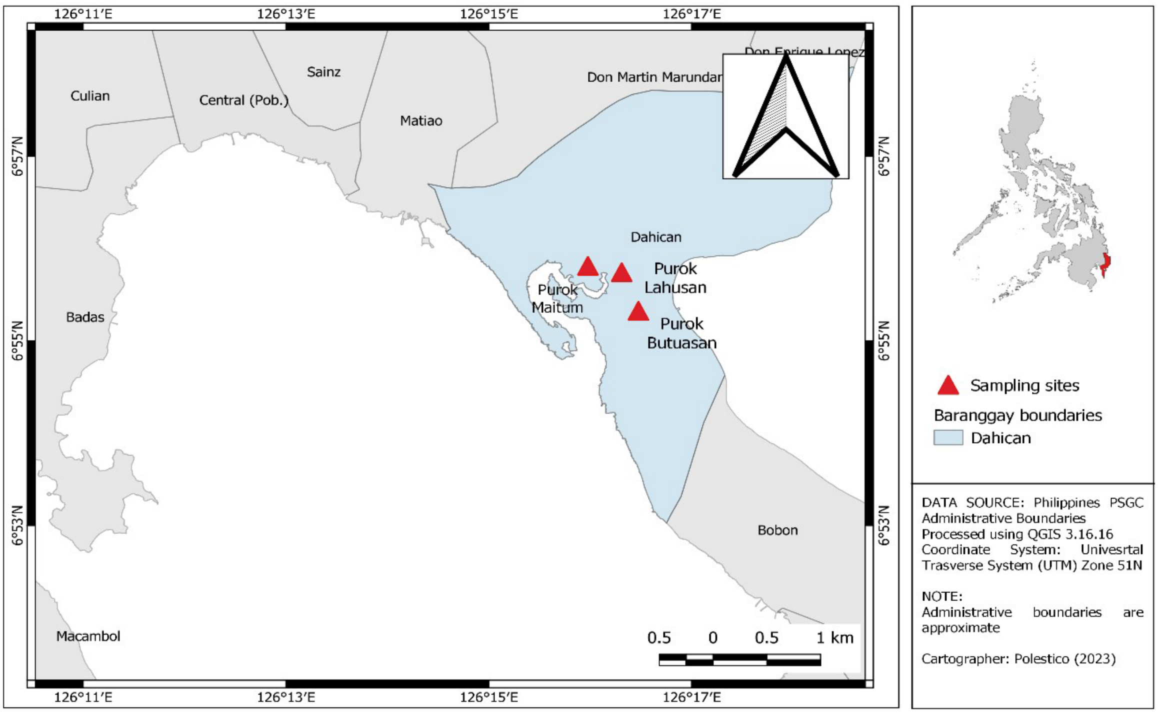

Figure 1. The map shows the sampling sites in the study area.

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Sample collection

Before sampling, the researchers prepared all the documents required by the City Environment and Natural Resources Office (CENRO), the City Agriculture Office (CAO), and the Barangay Dahican Local Government Unit. For the sample collection, shallow and deep parts of the pond were examined, and the scoop net was swept three times from the bottom up to the water's surface. The samples collected from the ponds were then rinsed, collected, sorted, counted, and identified to species level, measured using a caliper (mm), and photographed (Bagarinao, 2021). All samples were preserved in a transparent jar and submerged in a 10% formaldehyde solution. The references used for identification and determination of their trophic levels were based on FishBase (Froese and Pauly, 2022), Sealife Base (Palomares and Pauly, 2022), and scientific names which were verified in the World Registry of Marine Species (WORMS, 2024).

Data analysis

The sampled specimens' relative abundance and biodiversity count were all quantified per location and then compared. The data was then analyzed using Microsoft Office Excel 2019 and Minitab 17 (State College, Pennsylvania, USA). The collected abundance data was processed for descriptive statistics such as mean, minimum, maximum, and percentages. One-way Analysis of Variance (ANOVA) was used to determine whether there were significant differences in abundance for the different by catch species in the ponds and locations. The Tukey post-test showed the means with significantly different abundance among the associated species.

