


POLICY BRIEF

Ensuring Aquatic Food Security in the Philippines

Reniel B. Cabral^{1*} , Rollan C. Geronimo², Antonio Samuel S. Mamauag^{2,3}, Juan A. Silva^{4,5,6},
Roquelito H. Mancao⁷, Michael P. Atrigenio⁸

¹ Marine Biology and Aquaculture, College of Science and Engineering, James Cook University, Townsville, QLD, Australia

² Marine Environment and Resources Foundation, Inc., The Marine Science Institute, University of the Philippines Diliman, Quezon City, Philippines

³ Biology Department, College of Science, De La Salle University, Taft Ave., Manila, Philippines

⁴ Coastal Solutions Fellows Program, Cornell Lab of Ornithology, Ithaca, NY, USA

⁵ Fundación Refugia, Sector Huilquicura-Santa Rita, Ruta N-114 S/N, Cobquecura, Región del Ñuble, Chile

⁶ Institute of Ecology and Biodiversity (IEB), Victoria 631, Barrio Universitario, Concepción, Región del Biobío, Chile

⁷ Rare Philippines, Cebu City, Cebu, Philippines

⁸ The Marine Science Institute, University of the Philippines Diliman, Quezon City, Philippines

ABSTRACT

The human population of the Philippines is expected to reach 158 million by the year 2050, or an increase of 37% relative to 2022. This implies increased demand for aquatic food (or “fish” hereafter). This begs the question of whether the Philippines can meet the expected increase in fish demand. We estimate that even if the Philippines can maintain its current fish production, the Philippines will still require 1.67 million metric tons more fish per year by 2050 to at least maintain its current per capita fish consumption of 34.27 kg per year. Continued mismanagement of inland and marine fisheries will further widen the gap in fish supply. However, we argue that simultaneously rebuilding overfished fisheries, restoring degraded habitats crucial to supporting productive fisheries, addressing current threats to fisheries sustainability, and expanding sustainable marine aquaculture (or mariculture) have the potential to meet future fish demand in the Philippines. Sustainably expanding mariculture requires careful siting and management of mariculture development areas so that mariculture can improve food security without disenfranchising and marginalizing local coastal communities.

*Corresponding Author: reniel.cabral@jcu.edu.au
Received: September 15, 2022
Accepted: September 11, 2023

Keywords: Food security, inland and marine fisheries, aquaculture, mariculture, Sustainable Development Goals, Philippines

1. Introduction

Aquatic food, consisting of wild capture and cultured production of aquatic animals from marine and freshwater environments, is an important source of protein and micronutrients in the Philippines. Filipinos source most of the aquatic food or fish they consume from the ocean. However, wild capture fish catch has stagnated or declined in the past three decades in many municipal fisheries in the Philippines, primarily due to overexploitation (Muallil et al. 2014a; Anticamara and Go 2016). Furthermore, aquaculture production growth is minimal, and

inland capture fish production is stagnant or declining (BFAR 2021). Fish supply deficits have been reported recently (e.g., Jocson 2022). If current trends in fish production remain the same, a gap in the aquatic food supply is likely to widen in the future, given that the number of Filipinos is expected to increase by 25–37% in the next 20–30 years (i.e., years 2040–2050) (UN 2022). How can the Philippines sustainably increase fish production to meet the expected increase in fish demand? We estimate how much fish the Philippines will require in the future and explore opportunities to meet the country’s expected increased fish demand sustainably.

2. Fisheries and aquaculture production and consumption trends

Fisheries and aquaculture production data from 2010–2022 indicate that municipal marine capture fisheries production has declined by 19,187 metric tons (MT) per year, inland capture fisheries production by 2,644 MT per year, commercial fisheries production by 23,216 MT per year, and seaweed aquaculture production by 30,890 MT per year, while fish and shellfish aquaculture (inland and marine) production has increased by 8,431 MT per year (Figure 1). Most of the seaweed in the country is processed to produce carrageenan rather than locally consumed as fresh food (Pedrosa III et al. 2022). Excluding seaweed, the total production of fish and shellfish (or “fish”) intended for food has declined by 36,616 MT per year from 2010 to 2022.

