Agricultural Biodiversity and Coastal Food Systems: A Socio-ecological and Trans-ecosystem Case Study in Aurora Province, Philippines

Shan Faye Alejos[1], Marivic Pajaro[1], Mark Raquino[1], Alex Stuart[1,2,3], and Paul Watts[1]

[1]Daluhay~Daloy ng Buhay, Baler, Aurora, Philippines; [2]International Rice Research Institute, Metro Manila, Philippines; [3]School of Biological Sciences, The University of Reading, Berkshire, United Kingdom

ABSTRACT

This paper presents a ridge-to-reef case study on Philippine biodiversity conservation that focused on reducing agricultural chemicals as a contribution to development goals of optimized food security, improving water quality, and mitigating maternal malnutrition. Building upon an earlier study that engaged participants and jurisdictions, farmers were oriented on biodiversity considerations and engaged in ecologically-based rodent management that was extended across the province of Aurora through the Office of the Provincial Agriculturist. Subsequently, a Participatory Action Research and Learning (PARL) cycle was conducted among 14 farmer participants to support biodiversity-friendly agriculture. Developed with local farmers, a biodiversity assessment demonstrated that organic approaches in rice farms increased arthropod biodiversity and reduced the number of key insect pests. The organizational results from this biodiversity study further indicated that local government participation can promote positive change by helping overcome the disconnect between communities and sustainability research. The approach to biodiversity-friendly agriculture reached a milestone through the collaborative development of an agricultural protected area supported by drafting a municipal ordinance to encourage the continued expansion of biodiversity-friendly agriculture and reductions in the chemical load of a key Aurora watershed. This paper discusses the biodiversity analysis and organizational results within the context of trans-ecosystem knowledge management and the goal of improving chronic maternal malnutrition that has been identified in coastal settlements of Aurora.

Keywords: coastal resource management, waterscape, biodiversity conservation, local governance, maternal malnutrition

JEL code: Q15

Contact Mark Raquino E-mail: markraquino@daluhay.org https://doi.org/10.37801/ajad2021.18.2.5

INTRODUCTION

The Philippines is generally considered to be a less-developed archipelagic nation with limited land resources and a large population. Given the history of agricultural development in the country, there is a need for new and more optimal approaches to food security that are inclusive of biodiversity conservation. In many less-developed and developed countries, there is a lack of focus on ecocentric values when considering socio-ecological health or Ecohealth. It has been suggested that Ecohealth can be optimized through the pursuit of balance between the ecosystem approach to health and the health approach to ecosystem (Watts et al. 2015). Globally recognized as a biodiversity conservation hotspot, the Philippines has few programs or templates that holistically link social aspects of the Sustainable Development Goals (SDGs) to biodiversity conservation.

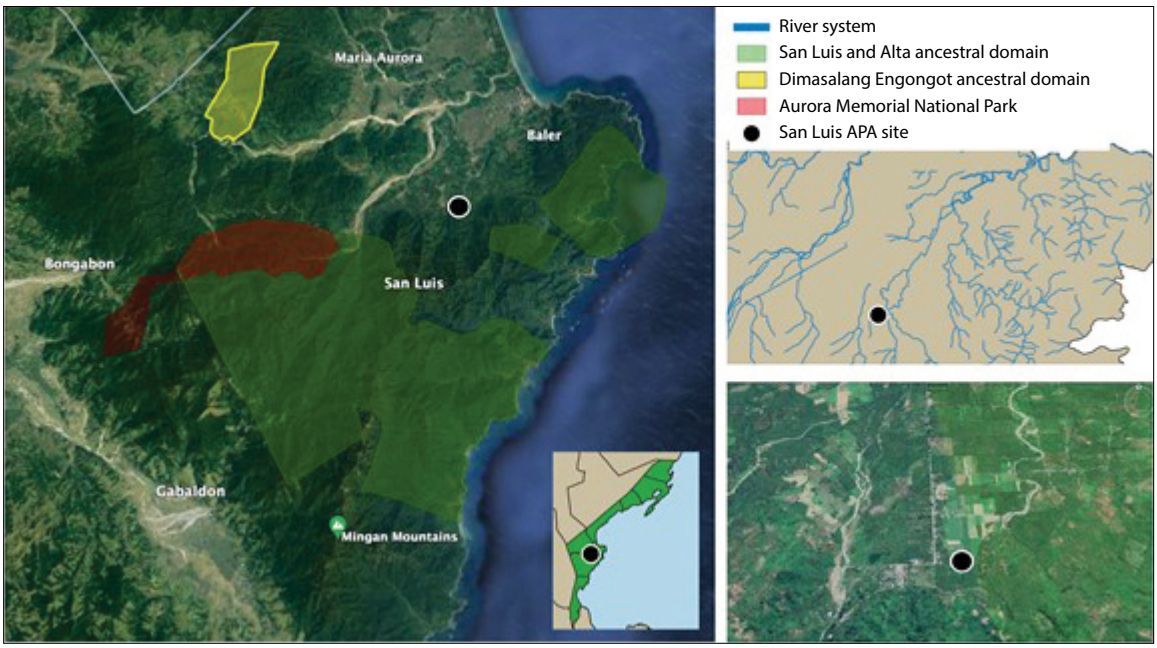
In Japan, organic farming practices have been found to support biodiversity conservation and other ecosystem services (Katayama et al. 2019). In the Philippines, there has been limited research on the connection between sustainable agriculture and both social and ecocentric goals. Agricultural chemicals clearly have a negative impact on coastal ecology (Islam and Tanaka 2004; Barletta, Lima, and Costa 2019); however, waterscape approaches to biodiversity conservation are also limited. The globally recognized disconnect between policy and positive environmental change (Gavin et al. 2018) appears to be extenuated when considering linkages between terrestrial activities and the marine environment. One approach to this challenge is to directly engage individuals who have a vested interest in both terrestrial and marine settings in a given area, in part considering their potential to influence policy. Optimally, interventions should result in positive environmental change at both the level of governance and society itself. Although agricultural components have rarely been integrated, this type of participatory approach has had positive results in other aspects of coastal resource management (Watts and Pajaro 2014; Ayala et al. 2016).