RESULTS AND DISCUSSION

Species composition

Seven species were collected using a scoop net in Purok Butuasan, Lahusan, Maitum, Dahican, City of Mati, Davao Oriental. FishBase (Froese and Pauly, 2022), Sealife Base (Palomares and Pauly, 2022), and the paper Maynawang and Macusi (2019) were used as guides to identify the species. *Oreochromis niloticus* (Nile tilapia), C*oenobita cavipes* (Land hermit crab), *Canarium labiatum* (Plicate conch), *Rochia nilotica* (Commercial top), *Clithon oualaniense* (Guamanian nerite), *Cerithium coralium* (Coral cerith), and *Callinectes sapidus* (Blue crab) are among the species.

Species abundance

A total of 1,528 individuals were found in the study sites (Maitum, Lahusan, and Butuasan) composed of different species (Table 1). In total, Butuasan had the highest total number of samples found in the area, with 562. Maitum followed this with 508 samples; next was Lahusan 2, which had 253 samples. The area with the least number of individuals was Lahusan 1, with a total count of 205. Results from sites Maitum, Lahusan 1, and Lahusan 2 showed that four species were found in the area, while site Butuasan had three species.

Table 1. The total counts of various species found in study areas.

Common name	Scientific name	Maitum	Lahusan 1	Lahusan 2	Butuasan
Blue crab	*Callinectes sapidus*	0	0	0	2
Plicate conch	*Canarium labiatum*	0	0	1	0
Coral cerith	*Cerithium coralium*	413	138	232	288
Land hermit crab	*Coenobita cavipes*	6	4	0	0
Guamanian nerite	*Clithon oualaniense*	88	62	19	272
Nile tilapia	*Oreochromis niloticus*	0	0	1	0
Commercial top	*Rochia nilotica*	1	1	0	0
Total		508	205	253	562

In addition, among all species, *Cerithium coralium* was the most abundant species in all areas, with 70% relative abundance. It was followed by *Clithon oualaniense*, the second most abundant species with 29% relative abundance. The least abundant species in all study areas was the *Coenobitacavipes*, with 0.65% next to *Oreochromis niloticus* and *Callinectes sapidus*, which had a relative abundance of 0.13%. The least abundant species were the *Rochia niloticus* and *Canarium labiatum*, with 0.07% relative abundance (Table 2).

The associated species populations in all four sampling locations displayed complex distribution patterns. All the ponds contained *Cerithium coralium*. This demonstrates their ability to adapt and thrive in various situations in the abandoned pond. Other species might not be suitable or adaptive to a new habitat, resulting in a very minimal population, like *Canarium labiatum* and *Rochia nilotica*, and some species' existence might be due to anthropogenic activity like *Coenobita cavipes* which are highly prone to disturbance as is commonly collected to serve as bait or as a toy for younger children and *Oreochromis niloticus* and *Callinectes sapidus* is highly targeted in an abandoned pond by fishers for food and income.

Table 2. Relative abundance and trophic level position of species in the study areas.

Local name	Scientific name	Count	RA (%)	Trophic level	Consumer level
Blue crab	*Callinectes sapidus*	2	0.13	2.59	Omnivore
Plicate conch	*Canarium labiatum*	1	0.07	2	Detritivore
Coral cerith	*Cerithium coralium*	1071	70.09	2	Detritivore
Land hermit crab	*Coenobita cavipes*	10	0.65	2	Omnivore
Guamanian nerite	*Clithon oualaniense*	441	28.86	2	Herbivore
Nile tilapia	*Oreochromis niloticus*	1	0.07	2	Omnivore
Commercial top	*Rochia nilotica*	2	0.13	2	Herbivore