Coupling the net decline in fish production with the increase in the human population of the Philippines of 20.9 million from 2010 to 2022 (UN 2022; World Bank 2023a), a reduction in the per capita fish consumption is expected. Indeed, the per capita fish consumption in the Philippines has declined in the last decade: 39.8 kg per year in 2013 (BFAR 2015, Cabral and Geronimo 2018), 37 kg per year in 2015 (BFAR 2020), and 34.27 kg per year in 2018–2019 (BFAR 2021) (Figure 2). The per capita consumption in 2018–2019 comprises 23.36 kg per year of fresh fish, 2.85 kg per year of dried fish, 4.97 kg per year of processed fish, and 3.10 kg per year of crustaceans and mollusks (BFAR 2021).

In theory, the total fish production should match the total fish consumption. To test that, we

estimate fish production from consumption data. Filipinos’ latest per capita fish consumption is 34.27 kg per year (2018–2019 data), expressed as “raw edible,” i.e., fish meat with no bones or shells (DOST-FNRI 2022). Given that most of the aquatic food consumed by Filipinos is fish, we use a 0.87 conversion factor (1 unit of live weight = 0.87 edible weight) (Edwards et al. 2019; Costello et al. 2020) to derive the amount of fish consumed by Filipinos in live weight, i.e., 34.27 kg per year of “raw edible” fish is equivalent to 39.39 kg per year of live weight fish. Multiplying this value with the 2022 Philippine population of 115.56 million (UN 2022; World Bank 2023a), the Philippines has been consuming 4.55 million MT of fish yearly (live weight) in recent years. This fish consumption exceeds the reported total fish supply of 2.79 million MT for 2022 (Table 1). The Philippines is a net fish importer, with a net import of 274,817 MT in 2021 (the latest data available), i.e., import of 533,235 MT and export of 258,418 MT (BFAR 2022) (Table 2). Considering the fish export and import intended for human consumption, we estimate a net import of 287,721 MT in 2021 (Table 2). Therefore, even when accounting for the fish import volume, assuming that the fish import for 2022 is the same as for 2021, total consumption is still higher than fish supply. The discrepancy in values is likely due to unreported and illegal fishing catches that do not enter the national fisheries catch statistics. A recent study suggests 516,000–766,000 MT of fish per year are illegally caught and potentially unaccounted for, and a further 583,000–907,000 MT of fish per year are unreported (Coastal Resources Center 2021).

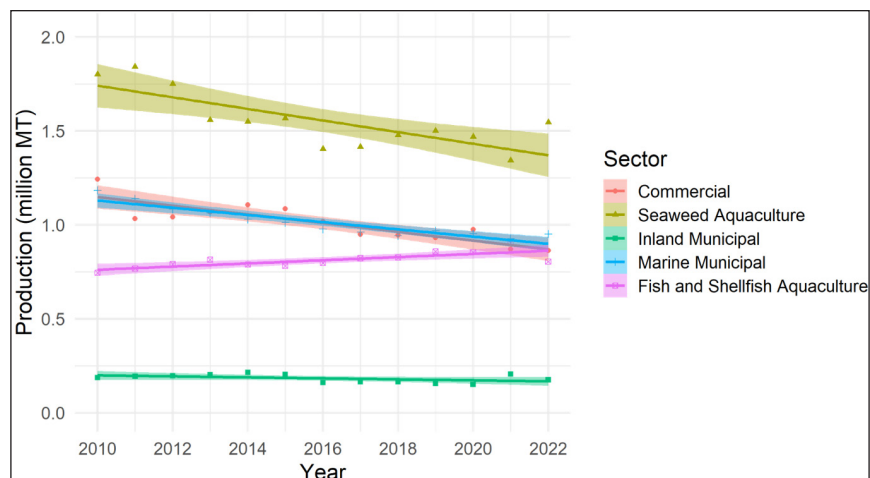


Figure 1. The trend in Philippine fish production from 2010 to 2022. MT is metric tons (1 MT = 1000 kg). Data from BFAR (2021), BFAR (2022), and PSA (2023).