In a country where deforestation currently dominates the landscape, the province of Aurora still has intact mountain rainforests with sections of old-growth forest as well as complex lowland agroecosystems (Figure 1). Aurora is defined by the coastal ridges of the Sierra Madre Mountains and the Pacific Ocean, and its indigenous settlements and other residents implement a ridge-to-reef food system, accessing subsistence resources across marine, agricultural, and forest systems that transcend local government unit (LGU) boundaries. The province also has one of the longest Philippine coastlines and critical marine habitat for reef fish populations and rare cetaceans such as dugongs (*Dugong dugon*) and whale sharks (*Rhincodon typus*) (Ong, Afuang, and Rosell-Ambal 2002).

Poverty mitigation goals through the 17 international SDGs and over 150 indicators provide 30,000 possibilities for positive combined approaches. To progress, it would be useful to prioritize, particularly regarding social aspects of the SDGs that can complement the Philippines' biodiversity priority. In the Philippines, endemic childhood malnutrition is most acute in coastal fisherfolk communities (Capanzana et al. 2018), which points to the need for setting maternal-child nutrition as an SDG national priority (Watts 2019). Previous research has indicated that Aurora has acute maternal malnutrition represented by protein intake that is less than 20 percent of national and international recommendations (PMNCH 2018).

Waterscape pollution problems have been identified along Aurora's coastline by both fisherfolk and recreational surfers but have neither been studied systematically nor mitigated through local governance. Furthermore, the intertidal areas that were traditionally used as protein reserves have been critically overharvested, contributing to a reduction in food security. In the past decade, the restoration of Aurora's biodiversity has focused on mountain forests and coastline mangroves. The project area is within the Sierra Madre Biodiversity Corridor (SMBC), which is of global conservation significance (van der Ploeg, Masipiqueña, and Bernardo 2003), with

Figure 1. Ridge-to-reef, watershed delta, and governance complexities around the agricultural biodiversity assessment site in San Luis, Aurora



biodiversity and food security linkages that stretch across the ridge-to-reef spectrum and include aspects of watershed delta management (Figure 1). Consideration is given to the development status of the Municipality of San Luis in the succeeding discussion below.

Recent Progress on Biodiversity Conservation and Social Goals in San Luis, Aurora

The Philippine archipelago is globally recognized for the richness of its biodiversity of plants, invertebrates, and vertebrates. Among its rich biodiversity assets is mammalian endemism (Heaney et al. 1998), supported by the highest peak of Aurora, the Mingan Mountains bordering San Luis. The Mingan mammalian biodiversity of 35 species, which includes giant fruit bats, civets, wild pigs, deer, and giant cloud rats, is recognized internationally as deserving of conservation (Balete et al. 2011). The province also contains the largest remaining cover of Philippine old-growth tropical rainforest with significant habitat diversity (Ong, Afuang, and Rosell-Ambal 2002). Aurora and San Luis are home to a diverse range of rare and threatened species, including the critically endangered Philippine eagle (*Pithecophaga jefferyi*). However, there is concern about the collapse of eagle and other large-bodied bird populations due to habitat destruction (Española, Collar, and Marsden 2013).

Historically, commercial logging was the largest threat to Philippine biodiversity. In the face of subsequent imposition of a national logging ban, current primary threats are habitat conversion for agriculture, often with links to small-scale illegal-logging and underlying challenges concerning waterscape pollution. Moreover, agricultural practices to curb pest damage, including rodent pests, include the use of pesticides and the destruction of regenerating forest on crop edges (Stuart 2009). Such practices may also be counter-productive by limiting the ability of native rodent species to reduce the impact of harmful invasive rodent species through interspecific competition (Stuart, Prescott, and Singleton 2016). Thus, it is important to apply ecological principles to study, design, and manage agroecosystems, as well as use an Ecohealth lens to link the health of

ecosystems to that of people (Altieri 2002; Watts and Williamson 2015; Watts et al. 2015). Jackson et al. (2010) suggested that strategic incentives can promote agro-biodiversity; this paper documents the creation of a legal framework for that, in the form of a municipal ordinance. The majority of Aurora residents work for subsistence, often moving across forests, agricultural areas, and marine fisheries. This study considers linkages between agricultural biodiversity conservation and food security in coastal Aurora, specifically considering the social priority of maternal nutrition.