Monitoring trophic levels was crucial for understanding organism interaction and the ecological processes within an ecosystem and explaining where animals fit within a food chain, from producers to apex predators (Nieblas et al.2013). Some species' trophic levels are based on their location in the aquatic food chain. Among the seven species collected during the entire duration of the study, only the *Callinectes sapidus* was observed to be in the higher trophic level (2.59), while all other species were in the second trophic level. This result shows that *Callinectes sapidus* belongs to primary and secondary consumers. The blue crabs were mainly omnivores and eat almost anything, including clams, oysters, mussels, smaller crustaceans, freshly dead fish, plants, detritus, smaller and soft-shelled blue crabs, and other organic waste available in the area (Hoeinghaus, 2007). At the same time, the *Canarium labiatum, Cerithium coralium, Coenobita cavipes, Clithon oualaniense, Oreochromis niloticus, and Rochia nilotica* are primary consumers, which mainly feed on detrital materials, feeding, or scavenging on the bottom sediments of the abandoned ponds looking for dead or living smaller invertebrates, planktons, algae, macrophytes, diatoms, plant material and other organic matter (Castell, 1997; Harper, 2022; Khallaf & Alne-na-ei 1987; Laidlaw, 2020; Mendelson, 2023; Schubiger, 2022; Vicente & Alves, 2013).

Comparison of diversity indices

The Shannon diversity index (*H')* and Simpson's Diversity (D) values for each area were compared. However, the results from Lahusan 1 and Butuasan showed a slight deviation from this bar. Lahusan 1, which had a higher *H'* than Butuasan, ranked second when using Simpson's index. In contrast, Butuasan, which displayed a higher Simpson's diversity index than Lahusan1, ranked second when applying Shannon's index (Table 4). Regarding the statistical result of ANOVA on associated species in the four areas, there were significant differences among species (df=6, MS=34.18, *F*=6.02, *P*=0.000). The Tukey test posthoc test showed the means with significantly different abundance among the associated species, e.g., *Cerithium coralium* has the highest count (1071). Followed by *Clithon oualaniense* (441) and *Coenobita cavipes* (10). At the same time, the species with the lowest counts were *Callinectes sapidus* (2), *Rochia nilotica* (2), *Oreochromis niloticus* (1), and *Canarium labiatum* (1). Regarding location, there were no significant differences in the abundance of associated species in the study sites (df=3, MS=18.71, *F*=2.08, *P*=0.12).

Table 3. Species diversity index of samples found in Maitum, Lahusan 1 and 2, and Butuasan.

Local name	Scientific name	Maitum	Lahusan 1	Lahusan 2	Butuasan
Blue crab	*Callinectes sapidus*	0	0	0	2
Plicate conch	*Canarium labiatum*	0	0	1	0
Coral cerith	*Cerithium coralium*	413	138	232	288
Land hermit crab	*Coenobita cavipes*	6	4	0	0
Guamanian nerite	*Clithon oualaniense*	88	62	19	272
Nile tilapia	*Oreochromis niloticus*	0	0	1	0
Commercial top	*Rochia nilotica*	1	1	0	0
Total		508	205	253	562
	Shannon-Wiener Diversity Index (*H'*)	0.537	0.731	0.318	0.714
	Simpson's Diversity Index (D)	0.31	0.46	0.15	0.5

Abundance comparison in other studies

The result of Shannon index *H'* and Simpson's index in all ponds under the four areas of Maitum, Lahusan 1, Lahusan 2, and Butuasan shows that all of the ponds have very low associated biodiversity with1, 528 individuals comprised of seven species only compared to the ponds of South-Western France (Céréghino et al., 2010) that caught 114 species in 36 ponds, in the Gulf of Thailand with 25 species represented in six ponds (Fujioka et al., 2007), and Tamil Nadu, India with 70 species recorded (Varadharajan and Soundarapandian, 2013). The specimens found in all areas are also lesser than aquaculture ponds in Western Mexico, which caught 4978 specimens (Hendrickx et al., 1996). Among all species, *Cerithium coralium* is the most abundant species in all ponds, with 70.09% of relative abundance. *Cerithium coralium* is also one of the most abundant gastropods found in the macrobenthic fauna in shrimp ponds located in the Gulf of Thailand (Fujioka et al., 2007) and in Dumangas, Iloilo, Philippines (Bagarinao, 2020); *Cerithium coralium* was also one of the most abundant in particular ponds. *Cerithium coralium* abundance is due to its habitat, which is found in intertidal, estuarine, and mangrove habitats, on muddy or sandy substratum between *Avicennia pneumatophores* and bare mud along the mangrove edge (Zvonareva and Kantor, 2016; GBIF secretariat, 2022; Poutiers, 1998).