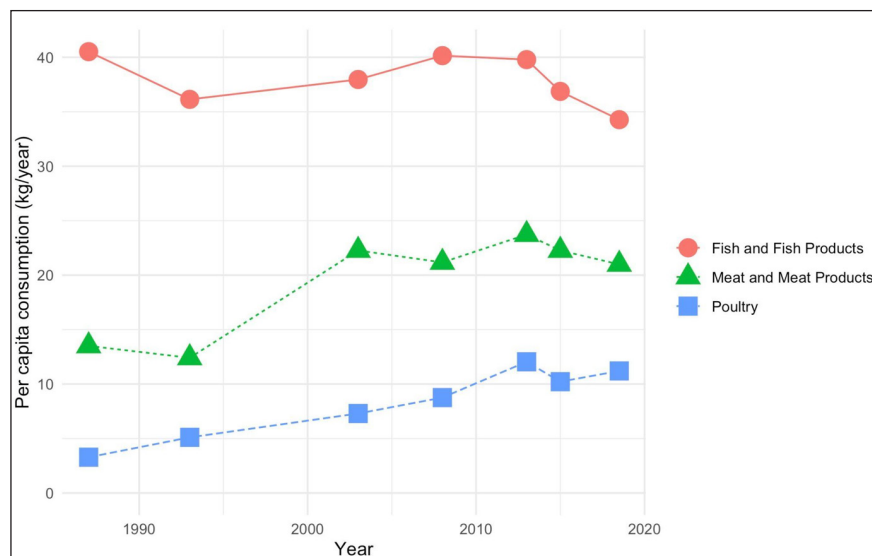


Figure 2. Mean annual per capita consumption of fish and fish products, meat and meat products, and poultry in the Philippines. Data for 1987, 1993, and 2003 from BFAR (2014); data for 2008, 2013, and 2015 from BFAR (2018); data for 2018-2019 from BFAR (2022), which was derived from the Expanded National Nutrition Survey of DOST-FNRI. We recorded the mean one-day per capita consumption values in grams per day from the BFAR reports cited above and converted them to annual per capita consumption in kg per year by multiplying the values by 365 days * 0.001 kg/gram.

Table 1. Fisheries and aquaculture production in the Philippines for the year 2022. MT is metric tons (1 MT = 1000 kg). Data from PSA (2023).

Category	Harvest (in MT)	Total (in MT)	Note
Municipal Capture Fisheries	1,126,260.25		Inland municipal capture fisheries catch constituted 15.57% of the total municipal catch in 2022. ~85% of the municipal catch, or 950,908.69 MT, is derived from the marine environment.
Commercial Capture Fisheries	862,686.33		
Total capture fisheries production		1,988,946.58	The total harvest from the marine environment is 1,813,595.02 MT
Aquaculture	2,349,252.01		
Seaweed	-1,544,959.98		Seaweed is 65.76% of the aquaculture production.
Total fish aquaculture		804,292.03	Fish aquaculture production, i.e., seaweed excluded.
Total capture fisheries and aquaculture fish production		2,793,238.61	This excludes seaweed.

Table 2. Export and import of fish and products for the year 2021. MT is metric tons (1 MT = 1000 kg). Data from BFAR (2022).

Category	Total volume	Estimated volume of fish for human consumption*	Note
Export	258,418 MT	217,978 MT	Seaweeds were removed from the estimated fishery export volume intended for human consumption to be consistent with the rest of our analysis. Of the total fishery export volume in 2021, 33,285 MT were seaweeds, 29,055 MT of which was Carrageenan (BFAR 2022). Ornamental fish weighing 7,155 MT was also removed from the fishery export volume for human consumption.

Continuation of Table 2. Export and import of fish and products for the year 2021. MT is metric tons (1 MT = 1000 kg). Data from BFAR (2022).

