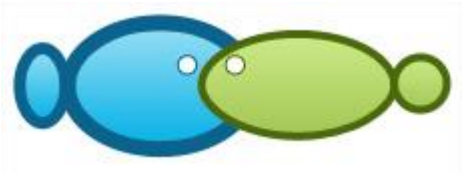

Socio-ecological system assessment for conservation planning in riverine and mangrove fishery areas in Bataan, Philippines

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Abstract. Tropical rivers are vital aquatic ecosystems supporting the subsistence fisheries and the economic growth of riverine and coastal communities; thus, participatory methods are indispensable for improved ecosystem management. The present study conducted a socio-ecological systems assessment to characterize the perceptions of coastal communities in the four major river systems of Bataan, Philippines (Almacen, Talisay, Morong, and Bagac) on riverine and mangrove fishery resources and economic importance, fishery changes and ecological impacts, and sustainable local coastal community development. The questionnaire-based survey revealed that the local populations are heavily dependent on riverine and mangrove fishery resources, accounting for no less than 30 fish species, nine types of penaeid shrimps, seven types of brachyuran species, and three mollusks. All respondents signified the conspicuous diminish in the yield of most native aquatic resources as attributed to overfishing, anthropogenically-induced pollution, and habitat degradation (mangrove conversion and settlement). Strategies suggested by the locals for improved sustainable community development include the industry-based alternative jobs for fisherfolks, re-launching of state-funded aquasilviculture and mangrove rehabilitation projects, use of non-invasive fishing methods (lambaklad), funding support for resource management, and sustainable implementation of coastal clean-up and solid waste management projects. These alternatives and the socio-ecological assessment are yearned to serve as a model for other fishery areas, experiencing similar socio-ecological plight and where economic subsistence is largely fisheries-based.

Key Words: Ayungin, black-chin tilapia, fisheries management, sustainability, Orani.

Introduction. Tropical riverine and mangrove ecosystem is an excellent example of socio-ecological systems (SES) (Santos et al 2017; Dunham et al 2018) as the multitude of ecological resources have been heavily used for food, agriculture, industry, transport mechanism, energy, tourism, (Parker & Oates 2016), and other goods and services linked to fluvial resources (Martin-Ortega et al 2015). Despite the apparent river and mangrove-dependent livelihood of the coastal communities in Bataan, Philippines (14°41'06"N 120°25'55"E), the extent of socio-ecological benefits of these aquatic habitats is still ambiguous from the perspective of local coastal inhabitants (Cervania et al 2018). Moreover, it was reported by PEMSEA (2006) that the riverine ecosystems of Bataan are fastly losing their biological and structural diversity, due to overexploitation and negative impacts of water pollution from cities, industries, intensive farming, and other human activities. The lack of appropriate resource management schemes has a large contribution to the degradation of these ecosystems. As documented by Cervania et al (2018) and Rabadon & Corpuz (2021), several human activities including riparian reclamation, mangrove deforestation, overfishing, pollution, logging in headwaters, draining of river floodplains, localized mining in headwaters, and the presence of non-native species are still being observed in Bataan Natural Park and its watershed (Llave et al 2018). Despite the value of information focusing on ecological processes and biodiversity, these alone are not likely to produce a realistic perspective of how

riverscapes function or how to manage them effectively (Crausbay et al 2017; Naiman 2013). Furthermore, emphasis on feedback between social and ecological processes will provide a greater understanding of riverscapes as complex, dynamic, interacting social-ecological systems (Dunham et al 2018). Therefore, the involvement of the main stakeholders in the conservation of the riverscape and its resources is a guarantee for successful management and sustainable use (Nishida et al 2006).

In a situation in which humans and the environment are connected and inter-reliant, SES assessment is an effective tool for river and mangrove management, since this will prioritize the local knowledge as key information for conservation planning. Evaluation of the importance of river fisheries for coastal communities and their underpinning knowledge and attitudes related to the ecosystem and fishery resource use is vital for instigating local conservation of fisheries stock and sustainable aquatic resource management (Flores et al 2015,2016; Santos et al 2017; Hand et al 2018). The view of local stakeholders must be considered in the refinement, cascading, and implementation of regulatory mechanisms concerning the utilization and management of fluvial resources (Satyanarayana et al 2013; Cabello et al 2015).

There is a paucity of information about SES in the riverine and mangrove ecosystems of Central Luzon, Philippines. Hence, this study characterized the use of economically important riverine and mangrove fishery resources by the fisherfolks of two river systems in the eastern (Almacen and Talisay), and western (Morong and Bagac) coast of Bataan, Philippines (1). The study also evaluated the perceptions of local communities on fisheries alteration, and their observation about contemporary issues on environmental degradation (2), and elucidated the viewpoint of fisherfolks concerning community sustainable development and improvement in their quality of life (3).

Material and Method

Study areas. Fishing communities from four riverine fishery areas were surveyed (Figure 1). The province has more than 100 lotic environments radiating from the two mountain groups (Natib and Mariveles).