Of all four areas in the study sites, Maitum, Lahusan 1, and Lahusan 2 have the most species caught by scoop net throughout the sampling period (Figure 6). Most of the ponds in the four areas have almost the same diversity index except for one in Maitum and Lahusan 1 (Tables 2 and 4) with 0 *H'* value. This result is because the pond with an *H'* value of 0 has only one species (Magurran, 2004; Dronkers et al., 2023). The results show that the ponds in the four study sites have a low diversity of pond-associated species, which indicates that the ponds were predominantly a monoculture and only supported by a few species. By this, it can indicate that the ponds experience an unbalanced species distribution. Low biodiversity means that the trophic system is likely less functional because fewer species were found to represent the various tropic levels. Fewer energy and nutrition pathways lead to a breakdown in ecological functioning where the decline has occurred (Rafferty, 2023).

CONCLUSION

This study was conducted to identify, characterize, and evaluate the biodiversity of shrimp-associated species in abandoned shrimp aquaculture ponds. The study also assessed the abundance and the feeding trophic levels of the shrimp-associated species in the abandoned shrimp ponds in Barangay Dahican, Mati City. Seven (7) species were caught using the scoop net in the 20 ponds examined in Maitum, Lahusan, and Butuasan. Among seven (7) species found, *Cerithium coralium* (Coral cerith) was the most abundant associated species (70.09%), followed by *Clithon oualaniense* (Guamanian nerite) with 28.86%. In contrast, the least abundant species were the *Oreochromis niloticus* (Nile tilapia) and *Canarium labiatum* (Plicate conch), with 0.07%. The number of species caught using scoop nets was small, even though 20 ponds were examined in the study area. Most species belong to the 2nd trophic level, which is a primary consumer and very helpful with energy flow throughout the ecosystem; without these organisms, an ecosystem can lose its balance and collapse. The diversity indices showed that Lahusan1 and Butuasan contained a more diverse set of organisms with Shannon's index, H' = 0.731 and Simpson's, D=0.46 (Lahusan1), and in Butuasan, Shannon's index, H' = 0.714 and Simpson's D=0.5.

In contrast, Lahusan 2 appeared to be the least diverse site (H' = 0.318; D = 0.15). In addition, the data also showed that all the areas were currently experiencing an imbalance in the distribution of different species, which led to low biodiversity. The aquaculture ponds were designed for monoculture, and seeing that other species caught in the non-competing area indicates a diverse ecosystem in the nearby area where the eggs and larvae of these organisms could have come from. Providing good management for the abandoned shrimp ponds in the area also means reverting them to their previous state, providing habitat to other organisms.

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REFERENCES

Ahmed, N., Thompson, S., and Glaser, M. (2018). Integrated mangrove-shrimp cultivation: Potential for blue carbon sequestration. *Ambio*, 47(4), 441–452.

Bagarinao, T. U. (2021). Biodiversity in mangrove-derived aquaculture ponds in Dumangas, Iloilo, Philippines. *Philippine Journal of Science*, 150(1), 153–169.

Boyd, C. E., D'Abramo, L. R., Glencross, B. D., Huyben, D. C., Juarez, L. M., Lockwood, G. S., and Valenti, W. C. (2020). Achieving sustainable aquaculture: Historical and current perspectives and future needs and challenges. *Journal of the World Aquaculture Society*, 51(3), 578-633.

Camacho, L. D., Gevaña, D. T., Sabino, L. L., Ruzol, C. D., Garcia, J. E., Camacho, A. C. D., Oo, T. N., Maung, A. C., Saxena, K. G., Liang, L., Yiu, E., and Takeuchi, K. (2020). Sustainable mangrove rehabilitation: Lessons and insights from community-based management in the Philippines and Myanmar. *APN Science Bulletin*,

Castell, LL. (1997). Population studies of juvenile Trochus niloticus on a reef flat on the north-eastern Queensland coast, Australia: *Marine & Freshwater Research*. [Mar. Freshwat. Res.], vol. 47, no. 3, pp. 211-217.