Category	Total volume	Estimated volume of fish for human consumption*	Note
Import	533,235 MT	505,699 MT	Prawn feeds (13,619 MT) and fish unfit for human consumption (13,917 MT) were removed from the fishery import volume for human consumption.
Net import	274,817 MT	287,721 MT	

*Crude estimate as we cannot disentangle some import and export fishery items.

3. Future fish demand

We estimate how much additional fish will be demanded by Filipinos in the future. As the human population increases and becomes wealthier, the historical trend in fish consumption relative to other potential substitutes (meat and poultry) can inform future fish demand. A global analysis that uses historical food consumption data suggests that the per capita consumption of meat, poultry, and fish increases as the country's per capita income increases (Gouel and Guimbard 2019). An analysis that disaggregates terrestrial meat and fish found that, on a global scale, increasing per capita income increases terrestrial meat consumption, while per capita fish consumption tends to be relatively flat for a wide range of per capita income (Naylor et al. 2021). A huge variation exists around the per capita fish consumption trend as a country becomes wealthier. For instance, the per capita consumption in China increased five-fold between 1975 and 2015 and is expected to increase further as China is expected to become more affluent (Naylor et al. 2021).

Using data for the Philippines published in the Bureau of Fisheries and Aquatic Resources (BFAR) reports, we found that from 1987 to 2019, there was an increase in per capita meat and poultry consumption, while the per capita fish consumption appears relatively flat, albeit showing a decreasing trend in recent years (Figure 2). The per capita income of the Philippines has also increased for the same period (World Bank 2023b). The trend in the Philippine terrestrial meat and fish consumption in relation to the country's increase in per capita income is consistent with the global trend reported by Naylor et al. (2021). The human population in the Philippines is expected to increase by 42.33 million in the next 28 years (i.e., from 2022 to 2050, UN 2022). We can conservatively assume that the demand for aquatic food linearly scales with the population size (i.e., the per capita

fish consumption will remain the same) and assume that the future growth in wealth in the Philippines will mainly increase per capita demand for meat and poultry. Using the current yearly fish consumption of 39.39 kg live weight (34.27 kg raw edible weight), the Philippines will require an additional 1.67 million MT of fish per year (live weight) by 2050.

4. Future fish supply

Considering the current trajectory of aquaculture production and managing the marine and inland capture fisheries sustainably, can the Philippines meet the future demand for fish for a growing number of Filipinos?

We first comment on the sustainable fish production potential of marine and inland capture fisheries and then on the aquaculture production trajectory. We give attention to the marine environment as over 80% of the fish production in the Philippines is from this space, but we also recognize the value of freshwater fisheries and aquaculture in the food security of landlocked communities (e.g., the Cordillera Administrative Region). Then, we comment on whether the projected supply of fish will be sufficient to fulfill future fish demand in the Philippines.

It is instructive to compare the marine capture fisheries harvest with its estimated multispecies maximum sustainable yield (MMSY). MMSY is the maximum yearly harvest that can be sustainably generated from the marine environment without collapsing the fisheries.

It was estimated that the total MSY for the Philippine marine fisheries (i.e., mixed fisheries) is 1.65±0.25 million MT per year (Barut et al. 1997; Barut et al. 2003). The total marine fisheries harvest for 2022 is 1.814 million MT and is within the range of the total MSY of the Philippine marine fisheries (Table 1). However, marine fish catch (combined

marine municipal and commercial fisheries) is higher in earlier years and, therefore, above MMSY, which indicates overfishing (Figure 1).

Production from inland capture fisheries in 2020 is 175,352 MT, showing a slightly declining trend in the past decade (2010-2022 data) (Figure 1). A study indicated that the freshwater resources of the Philippines could produce 250,000 MT of fish per year (Palma 2016).

Aquaculture production is linearly increasing by 8,431 MT per year from 2010 to 2022 (Figure 1), mainly due to increased production in the marine and brackishwater environments (Figure 3). If this trend continues, fish aquaculture production is expected to produce an additional 236,068 MT per year relative to 2022 fish aquaculture production of 804,292 MT or a yearly aquaculture production of 1.04 million MT by 2050.