The remarkable biodiversity heritage of the central SMBC is nurtured by disconnected and marginally developed groups of indigenous people and their ancestral domains (Figure 1). These protected areas are isolated from national and LGU efforts, often with differing approaches. Communities managing coastal resources need to incorporate traditional knowledge and practices with university-based science. Stakeholders continue to report extirpation and declining populations of native wildlife species, involving species that are both culturally and economically important, in the central SMBC. All provincial watersheds empty into Aurora's coastal waters, characterized by declining intertidal biodiversity and unsubstantiated reports by both local and visiting surfers of water-borne illness. One challenge is that development is fragmented by sectoral and jurisdictional interests. Forests, agriculture, urban settlements, and coastal reefs are governed separately and waterscapes and/or watersheds are not managed as entities. Across the foothills of the SMBC, farmers often work up into the forested mountain areas and out into the ocean as fishers. This is particularly true for indigenous people whose ancestral domain claims cover most of the provincial forest land, overlapping with municipal jurisdictions (Figure 1). The situation signifies the need to further consider biodiversity continuity within one specific goal of society. Recognizing that there are many causal factors in the challenges of food security, water quality, and maternal malnutrition, emphasis is placed herein upon one holistic socio-ecological paradigm and a theory of change connecting agricultural biodiversity and maternal malnutrition through initiating the institutionalization of biodiversity-friendly agriculture (Figure 2).

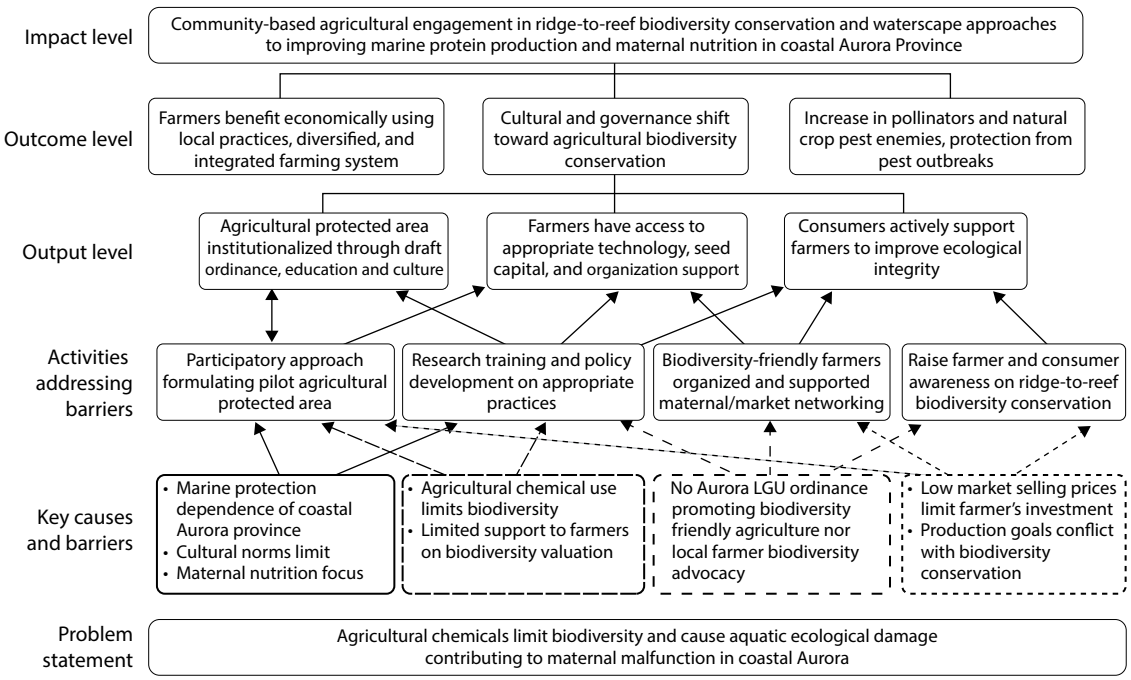
Sustainable Agriculture and Ridge-to-Reef Food Systems in Aurora Province

This paper aims to further consider biodiversity continuity within one specific goal of society. There is growing national and international demand for sustainable agricultural practices (Stuart et al. 2009; Islam and Tanaka 2004; Barletta, Lima, and Costa 2019). Although there are formal farmer-led approaches to related science partnerships in many places across the Philippines (Watts and Williamson 2015), these have not been extended to coastal Aurora. However, biodiversity conservation within agricultural practices has been piloted though local innovation and catalyst research (Stuart 2009).

There is increasing global awareness of the critical need to consider food security and biodiversity together (Fedotova et al. 2021) through context-specific strategies (Delzeit et al. 2017). Although not yet characterized in detail, Aurora's food systems are ridge-to-reef based. As is the case nationally, protein provision is impacted by declining marine biodiversity. Meanwhile, agricultural chemicals reduce the biodiversity of soil microbes linked to healthy crop yields, cause a decline in coastline ecosystem quality (Barletta, Lima, and Costa 2019), and threaten both food safety and food security (Garcia, Osburn, and Jay-Russell 2020). Biodiversity-friendly solutions require appropriate governance and support mechanisms to facilitate a transition, particularly in less developed settings such as Aurora. Local women's needs have been acted upon to promote their empowerment in coastal Aurora (Pajaro et al. 2013). Maternal marine protected areas have been piloted (PMNCH 2018), and biodiversity-friendly agricultural practices were previously introduced to the province as part of an ecological-based rodent management approach (Stuart 2009).