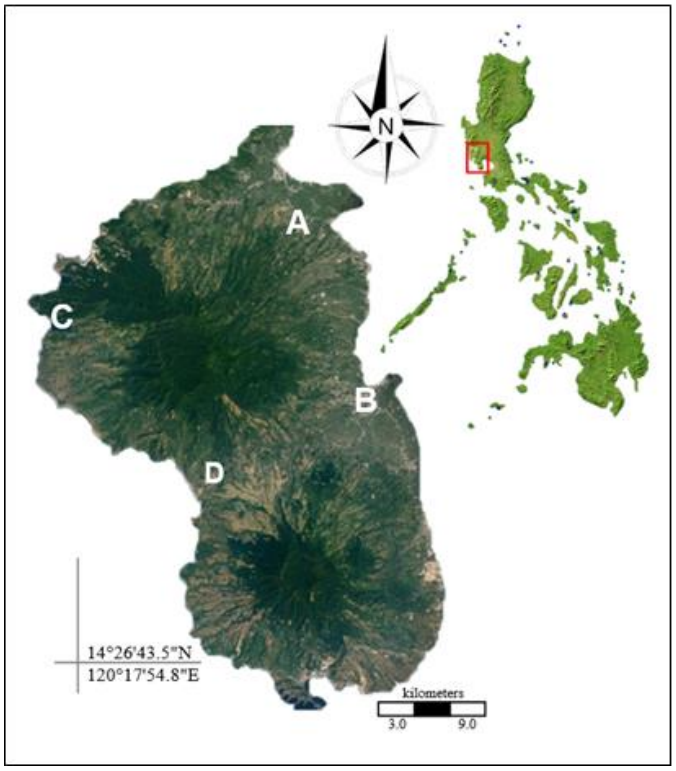


Figure 1. Bataan, Luzon Island, Philippines four riverine fishery areas: Almacen (A, Dinalupihan - Orani continuum), Talisay (B, Balanga - Pilar continuum), Morong (C), and Bagac (D).

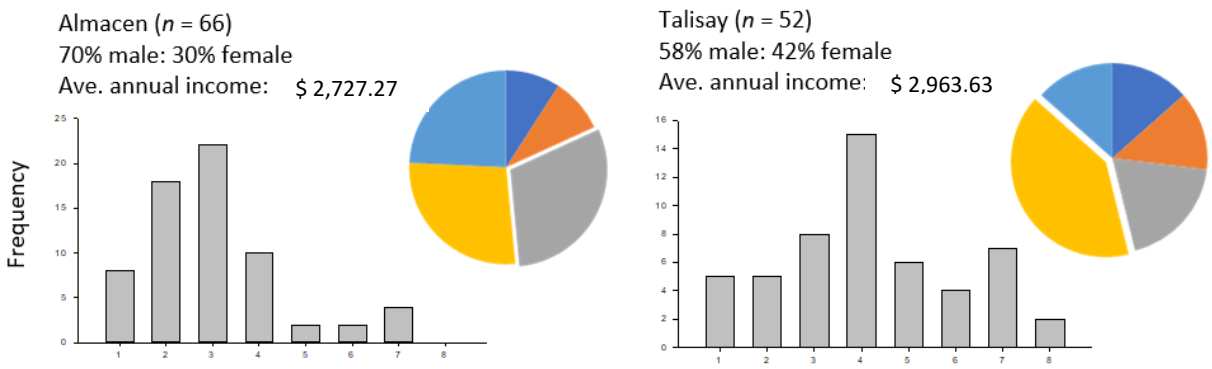
Talisay and Almacen rivers are the two major river systems on the east coast of Bataan. Talisay has its headwaters in the Mariveles mountain group, extending up to Pilar and Balanga, into Manila Bay. The Bagac river is located in the west, where the water is emptied into the West Philippines Sea (WPS). Almacen River has its headwaters in the Natib Mountains, extending down to Hermosa and exiting through the Orani Channel to Manila Bay, whilst on the western side is located the Morong river that drains in WPS (PEMSEA 2006).

Survey protocol. Fieldworks were done to collect information about the utilization of riverine fishery resources and their importance to the human populations from selected riverscapes. Likewise, their insights on the local fisheries resources and management (e.g. catches of fish, shrimps, and crabs) were assessed. Four coastal villages were sampled and the representative population was determined using Slovin's formula (marginal error ±3%). The sampling of the interviews was random, and a native inhabitant acted as a local mediator. Local specialists (e.g. representatives from the Provincial and Municipal Fisheries and Aquatic Management Office) were also interviewed. Structured interviews were digitally filmed, recorded, and photographed when the interviewees permitted. A formal approach using interview consent forms was adopted, although it was anticipated that the majority of the respondents (fisherfolks and fish farmers) would find the questionnaires and survey materials difficult to understand. The interviews consisted of open-ended, yes/no, and multiple-choice questions to suit the respondents' literacy level. The interviews were individual, but in some cases, they were performed in a focus group discussion with the number varying from two to five people.

Data analyses. All recorded interviews were transcribed, and all information collected on the interviews was considered. Subsequently, the responses were categorized and tabulated. The chi-square test was used to compare the frequencies of respondents among the fishery locations, and it was carried using SPSS version 21. This test was employed to confirm if the responses given by the respondents in each sampling location are statistically different ($P<0.05$).