Céréghino, R., Ruggiero, A., Marty, P., and Angélibert, S. (2010). Biodiversity and distribution patterns of freshwater invertebrates in farm ponds of a south-western French agricultural landscape. *Pond Conservation in Europe*, 43-51.

Clapano, M. B., Diuyan, J. M. T., Rapiz, F. G. B., and Macusi, E. D. (2022). Typology of smallholder and commercial shrimp (Penaeus vannamei) farms, including threats and challenges in Davao region, Philippines. *Sustainability*, 14(9), 5713.

Cuenca, G. C., Macusi, E. D., Abreo, N. A. S., Ranara, C. T. B., Andam, M. B., Cardona, L. C., and Guanzon, G. C. (2015). Mangrove ecosystems and associated fauna with special reference to mangrove crabs in the Philippines: A Review. *IAMURE Int. J. Ecol. Conserv*, 15, 60-110.

De Lacerda, L. D., Ward, R. D., Godoy, M. D. P., De Andrade Meireles, A. J., Borges, R., and Ferreira, A. C. (2021). 20-years cumulative impact from shrimp farming on mangroves of Northeast Brazil. *Frontiers in Forests and Global Change*, 4, 653096.

Diana, J. S. (2009). Aquaculture production and biodiversity conservation. *Bioscience*, 59(1), 27-38.

Dronkers, Sohier and Charlotte (2023). Measurements of biodiversity.

Duncan, C. (2016). Returning ponds to mangrove forests in the Philippines. ZSLletsworkforWildlife.

FAO. 2020. The State of World Fisheries and Aquaculture (2020). Sustainability in action. *In Inform* (Vol. 32, Issue 6).

FROESE, R. (2010). Fish Base. World Wide Web electronic publication. www. fishbase. org.

Fujioka, Y., SHIMODA, T., and Srithong, C. (2007). Diversity and community structure of macrobenthic fauna in shrimp aquaculture ponds of the Gulf of Thailand. *Japan Agricultural Research Quarterly*: *JARQ*, 41(2), 163-172.

Garcia, K. B., Malabrigo, P. L., and Gevaña, D. T. (2014). Philippines' mangrove ecosystem: status, threats and conservation. *Mangrove ecosystems of Asia: Status, challenges and management strategies,* 81-94.

GBIF Secretariat (2022). Cerithium coralium Kiener, 1841. GBIF Backbone Taxonomy. *Checklist dataset.*

Guadalquiver, N. (2023). Philippine Shrimp, Prawn Production seen to grow further in 2023. *Philippine News Agency*. Date Accessed: February 1, 2024.

Faridah-Hanum, I., Latiff, A., Hakeem, K. R., and Ozturk, M. (Eds.). (2013). Mangrove ecosystems of Asia: status, challenges and management strategies. *Springer Science & Business Media.*

Tengku Hashim, T. M. Z., Engku Ariff, E. A. R., and Suratman, M. N. (2021). Aquaculture in mangroves. *Mangroves: Ecology, Biodiversity and Management*, 419-438.

Hendrickx, M. E., Salgado-Barragán, J., and Meda-Martinez, M. A. (1996). Abundance and diversity of macrofauna (fish and decapod crustaceans) in Penaeus vannamei culture ponds in Western Mexico. *Aquaculture*, 143(1), 61-73.

Herbert, K. (2017). aquaculture. TechTarget.

Hoeinghaus, D. J., and Davis III, S. E. (2007). Size-based trophic shifts of saltmarsh dwelling blue crabs elucidated by dual stable C and N isotope analyses. Marine Ecology Progress Series, 334, 199-204.

Hostetter, T. (2005). Human Impact on Biodiversity.

Jickling, N. (2017). Shrimp Aquaculture in Aguadulce: Impacts on mangrove forest health and shrimp larvae populations in two sites on the Salado coastline.

Kungvankij, P., Chua, T. E., Pudadera Jr, B. J., Corre, K. G., Borlongan, E., Tiro Jr, L. B., and Talean, G. A. (1986). Shrimp culture: pond design, operation and management.