In Aurora, the introduction of biodiversity-friendly agricultural practices for rodent pest management was initiated at the conclusion of

Figure 2. Theory of change for integrating agriculture with ridge-to-reef biodiversity conservation and the Sustainable Development Goals



a doctoral study (Stuart 2009), wherein training workshops were conducted with the Aurora Provincial Agriculturalist, municipal agriculture office staff, and farmers. Topics included native non-pest rodents and their beneficial roles, and the ecology of non-native pest rodent species. Recommendations were given for ecologically-based rodent management approaches that minimized risks to non-target wildlife (Stuart, Singleton, and Prescott 2015). Farmers were encouraged to conduct rodent management on a community scale and were supported with the provision of rat traps. Using the training material, the Office of the Provincial Agriculturist expanded the training of biodiversity-friendly pest-control across the province. Targeted rat campaigns were focused on non-native pest species, while efforts were made to minimize harmful effects towards native non-pest rodents. The government supplied farmers with zinc phosphide, which remains the rodenticide of choice. However, it should be noted that pre-baiting to improve efficacy is now widely practiced and bait is applied in individual plastic sachets to reduce non-target poisoning. The farmers were more willing to accept related recommendations upon recognizing that the approaches were based on research that had been conducted specifically in their province and adapted according to the local context. This is in accordance with previous research suggesting that recommendations based on existing farmer practices will increase the likelihood of farmer adoption (Palis, Singleton, and Flor 2008).

Due to limited income, smallholder farmers have little to spend on rodent management (Stuart et al. 2011; Stuart, Singleton, and Prescott 2015). Guidance on sustainable and effective use of existing rodent control methods allow farmers to adjust their rodent management strategies without the need for additional expense. By adopting these strategies, it is expected that there will be a reduction in costs associated with rodent control, as well as reduced yield loss to rodent pests and reduced risk to non-target species (Stuart, Singleton, and Prescott 2015). Strategically, this action cycle linked the farmers to spatial and

temporal scales through exposure to multiple knowledge systems (Jackson et al. 2010).

The initial agricultural biodiversity project cycle reviewed above provided a basis for the development of Aurora's first agricultural protected area (APA) as described below. This paper reports on an area within the largest Aurora watershed, targeted for improvement through biodiversity-friendly agricultural practices and facilitation of supporting government action. Action research is one response to growing awareness that policy-based approaches in themselves are not able to meet the challenges of development, biodiversity depletion, or other forms of environmental degradation (Gavin et al. 2018). This paper discusses how the use of participatory action research and learning (PARL) (Keahey 2021) enabled positive change in agriculture through the engagement of both farmers and local government policy, with a focus on biodiversity, waterscape quality, and chronic and acute maternal malnutrition in coastal areas.

METHODS

Arthropod Biodiversity

To assess and compare arthropod biodiversity between organic, semi-organic, and non-organic rice farms, sweep-net surveys were conducted within a 0.8 ha rice-based landscape in the municipality of San Luis, within Aurora's coastal watershed. Surveys were conducted in three different rice farms consisting of (1) 100 percent synthetic site, where only synthetic fertilizer and pesticide inputs were applied; (2) semi-organic site where organic and synthetic methods were used interchangeably; and (3) 100 percent organic site, where no synthetic inputs were applied (Figure 3). Each of the sites was surveyed three times in different locations, and each survey involved 15 sweeps of the arthropod sweep net. Insects were identified to the family level and spiders were identified as belonging to either the *Tetragnathidae* family (i.e., long-jawed spiders) or all other families of spider. The rice fields surveyed were within two weeks of harvest in the first cropping season.

Participatory Action Research and Learning (PARL)

The planning section of this PARL cycle was focused on the selection and engagement of individual farmers. In collaboration with the LGU, farmers who were recognized for their local leadership and had either experience or an interest in sustainable agriculture were selected. Targeting keystone sustainable agricultural practices in San Luis, Aurora was one component of a multi-faceted approach to improving provincial maternal health. The project was launched in 2015 as part of a larger United Nations Development Program initiative. Although there was a lack of available females, the municipal agriculture office helped identify 14 suitable farmer participants (13 male, 1 female) based on their interest in biodiversity-friendly agriculture. The group's core had previous experience with either ecologically-based rodent management, as discussed above, organic agricultural practices, and/or biodiversity conservation. In addition to coastal maternal health concerns, the PARL cycle emphasized three biodiversity values: (1) conservation and protection enhancement of rare and threatened species; (2) ecology, ecological resilience, and ecosystem functioning based on species biodiversity; and (3) biological control (i.e., biodiversity and abundance of natural enemies of potential pest organisms) (Duelli and Obrist 2003). More than two-thirds of the group had experience with farmers' organizations, which provided important experience on group action. Once the group was established and further oriented regarding the possible expansion of biodiversity conservation, the next step was to determine if there was a difference in arthropod biodiversity when comparing management approaches that limit the use of fertilizers and pesticides to sites that injudiciously apply chemicals to target maximum crop production. Arthropods were selected due to their expected abundance.

Using a pre-structured questionnaire, the participating farmers were interviewed to understand their farming practices, socioeconomic status, and current knowledge and perspective on biodiversity. Educational attainment was determined to assist in designing appropriate facilitation approaches. Income levels were characterized as well as spending priorities, land status, and the types of crops grown. The farmers were asked if they had experience with the use of organic farming and what methods they employed for pest control. The approach used for marketing crops and the profit margins were determined.

RESULTS

Arthropod Biodiversity

The largest number of individual arthropods was recorded in the site that was 50 percent organic, while the largest number of insect families was found in the site that was 100 organic (Table 1). Simpson's biodiversity index was used to compare both species diversity and abundance at the treatment sites. The results indicate that the highest biodiversity of arthropods was recorded in the organic farm with a value of 0.831, followed by the semi-organic farm with a value of 0.764. The management approach with the lowest biodiversity (0.545) was the 100 percent synthetic farming practice. These results support previous studies in rice ecosystems that recorded higher biodiversity of arthropods, higher abundance of natural enemies of insect pests, and lower insect pest abundance in rice fields that received less chemical inputs (Hardin et al. 1995; Stuart et al. 2018). Of particular significance was how the lowest number of a primary pest, the rice black bug (*Scotinophara coarctata*), was found in the organic treatment site.