Results and Discussion

Participants' profile. The summary of participants' socio-demographic profiles in each studied site is presented in Figure 2. A total of 192 respondents were interviewed, with the participation of 120 males (62.5%) and females (37.5%), whose ages varied between 23 and 74. This represents around 10% of the local fisherfolk populations in the four studied rivers. About 78.77% of the participants were not able to reach college level; 31.25% were high school graduates, whilst 21.88% got enrolled in a vocational course(s). The majority of participants (55%) belongs to low-income earner household with a monthly average income of USD 212.50 and has three to six members in the family.



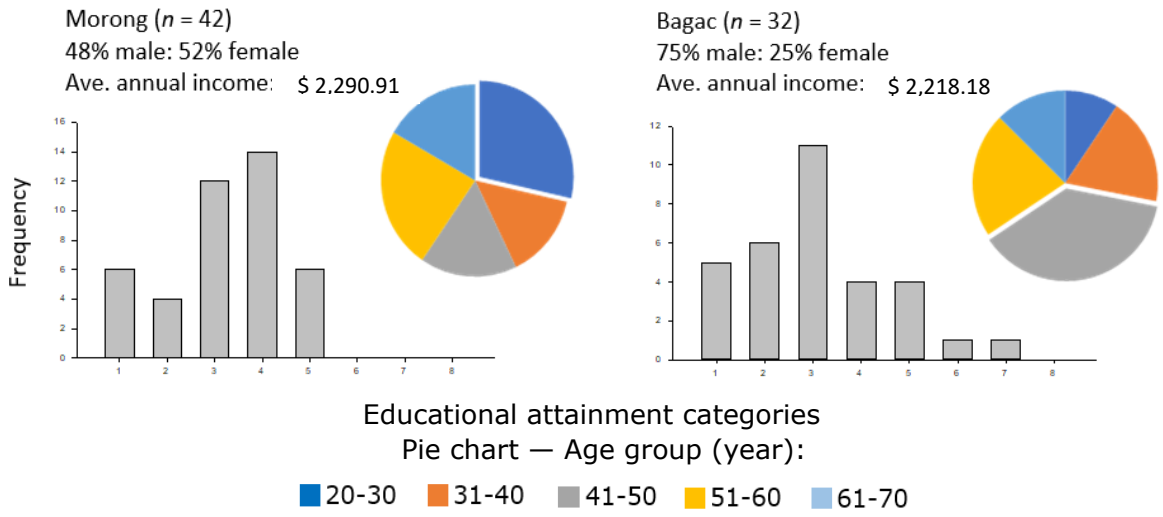


Figure 2. Respondents' socio-demographic profile. Bar graph represents educational attainment - elementary undergraduate (1), elementary graduate (2), high school undergraduate (3), high school graduate (4), vocational course (5), college undergraduate (6), college graduate (7), and graduate school (8). (1 USD=PhP 55).

Fishery resources and socio-economic importance. At least 50 different types of fishery resources were indicated to be occurring in the four studied rivers; 31 of which were teleost (fish), nine types of natantian decapods (shrimps and prawns), seven kinds of reptantian decapods (crabs), and three mollusk groups. All respondents noted that mangrove areas (downstream) harbored 95% of these fishery resources. The major river-fishery resources were largely composed of aquatic species known for aquaculture and exploitable stock for artisanal fisheries (Figure 3, Figure 4). Among the top major fishery resource groups, fish was the most exploited, followed by shrimps and prawns, and crabs. As pointed out by the respondents, fish was the most diverse and preferred in local markets, due to consumers' demand and ease of collection. Introduced cichlids, including black-chin tilapia (*Sarotherodon melanotheron*) and Nile tilapia (*Oreochromis niloticus*), were the most esteemed, with the latter having a higher commercial value price. Various species of gobies (ipon) and mullets (*Liza* sp.) were relatively abundant in Almacen and Talisay (east of Bataan) but were caught mainly for subsistence use. On the other hand, silver therapon (*Leiopotherapon plumbeus*), spotted scat (*Scatophagus argus*), eel (*Anguilla* sp.) and snakehead murrel (*Channa striata*) had a higher market price per wet weight than the aforementioned fishes, but their relative abundance was seasonal.

Crabs and shrimps are some of the most commercially important crustaceans in Bataan (Figures 3 and 4). Among the native crabs species, King crab or mangrove crab (*Scylla serrata*), orange mud crab (*S. olivacea*), and blue-swimming crab (*Portunus pelagicus*) were pointed out by the respondents as the most demanded on the local markets (2.20 to 7.27 USD per kg). Crabs were claimed to be the second most important source of income for the local fisherfolks, second to fish. Common penaeids including whiteleg shrimp (*Litopenaeus vannamei*), giant tiger prawn (*P. monodon*), and *Metapenaeus* sp. (*ipon* fisheries) are exploited both for commercialization and subsistence purposes. The market price for wild-caught shrimps ranged from 1.45 to 5.45 USD per kilogram. As emphasized by the local fisherfolks, all these aquatic resources are caught downstream, particularly in estuaries with a high concentration of mangroves. Giant freshwater prawn (*Macrobrachium rosenbergii*) is captured mainly from upstream and midstream of each sampling river and exploited for family consumption. The species of crabs and penaeid shrimps being exploited by the locals are also among the most important crustacean for aquaculture in the Philippines (BFAR 2014; FAO 2021).