Macusi, E. D., Estor, D. E. P., Borazon, E. Q., Clapano, M. B., and Santos, M. D. (2022). Environmental and socioeconomic impacts of shrimp farming in the Philippines: A critical analysis using PRISMA. Sustainability, 14(5), 2977.

Magurran, A. E. (2024). Measuring biological diversity. Current Biology, 31(19), R1174-R1177.

Maynawang, I. S. and E. D. Macusi (2023). "Catch assessment of commercially important gastropods in Guang-Guang, Mati City, Davao Oriental, Philippines." Academia Biology 1(1).

Mendelson, W. (2023). Cerith Snail – The Cleaner That Never Rests. Escargot World.

Bhagarathi, L. K., and DaSilva, P. N. (2024). Impacts and implications of anthropogenic activities on mangrove forests: A review. *Magna Scientia Advanced Research and Reviews*, 11(1), 040-059.

Mitra, A. (2013). Sensitivity of mangrove ecosystem to changing climate (Vol. 62, pp. 143-157pp). *New Delhi: Springer.*

Nazemroaya, S., Amini, M., Khatam, B., Madadi, H., and Nekooei, A. (2009). Effects of shrimp culture on mangrove forest and its eutrification of Gowater bay Changes in digestive enzyme activities during ontogeny of Yellowfin sea bream (Acanthopagrus latus) larvae View project Investigation on physiological and behavioral changes of zebrafish (Danio rerio) exposed to cadmium and lead View project Effects of shrimp culture on mangrove forest and its eutrification of Gowater bay.

Bonhommeau, S., Dubroca, L., Le Pape, O., Barde, J., Kaplan, D. M., Chassot, E., and Nieblas, A. E. (2013). Eating up the world's food web and the human trophic level. *Proceedings of the National Academy of Sciences*, 110(51), 20617-20620.

Palomares, M. L. D., and Pauly, D. S. (2022). World Wide Web electronic publication. Version (08/2022). Available online: www. sealifebase. org (accessed on 4 September 2022).

Carpenter, K. E., and Niem, V. H. (2001). FAO species identification guide for fishery purposes. The living marine resources of the Western Central Pacific. Volume 6. Bony fishes part 4 (Labridae to Latimeriidae), estuarine crocodiles, sea turtles, sea snakes and marine mammals. *FAO Library*.

Rafferty, J. (2023). Biodiversity Loss. Encyclopedia Britannica.

Reyne, M., Nolan, M., McGuiggan, H., Aubry, A., Emmerson, M., Marnell, F., and Reid, N. (2021). Artificial agri‐environment scheme ponds do not replicate natural environments despite higher aquatic and terrestrial invertebrate richness and abundance. *Journal of Applied Ecology*, 58(2), 304-315.

Schubiger, V. (2022). What do Nerite snail eats?. AZ Animals.

Varadharajan, D., and Soundarapandian, P. (2013). Macrobenthos species diversity in and around shrimp farm. *World Applied Sciences Journal*, 22(8), 1111-1115.

Vicente, I. S., and Fonseca-Alves, C. E. (2013). Impact of introduced Nile tilapia (Oreochromis niloticus) on non-native aquatic ecosystems. *Pakistan Journal of Biological Sciences: PJBS*, 16(3), 121-126.

Wang, L., Jia, M., Yin, D., and Tian, J. (2019). A review of remote sensing for mangrove forests: 1956–2018. *Remote Sensing of Environment*, 231, 111223.

Wezel, A., Oertli, B., Rosset, V., Arthaud, F., Leroy, B., Smith, R., and Robin, J. (2014). Biodiversity patterns of nutrient-rich fish ponds and implications for conservation. *Limnology*, 15, 213-223.

Wood, J. (2019). 5 reasons to protect mangrove forests for the future. World Economic Forum.

WoRMS Editorial Board (2024). World Register of Marine Species.

Zvonareva, S., and Kantor, Y. (2016). Checklist of gastropod molluscs in mangroves of Khanh Hoa province, Vietnam. *Zootaxa*, 4162(3), 401-437.