Participatory Action Research and Learning (PARL)

To promote the engagement and participation of farmers, the results of the biodiversity survey were presented to the farmer group and the farmers were encouraged to discuss the results and identify the existing determinants of their use of chemicals. They were then asked to define their approach and caveats regarding an APA that limited chemical use.

About half of the farmers in the group were influenced by the interests of either bulk buyers or middlemen. Nearly half of rice farmers sold their harvest directly (44%), followed by those who had bulk buyers (33%), and those who relied on middlemen (*ahente*) to sell their products (22%). More than half of fruit and vegetable farmers had buyers (60%), while the rest sold their products directly in their municipality (40%). Among the respondents, only two were rice farmers that used purely organic methods. One had a 0.5 ha rice field that cost PHP 5,000 (USD 100) for one cropping season, while the other had a 0.1 ha field and spent approximately PHP 2,000 (USD 40) per season. They opted not to sell their products due to the size of their rice farm. Those that used inorganic inputs described that they usually earned less than what they spent on taking care of the crops.

Table 1. Sweep-net survey results in three rice field treatment types in San Luis, Aurora, Philippines

	100% Synthetic Treatment	50% Organic Treatment	100% Organic Treatment
Number of insect families	7	7	10
Total number of insects	100	145	110
Long-jawed spiders *(Tetragnathidae)*	32	12	48
Total number of other spiders	19	14	8

On the other hand, rice farmers that used semi-organic methods earned relatively better income in their 0.5 ha and 0.75 ha rice farms since their farms required less expense on inorganic inputs.

This PARL cycle established a foundation for the coastal farmers to become involved in establishing a waterscape approach to biodiversity and health, led by recognized farm-leaders from across the municipality. After reviewing the biodiversity assessment results through a facilitated focus group discussion, the farmers identified five reasons why establishing an APA is advantageous:

1. Potential livelihood and tourism opportunities from establishing a premium market for organic products
2. Health benefits from consuming organic products and clean water runoff in their farms and community, potentially reducing the need for medicines and hospital trips
3. Reduced effort required in soil maintenance and pest control (i.e., enhanced ecosystem services)
4. Promotion of community participation in reducing synthetic inputs for fertilizers and pesticides
5. Alignment with national and local laws for organic agriculture implementation and incentive schemes from the LGU

As a direct result of the project, the San Luis Municipal Agriculture Office developed an ordinance that recognizes and promotes the development of biodiversity-friendly agriculture. The ordinance, which declared a policy on promoting organic farming and agricultural biodiversity, sustainable farm tourism, and incentive provision, is the first such ordinance to be developed in coastal Aurora. The municipal ordinance was drafted to also establish linkages with two national laws (Republic Act 10068, the Organic Agriculture Act of 2010, and Republic Act 10816, the Farm Tourism Development Act) and to contribute to the international Aichi Biodiversity Targets and the SDGs. The ordinance provides for the formation of an executive committee to promote organic and agricultural biodiversity, sustainable farm tourism, the development of biodiversity-friendly product marketing strategies, and the provision of incentives. Delayed by the pandemic, further ordinance development and related actions are planned for 2022. In considering the development of future APAs, the involvement of farmers and the municipal agriculture office throughout the process was seen as critical to the attainment of the targeted results.

DISCUSSION

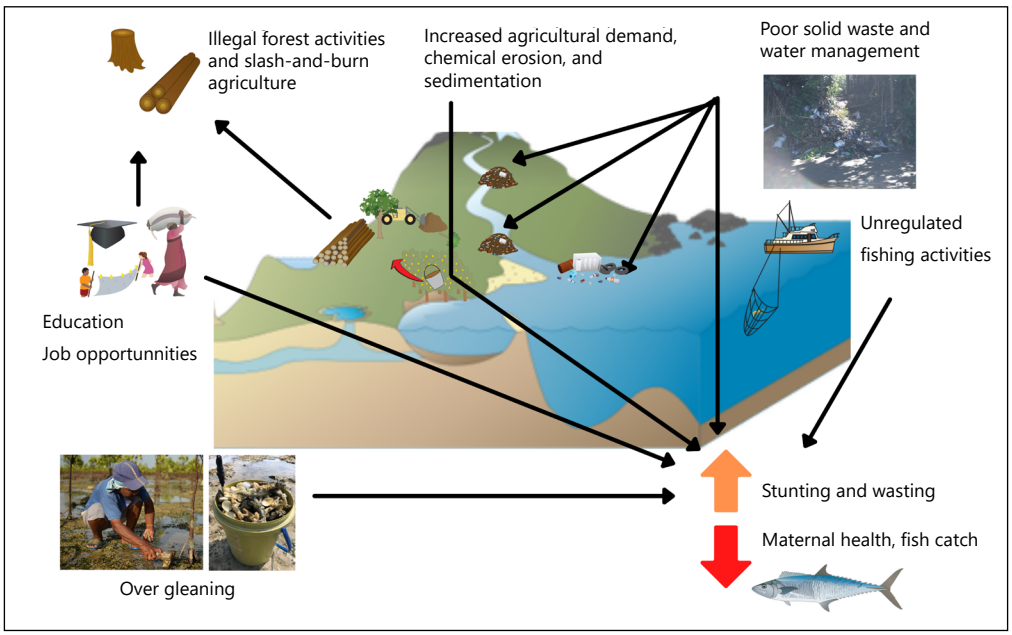
Change in Biodiversity Conservation at the Municipal Level