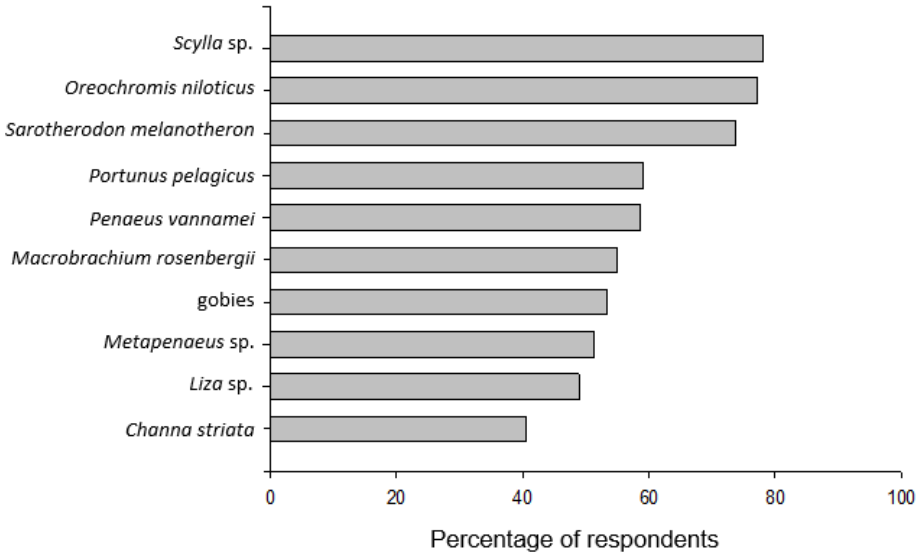
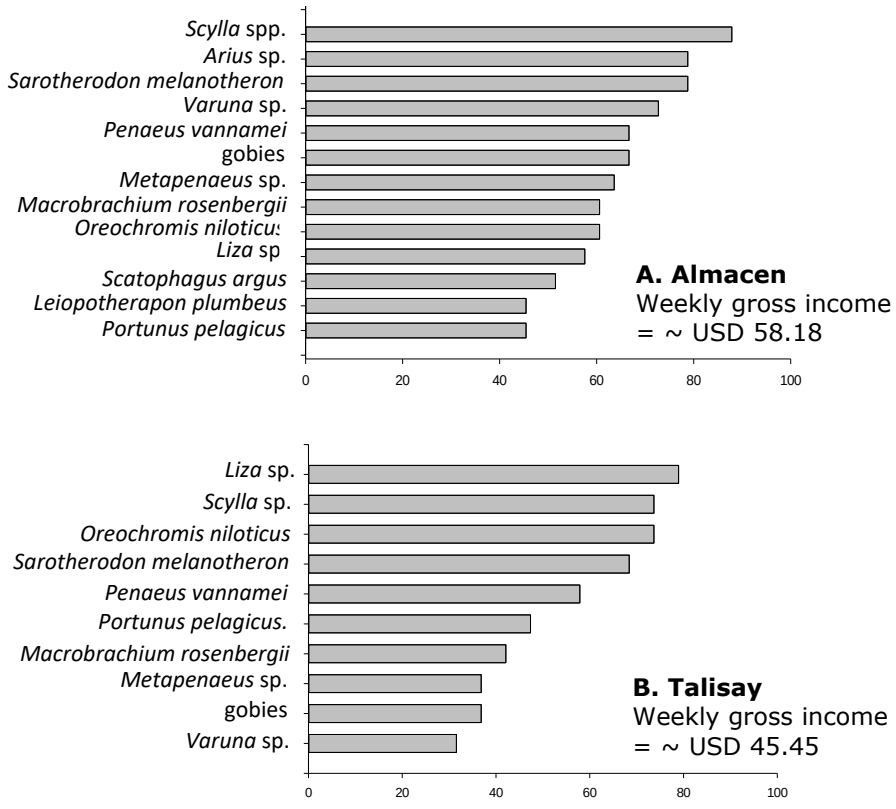


Figure 3. The major exploitable fishery resources in the four studied rivers in Bataan and the percentage (%) of respondents that use these resources. Gobies are an aggregate of diminutive fishery resources from various genera including *Glossogobius* spp., *Rhinogobius* spp., and *Neogobius* spp.

The *Cyrena* sp., a native mollusk, locally known as lukan that naturally thrives associated with the mangrove habitat is also an exploited resource and is an important source of income for 3% of the interviewees. About 35% of the respondents also recognized the occurrence of wild-caught oysters (*Crassostrea* sp.) and mussels (*Mytilus* sp.), albeit with negligible commercial importance due to small size, source, (urban areas, polluted waters), and their association to paralytic shellfish poisoning (red tide incidence). These mollusks are the fourth most exploited type of resource, albeit they were not indicated as of major importance for income generation due to their low local commercial value (0.5 to 1.09 USD per kg), and are sold as crab feeds or gasang.