Through a PARL approach, this project demonstrated the process applied in establishing the first APA in the SMBC. This was supported by drafting a municipal ordinance to encourage the continued expansion of biodiversity-friendly agriculture and reductions in the chemical load of a key Aurora watershed. The involvement of the public was limited to one group of farmer leaders. However, their contribution to the development of an ordinance set a municipal and provincial precedent for sustainable agriculture and established a culture-based reference for the process. The overall results of the interventions indicated that there is a governance and farmer interest in supporting biodiversity-friendly agriculture at the municipal level in San Luis, Aurora. In consideration of the development of future agriculture protected areas, the involvement of farmers in other municipalities as well as the provincial and municipal agriculture offices is clearly optimal for the expansion of biodiversity-friendly agriculture.

Linkages of Trans-ecosystem Biodiversity Conservation to Maternal Health

This study intended to demonstrate how a PARL cycle can be used to initiate holistic approaches that include ecocentric values for agricultural biodiversity and priority social values, herein considered to be maternal nutrition.

Figure 3. Trans-ecosystem linkages to coastal maternal health



The dependence upon marine resources for maternal protein is both provincial and national, requiring complex trans-ecosystem solutions. Developing an ordinance to support sustainable agriculture and to reduce chemical loads going into the water and coastal habitats contributes to reversing acute maternal malnutrition across the province (Figure 3). The results demonstrate that a shift toward organic practices will improve agricultural biodiversity. Apart from improving agricultural biodiversity, a shift towards organic practices reduces coastline pollution that can be detrimental to marine ecosystems.

A ridge-to-reef approach to biodiversity conservation is particularly important in Philippine provinces such as Aurora, where many communities have interconnected livelihood activities in forest, agriculture, and marine settings. The marine ecosystem is critical for the provision of protein, with the Philippines recognized as having the highest rate of marine resource consumption for any large country in Southeast Asia (Silvestre and Pauly 2004). Recently, the World Health Organization showcased a related study in Aurora indicating that coastal women were receiving less than 20 percent of the required protein during maternity (PMNCH 2018). That report featured an approach identified by the current authors to optimize intertidal zones for maternal nutrition, partly based on a wide range of ecologically sound improvements regarding waste disposal, land use, and agriculture (Figure 3). These changes include the control and management of gleaning or the collection of intertidal invertebrates and other forms of more sustainable approaches to fisheries.

There is increasing local action and recognition that farmers have a responsibility as natural resource managers to minimize their negative impacts on associated ecosystem services that are valuable to both farming and society (Blasi et al., 2016). Through fertilizer and pesticide run-off into rivers, synthetic chemicals used in agricultural fields also end up degrading coastal habitats that are important for protein production. The PARL cycle documented herein specifically addressed minimizing the use of synthetic chemicals in agriculture to reduce the negative effects on coastal ecosystems. Part-time farmers that are engaged in forest-related income generation are also being targeted to develop biodiversity friendly approaches for agroforestry. The protection of native non-pest rodents and the

reduction of chemical loads across waterscapes are the first two strategies implemented in the coastal SMBC to move the agro-livelihoods toward more biodiversity-friendly applications.

CONCLUSIONS AND RECOMMENDATIONS

There is increasing global recognition that there is a need to produce food more sustainably while protecting biodiversity and the environment, which are considerations for the ongoing development of new Philippine marine fisheries management (BFAR 2020). These considerations are highly relevant to the Sierra Madre Biodiversity Corridor (SMBC) where Aurora Province is situated, one of the most biologically rich regions of the world (van der Ploeg et al. 2003). Through a PARL approach, this project demonstrated the process applied to establish the first APA in the SMBC. Apart from reducing the negative impacts of agriculture on biodiversity and the environment within the APA, this will have far-reaching positive effects beyond the agricultural border out to coastline ecology. These coastal areas are directly influenced by agricultural runoff that impairs the reliance of coastal communities on intertidal and open water ecosystems for food and nutrition, particularly protein. Further efforts are now needed to replicate this approach across the SMBC and in other environmentally-sensitive areas of the Philippines. It will safeguard the environment and ensure sustainable food production for future generations in a country that is somewhat isolated as an archipelagic nation. This study recommends the development of future PARL cycles focusing on establishing a network of farmers' organizations, fisherfolk, non-government organizations, LGUs, and scientists specifically for the SMBC that will work toward waterscape-level food security through the sustainable use and management of land and water in a ridge-to-reef approach. A holistic approach to acute maternal malnutrition in Aurora requires a project-based approach to steps or cycles for positive change. Future PARL cycles currently in the planning stage include successional agroforestry pilot projects and expansion of biodiversity-friendly protected areas, enhanced governance, and related livelihoods across the province. Moreover, related initiatives focus on maternal nutrition considerations such as reforestation, women's advocacy groups, coastal reef restoration, and maternal marine protected areas.

ACKNOWLEDGMENT

The results of the agricultural project discussed in this study was made possible by the dedication and enthusiasm of the local farmers and the support of government officials in the Municipality of San Luis and the Province of Aurora. The strategic project was awarded to Daluhay through the United Nations Small Grants Program for Aurora Province, Philippines.