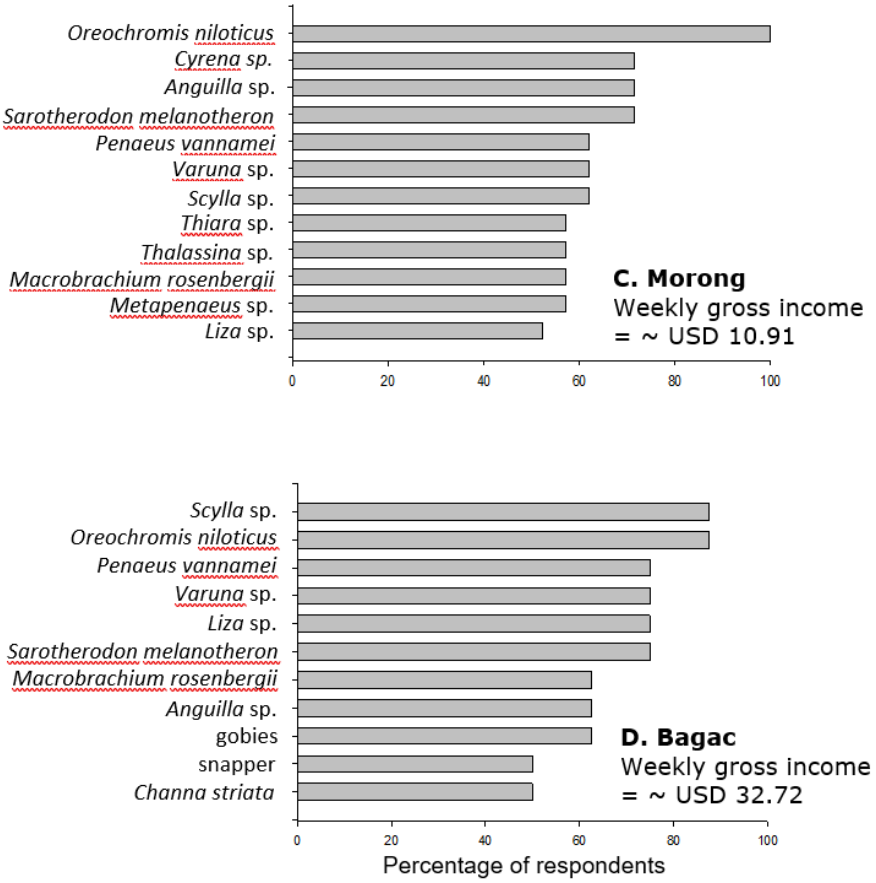


Figure 4. Major exploitable fishery resources in each studied river, percentage (%) of respondents that utilize these resources, and average weekly income of respondents derived from river fisheries activities.

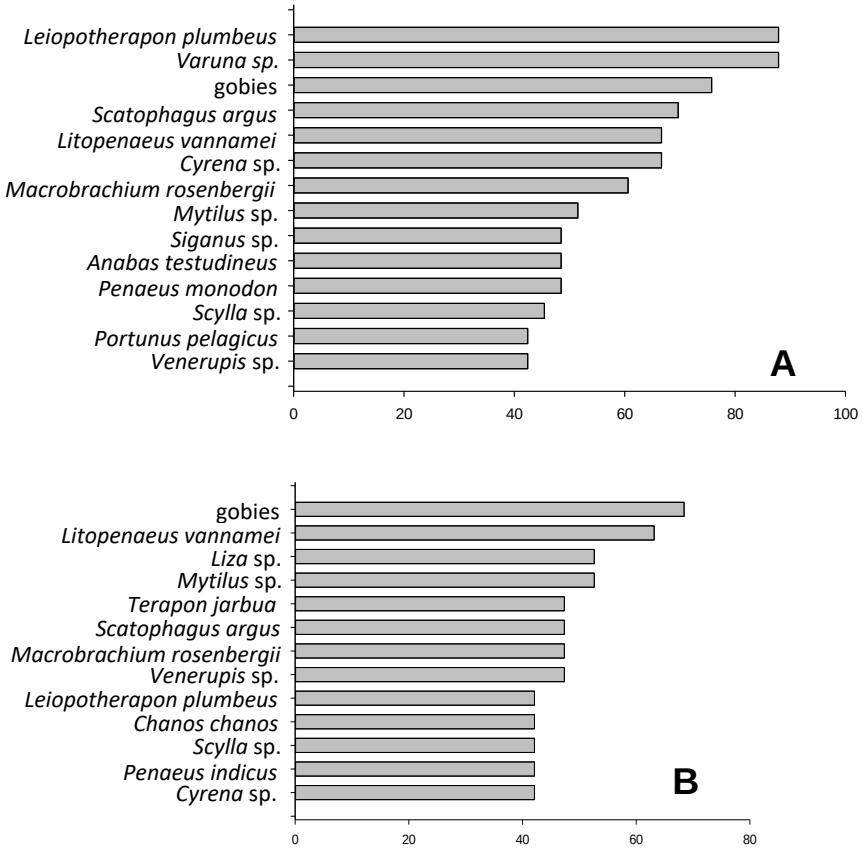
About 94% of the fisherfolk respondents had explored at least three types of these fishery resources (fish, crabs, shrimps, and mollusks), although 42% of the interviewees claimed that they tend to be selective as to the fish type and relative abundance. Several key factors influencing the preference of fisherfolks in fishery resources exploitation were noted (in order of importance) viz. (1) the economic value of the fishery resources, (2) availability of appropriate fishing methods, (3) seasonal abundance and distribution of fishery resources (jurisdictional regulation in fishing zones), and (4) size or sexual maturity of the fishery resources. About 52% of the respondents were primarily dependent on the fishery resources for their economic subsistence, 39% of the fisherfolks were also engaged in agri-aquaculture jobs, whilst 10% of the participants were either self-employed or hired on jobs with regular compensation. Variations among the average weekly income of fisherfolk respondents were significant ($P<0.01$), with the western local populations (Morong and Bagac) having a lower mean income relative to eastern populations (Almacen and Talisay) (Figure 4). The finding shows that the economic subsistence of fishing communities in Almacen and Talisay is heavily reliant on the productivity of mangrove ecosystems and fishery resources. On the other hand, respondents from Morong and Bagac are mainly engaged in municipal fishing in the West Philippine Sea and the collated income data covered only the remuneration derived from fishery activities in the riverscape, including sales of fishery resources and processed fish products, and fishponds caretaking. Regardless, income derived from fisheries (USD 6.14) is lower relative to the daily value of the minimum Philippine wage for Agriculture (USD 6.54).