REFERENCES

Altieri, M.A. 2002. "Agroecology: The Science of Natural Resource Management for Poor Farmers in Marginal Environments." *Agriculture, Ecosystems & Environ*ment 93(1–3): 1–24. doi:10.1016/S0167-8809(02)00085-3

Ayala, J., P. Bautista, M. Pajaro, M. Raquino, and P. Watts. 2016. "Sustainable Development of Philippine Coastal Resources: Subsidiarity in Ethnoecology Through Inclusive Participatory Education." *International Review of Education* 62(2): 161–185. doi:10.1007/s11159-016-9546-9

Balete, D.S., P.A. Alviola, M.R.M. Duya, M.V. Duya, L.R. Heaney, and E.A. Rickart. 2011. "Chapter 3: The Mammals of the Mingan Mountains, Luzon: Evidence for a New Center of Mammalian Endemism." *Fieldiana Life and Earth Sciences* 2011(2): 75–87. doi:10.3158/2158-5520-2.1.75

Barletta M., A.R.A. Lima, and M.F. Costa. 2019. "Distribution, Sources and Consequences of Nutrients, Persistent Organic Pollutants, Metals and Microplastics in South American Estuaries." *Science of the Total Environment* 651(Part 1): 1199–1218. doi:10.1016/j.scitotenv.2018.09.276

Blasi, E., N. Passeri, S. Franco, and A. Galli. 2016. "An Ecological Footprint Approach to Environmental–Economic Evaluation of Farm Results." *Agricultural Systems* 145: 76–82. doi:10.1016/j.agsy.2016.02.013

BFAR (Bureau of Fisheries and Aquatic Resources) and USAID-URI Fish Right Program (United States Agency for International Development-University of Rhode Island Fish Right Program). 2020. *Toolkit on Rolling-out Fisheries Management Area Implementing FAO No. 263 S. 2019*. https://www.bfar.da.gov.ph/FMA2020/FMA%20Toolkit%20(July%202020)(1).pdf

Capanzana, M.V., D.V. Aguila, G.M.P. Gironella, and K.V. Montecillo. 2018. "Nutritional Status of Children Ages 0–5 and 5–10 Years Old in Households Headed by Fisherfolks in the Philippines. *Archives of Public Health* 76: 24. doi:10.1186/s13690-018-0267-3

Delzeit, R., F. Zabel, C. Meyer, and T. Václavík. 2017. "Addressing Future Trade-offs Between Biodiversity and Cropland Expansion to Improve Food Security." *Regional Environmental Change* 17(5): 1429–1441. doi:10.1007/s10113-016-0927-1

Duelli P., and M.K. Orbist. 2003. "Regional Biodiversity in an Agricultural Landscape: The Contribution of Seminatural Habitat Islands." *Basic and Applied Ecology* 4(2): 129–138. doi:10.1078/1439-1791-00140

Española, C.P., N.J. Collar, and S.J. Marsden. 2013. "Are Populations of Large-bodied Avian Frugivores on Luzon, Philippines, Facing Imminent Collapse?" *Animal Conservation* 16(4): 467–479. doi:10.1111/acv.12018

Fedotova, G.V., L.F. Sotnikova, E.R. Orlova, A.F. Baranova, and A.V. Goncharova. 2021. "Global Problems of Biodiversity and Food Security." *IOP Conference Series: Earth and Environmental Science* 677: 032010. doi:10.1088/1755-1315/677/3/032010

Garcia, S.N., B.I. Osburn, and M.T. Jay-Russell. 2020. "One Health for Food Safety, Food Security, and Sustainable Food Production." *Frontiers in Sustainable Food Systems* 4: 1. doi:10.3389/fsufs.2020.00001

Gavin, M.C., J. McCarter, F. Berkes, A.T.P. Mead, A., E.J. Sterling, R. Tang, and N.J. Turner. 2018. "Effective Biodiversity Conservation Requires Dynamic, Pluralistic, Partnership-based Approaches." *Sustainability* 10(6): 1846. doi:10.3390/su10061846

Hardin, M.R., B. Benrey, M. Coll, W.O. Lamp, G.K. Roderick, and P. Barbosa. 1995. "Arthropod Pest Resurgence: An Overview of Potential Mechanisms." *Crop Protection* 14(1): 3–18. doi:10.1016/0261-2194(95)91106-P

Heaney, L.R., D.S. Balete, M.L. Dolar, A.C. Alcala, A.T.L. Dans, P.C. Gonzales, N.R. Ingle, M.V. Lepiten, W.L.R. Oliver, P.S. Ong, E.A. Rickart, B.R. Tabaranza Jr., and R.C.B. Utzurrum. 1998. "A Synopsis of the Mammalian Fauna of the Philippine Islands." *Fieldiana: Zoology New Series* (8):1–61.

Islam M.S., and M. Tanaka. 2004. "Impacts of Pollution on Coastal and Marine Ecosystems Including Coastal and Marine Fisheries and Approach for Management: A Review and Synthesis." *Marine Pollution Bulletin* 48(7–8): 624–649. doi:10.1016/j.marpolbul.2003.12.004

Jackson, L., M. van Noordwijk, J. Bengtsson, W. Foster, L. Lipper, M. Pulleman, M. Said, J. Snaddon, and R. Vodouhe. 2010. "Biodiversity and Agricultural Sustainability: From Assessment to Adaptive Management." *Current Opinion in Environmental Sustainability* 2(1–2): 80–87. doi:10.1016/j.cosust.2010.02.007

Katayama, N., Y. Osada, M. Mashiko, Y.G. Baba, K. Tanaka, Y. Kusumoto, S. Okubo, H. Ikeda, and Y. Natuhara. 2019. "Organic Farming and Associated Management Practices Benefit Multiple Wildlife Taxa: A Large-scale Field Study in Rice Paddy Landscapes." *Journal of Applied Ecology* 56(8): 1970–1981. doi:10.1111/1365-2664.13446

Keahey, J. 2021. "Sustainable Development and Participatory Action Research: A Systematic Review." *Systemic Practice and Action Research* 34(3): 291–306. doi:10.1007/s11213-020-09535-8

Ong, P.S., L.E. Afuang, and R.G. Rosell-Ambal. 2002. *Philippine Biodiversity Conservation Priorities. University of the Philippines Center for Integrative and Development Studies*. 113. Quezon City, Philippines. Foundation for the Philippine Environment.

Pajaro, M., M. Raquino, A.C. Tangson, F. Tiburcio, G. Valenzuela, and P.D. Watts. 2013. "Strategic and Challenge Driven Municipal Action for Remote Philippine Coastal San Luis Communities." *Journal of Research in Peace, Gender and Development* 3(2): 24–28.

Palis, F.G., G.R. Singleton, and R.B. Flor. 2008. "Humans Outsmarting Rodents: Adoption and Impact of Ecologically Based Rodent Management in Asia." In *Philippine Rats: Ecology and Management*, edited by G.R. Singleton, R.C. Joshi, and L.S. Sebastian, 127–142. Science City of Muñoz: Philippine Rice Research Institute.

van der Ploeg, J., A.B. Masipiqueña, and E.C. Bernardo, eds. 2003. *The Sierra Madre Mountain Range: Global Relevance, Local Realities*. Papers presented at the 4th Regional Conference on Environment and Development. Tuguegarao City: Cagayan Valley Program on Environment and Development. https://aboutphilippines.org/documents-etc/van+der+Ploeg+et+al+2003.pdf

PMNCH (Partnership for *Maternal* Newborn and Child Health). 2018. Multisectoral Collaborations – Country Examples. World Health Organization. https://www.who.int/pmnch/en/

Silvestre, G., and D. Pauly. 2004. "An Overview of Tropical Coastal Fisheries in Asia: Key Challenges and Opportunities." In *In Turbulent Seas: The Status of Philippine Marine Fisheries*, 150-167. Philippines: Coastal Resource Management Project, Cebu City; and Department of Environment and Natural Resources.

Stuart, A.M. 2009. "Rodent Ecology and Management in the Complex Lowland Agro-ecosystems of the Sierra Madre Biodiversity Corridor, Philippines." School of Biological Sciences. University of Reading. PhD Thesis.

Stuart, A.M., C.V. Prescott, G.R. Singleton, and R.C. Joshi. 2011. "Knowledge, Attitudes and Practices of Farmers on Rodent Pests and their Management in the Lowlands of the Sierra Madre Biodiversity Corridor, Philippines." *Crop Protection* 30(2): 147–154. doi:10.1016/j.cropro.2010.10.002

Stuart, A.M., G.R. Singleton, and C.V. Prescott. 2015. "Population Ecology of the Asian House Rat (*Rattus tanezumi*) in Complex Lowland Agroecosystems in the Philippines." *Wildlife Research* 42(2): 165–175. doi:10.1071/WR14195

Stuart, A.M., C.V. Prescott, and G.R. Singleton. 2016. "Can a Native Rodent Species Limit the Invasive Potential of a Non-native Rodent Species in Tropical Agroforest Habitats?" *Pest Management Science* 72(6): 1168-1177. doi:10.1002/ps.4095

Stuart, A.M., K.P. Devkota, T. Sato, A.R.P. Pame, C. Balingbing, N.T.M. Phung, N.T. Kieu, P.T.M. Hieu, T.H. Long, S. Beebout, and G.R. Singleton. 2018. "On-Farm Assessment of Different Rice Crop Management Practices in the Mekong Delta, Vietnam, Using Sustainability Performance Indicators." *Field Crops Research* 229: 103–114. doi:10.1016/j.fcr.2018.10.001

Watts, P.D. 2019. "Maternal Indigenous and Artisanal Coastal Nutrition, the SDG Imperative: A Suggested Renaissance of Ethics for Research and Tertiary Education in the Anthropocene Era." *International Journal of Nutrition* 4(3): 1–6. doi:10.14302/issn.2379-7835.ijn-19-2774

Watts, P.D., and M.G. Pajaro. 2014. "Collaborative Philippine-Canadian Action Cycles for Strategic International Coastal Ecohealth." *Canadian Journal of Action Research* 15(1): 3–21.

Watts, P., B. Custer, Z.-F. Yi, E. Ontiri, and M. Pajaro. 2015. "A Yin-Yang Approach to Education Policy Regarding Health and the Environment: Early-careerists' Image of the Future and Priority Programmes." *Natural Resources Forum: A United Nations Sustainable Development Journal* 39(3–4): 202–213. doi:10.1111/1477–8947.12083

Watts, M., and S. Williamson. 2015. "Replacing Chemicals with Biology: Phasing Out Highly Hazardous Pesticides with Agroecology." Penang: Pesticide Action Network Asia and the Pacific. https://panap.net/resource/replacing-chemicals-with-biology-phasing-out-highly-hazardous-pesticides-with-agroecology/