As reported in other riverscape and estuary communities worldwide, mangrove environments exhibit a high level of aquatic biodiversity and standing biomass and are characterized by the abundance and distribution of teleosts, crustaceans, and mollusks

(Rönnbäck 1999; Walters et al 2008; Flores et al 2015; Santos et al 2017). In the present finding, these fishery resources are highly exploited by the local human populations, implying the significance of mangrove ecosystems and natural vegetation as sources of quality foods and livelihood for the riparian and coastal communities. Mangrove species prominent in the studied areas are *Rhyzophora* sp., *Sonneratia* sp. and *Nypa fruticans.*

Artisanal fishing methods are common and they optimize the use of a relatively small amount of capital and energy and small fishing vessels. Cast nets (59%), and gill nets (69%) were identified as the most important fishing gears used to catch river-fishery resources. Lift nets and traps (31%) were mostly utilized to collect crabs. Moreover, gamers and fish hobbyists mainly utilized angling or hook-and-line fishing (75%). However, prohibited and illegal fishing methods as stipulated in the Philippine Republic Act (RA) 8550 as amended by RA 10654), including fishing with noxious and poisonous substances (17%), electrofishing (13%), and fine-mesh nets (1%) are still being used in the studied fishery locations.

Changes in fishery resources. Fishery resources that have decreased in abundance and occurrence in each studied river are presented in Figure 5. The aquatic resources that were reduced in the last 40 years as perceived by at least 40% of interviewees are included in the graphs. Overall, reductions in yield as indicated by fisherfolks were observed in gobies, mullets, eel (most probably *Anguilla marmorata*), and terapontids (*Leiopotherapon plumbeus* and *Terapon jarbua*). For invertebrates, the yield has plummeted for river crabs (*Varuna* sp.), mangrove clam or *lukan* (*Cyrena* sp.), native penaeids shrimps (*Litopenaeus vannamei* and *Penaeus indicus*), mangrove crab (*Scylla* sp.), and giant freshwater prawn (*Macrobrachium rosenbergii*). Among the fishery resources exploited by the local communities, gobioid assemblages were, unanimously, the most signified fishery resources with diminishing yield in the last four decades (Figure 5). The diminishing yield of these aquatic species can serve as bioindicators of the ecological health status of the river system (Paller et al 2011; Corpuz et al 2015), which can be the basis of local government units for improved riverine and mangrove conservation management towards native fishery resource enhancement.



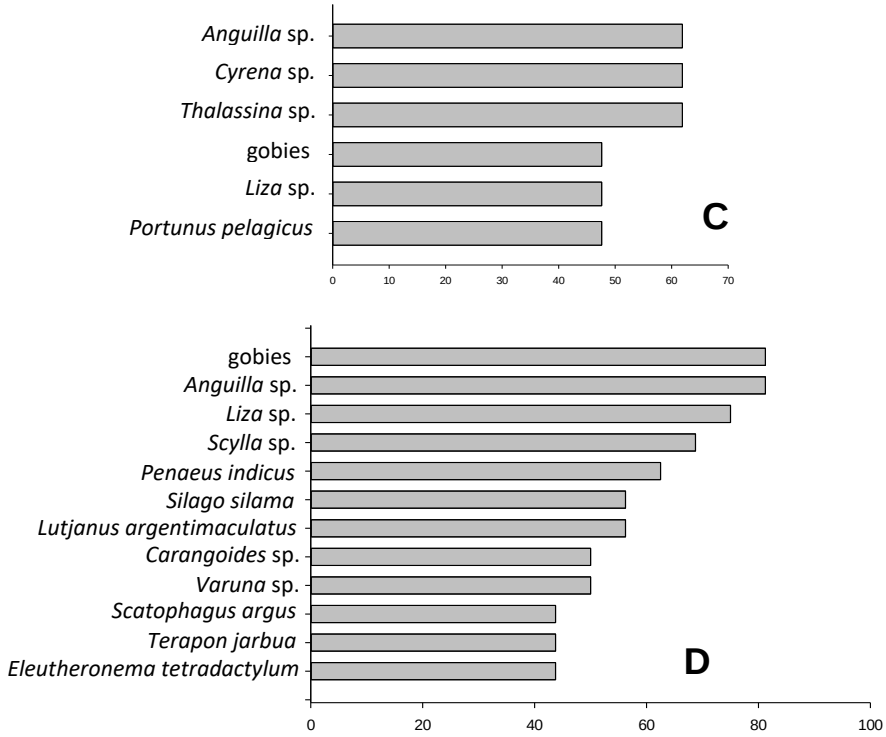


Figure 5. The fishery resources that have decreased in yield as observed by the fisherfolks. Almacen (A), Talisay (B), Morong (C) and Bagac (D). Gobies are an aggregate of diminutive fishery resources from various genera including *Glossogobius* spp., *Rhinogobius* spp., and *Neogobius* spp.

The pronounced increase in fishery yield of introduced cichlids (*S. melanotheron* and *O. niloticus*) in the studied rivers was greatly recognized by the fisherfolks (Figure 6).

Figure 6. Introduced fish species that established feral populations in Almacen and Talisay rivers. (A) Black-chin tilapia (*Sarotherodon melanotheron*) and (B) Nile tilapia (*Oreochromis niloticus*) are abundant in all studied fishery locations, whilst (C) bighead carp (*Hypophthalmichthys nobilis*) and (D) Mayan cichlid (*Mayaheros uropthalmus*) are consumed by the fishing communities in Almacen and Talisay (original photos).

These fish species were also dominant in several fish surveys conducted in the river systems of Bataan (Romero et al 2016; Roque et al 2019). Their mode of introduction

and establishment in the natural waters are still unknown, 80% of the respondents are appreciative of their occurrence considering that these fish species serve as food for their families, and the excess catch is sold to local markets providing a source of income to the fisherfolks. The Nile tilapia has a higher price on the market (0.54 to 1.09 USD per kg) as compared to black-chin tilapia (0.27 to 0.63 USD per kg). Mayan cichlid (*Mayaheros uropthalmus*) and bighead carp (*Hypophthalmichthys nobilis*) were also reported by several interviewees in Almacen, with the latter being regarded as the most esteemed among the abovementioned fishes. American sailfin catfish or janitor fish (*Pterygoplichthys* sp.), and Mozambique tilapia (*O. mossambicus*) were also present in Almacen and Talisay. Except for black-chin tilapia and janitor fish, the other non-native fishes reported herewith have no solid evidence of the adverse effect on the native species (Guerrero III 2014).

Environmental degradation as perceived by the fisherfolks. Different causes for fishery decrease were pointed out by the locals (Figure 7), with frequencies that did not statistically differ (χ^2=3.601; P=0.308). The main causative factor in the decline of fishery yield was the overexploitation of the fishery resources (72.38%). The finding indicates the lack of job opportunities and alternative income for the fisherfolks, a social issue that compromises both the local economic subsistence and the sustainable use of the river and mangrove resources.

Figure 7. Representative photos of anthropogenic disturbance occurring in Bataan River systems. (A) habitat alteration, (B) water pollution and solid wastes, (C) mangrove destruction (original photos).

Similar concern about overexploitation and excessive fishing capacity was also reported elsewhere (David Allan et al 2005; Santos et al 2017). Water pollution was noted as the second main reason for the decrease in fishery yield (67.03%). According to some respondents, the effluents from local populations and highland villages were released into rivers killing the aquatic resources. Apart from domestic waste, plastic pollution and solid waste management are of great concern for villagers living in Talisay and Almacen. The pollution of the river and mangrove ecosystems greatly affects riparian and coastal human populations living harmoniously with the environments (Diegues 1999), and residents are, in general, concerned regarding water quality degradation, which can lead to massive fish mortality (Satyanarayana et al 2013; Rabadon et al 2022). The

fisherfolks are also aware of the sporadic red tide occurrence on the east coast of Bataan, linked to the deteriorated water quality of the river flowing into the mangrove habitats.

The third reason most indicated for the fishery fall was the mangrove destruction caused by habitat alteration (57.29%); 63.63% of respondents from Almacen emphasized that the activity of aquaculture in the east of Bataan resulted in the decrease of the native fishery resources. Not only in the Philippines but also worldwide, brackishwater fishpond operations have been blamed as one of the anthropogenic activities responsible for the conversion and degradation of mangrove forests (Alongi 2002; Primavera 2006; FAO 2007; Flores et al 2016). Furthermore, anthropogenically-induced siltation caused by artificial meandering and desiltation activities in the rivers have negative impacts on river fishery resources and in the mangrove ecosystems (Extence et al 2011; Graf et al 2015). Induced siltation as attributed to the current housing construction in the upstreams and intermittent remeandering, desiltation activities and construction of flood control structures were also indicated.

Suggestions for local sustainable community development. The majority of the respondents (65.10%) stated the need for an increase in their income by providing alternative livelihoods from small-scale industries. When asked about these possible job opportunities, all interviewees emphasized several job preferences including carpentry (43.23%), construction and automotive (42.70%), retailing of various goods and lending businesses (40.10%), and commercialization of value-added products (32.29%). Alternative livelihood is important to break the dependence of the fisherfolk in extracting fishery resources, decreasing the fishing pressure in the area and thereby allowing the aquatic stock to replenish (Asiedu & Nunoo 2013).

The second most indicated alternatives were the support of the government to revive the aquasilviculture and mangrove rehabilitation program (57.29%), which was implemented by BPSU between 2011 and 2014 (Flores et al 2016). Should this will be launched again, officers of the Fisheries and Aquatic Resources Management Council (FARMC) suggested flourishing the select areas to become an eco-tourism site and a techno-demonstration site for mangrove crab fattening, mangrove-associated native fish production, and a breeding ground for sessile mangrove bivalves (e.g. *Cyrena* sp. and *Venerupis* sp.).

In the west coast, FARMC members highlighted the need for government support to fund the construction of a trap set net (*lambaklad* or *otoshi-ami*) as an alternative marine fishing method to obtain a variety of marine fish and become an alternative source of income. Several participants and coastal villagers also emphasized the current initiatives to save sea turtles or pawikan being implemented by the designated FARMCs and other local government unit volunteers; however, the initiatives are hampered by the lack of funds, facilities, supplies, and complementary human resources. Moreover, communal fisherfolks are requesting expanded government support for the milkfish fry industry and a possible establishment of sea salt production in strategic areas in Morong

The respondents were also appreciative of the current projects of the government on fish fingerlings dispersal, and the donation of nets, motorized fishing vessels, and other fishing equipment (36.65%). However, several participating fisherfolks raised their concern regarding the selection system of the beneficiaries for the project. Although these initiatives appear to be beneficial for the fisherfolks, there is the possibility of increased fishing efforts on mangrove habitats serving as nursery areas of fishery resources. In this context, establishing a limitation of the number of vessels, in order to attain fisheries sustainability appears unavoidable. Mapping the areas to designate particular fishing areas can be considered to further strategize the conservation management in estuaries and mangroves. Moreover, only 28.88% of the fisherfolks were aware of the ongoing college scholarship for children of fisherfolks, granted by the Bureau of Fisheries and Aquatic Resources (BFAR). Fisherfolks on the western coast had no knowledge about the scholarship program. All respondents agreed to the continuation and expansion of the program since the privilege of getting a college degree is a momentous aspiration of all fisherfolk parents for their children. Besides the scholarship, the respondents were fairly satisfied (25.52%) with the ongoing solid waste management

and river clean-up program of their respective local government units. As mentioned in the preceded statements, mismanagement of effluents and solid wastes from the upstream remains a major concern in the communities.

Conclusions. In this study, riverine and mangrove fishery resources are the primary source of economic subsistence of the coastal communities in the four studied river systems in Bataan. A scenario comparable to the river and mangrove ecosystems worldwide, characterized by a complex socio-ecological system, wherein the human and natural resources are entirely interdependent. These findings signify the need for holistic and participatory approaches for improved conservation planning and and fishery resources management in both the river and mangrove habitats. This can be reinforced by the application of appropriate fisheries biology and management tools coupled with socio-ecological assessment measures. Strategies for poverty alleviation and fisheries sustainability can be adopted, largely by creating designated areas for fishery resources extraction and conservation zone, where the main front liners of operation are the fisherfolks themselves. Industry-based livelihood projects based on beneficiaries' skill competencies and the use of alternative non-invasive fishing methods can be implemented through funding by the government, in order to further support the livelihood of the fisherfolks and to ease the fishing pressures. It is highly suggested to incorporate these alternatives into a local environmental planning and impact assessment and boost the dissemination of BFAR's projects among local fisherfolks through participatory local education, and IEC activities. Although this study is limited to Bataan, it is hoped that this will serve as a guideline for other areas with similar socio-ecological conditions and concerns, in order to ultimately achieve long-term food security and sufficiency.

Acknowledgements. This study is part of a bigger project funded by the Philippine Department of Science and Technology – Accelerated Science and Technology Human Resources Development Program and it is partially funded by BPSU Research and Development Office. Authors' appreciation is addressed to the Southeast Asian Regional Center for Graduate Study and Research in Agriculture for the SES scholarly materials; sincerest gratitude is also given to the members of Bataan FARMC, especially to their Chairman, Mr. Avelino V. Capuli, to the officers of Bataan Provincial Agriculture Office, particularly to Mr. Richard M. San Diego, and to the enumerators namely, Francis B. Mamawe, Joshua G. Camba, Rajean D. Vasquez, and Eugene Santos.

Conflict of interest. The authors declare no conflict of interest.

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Received: 15 October 2022. Accepted: 05 April 2023. Published online: 19 April 2023.
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How to cite this article:
Corpuz M. N. C., Espaldon M. V. O., 2023 Socio-ecological system assessment for conservation planning in riverine and mangrove fishery areas in Bataan, Philippines. AACL Bioflux 16(2):1114-1126.