Assuming that both marine and inland capture fisheries are well-managed in the future and are able to provide the maximum sustainable amount of food, i.e., the higher bound estimate of MMSY of 1.9 million MT per year for marine fisheries and 250,000 MT per year for inland fisheries, the aquaculture continue its increasing trend and able to produce ~1 million MT per year by 2050, and import of fish is maintained at current level of ~300,000 MT per year, the future supply of fish by 2050 is estimated to be 3.45 million MT per year. This expected production in 2050 falls short of the current yearly fish consumption of the Philippines of 4.55 million MT by 1.1 million MT per year. Adding in the fish that will be demanded by the additional 43 million Filipinos by 2050, a gap of

2.77 million MT of fish per year by 2050 is estimated. How can we ensure that maximum sustainable yields from the marine and inland fisheries are generated in the future, and where can the Philippines source the extra fish needed to meet its future demand?

5. Address threats to Philippine fisheries

Achieving sustained productive fisheries harvest requires addressing threats to fisheries sustainability. It is, therefore, important to identify the major threats to Philippine fisheries.

Silvestre and Pauly (1997) documented major threats to marine fisheries in South and Southeast Asia, which are still relevant in the Philippines context at present. These include 1) overfishing and overcapacity in fisheries; 2) the use of inappropriate fishing practices, i.e., the use of unselective fishing gears, poison fishing, illegal fishing, and poaching; and 3) marine habitat degradation from pollution, sedimentation, and destructive fishing. These threats are still prevalent at present and are considered the primary threats to fisheries sustainability identified in the State of the Coral Triangle - Philippines Report (Asian Development Bank 2014) and other publications (e.g., Muallil et al. 2014b; Macusi et al. 2020).

Improved management has substantially reduced the prevalence of destructive and dangerous fishing practices such as blast and cyanide fishing (e.g., Selgrath et al. 2018), although these fishing practices are still in use in the Philippines (e.g., Macusi et al. 2020). Illegal, unreported, and unregulated (IUU)

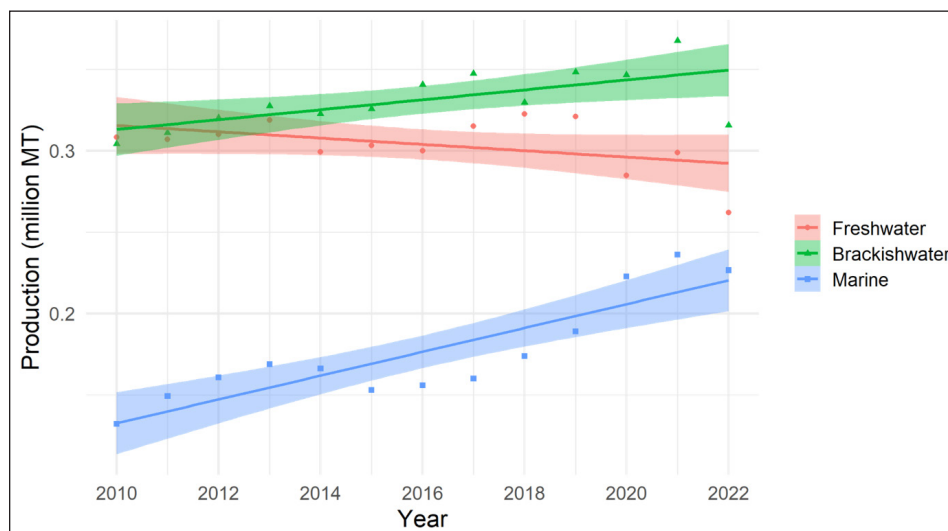


Figure 3. Philippine aquaculture production disaggregated by aquatic environments from 2010 to 2022. MT is metric tons (1 MT = 1000 kg). Data from PSA (2023).

fishing remains a significant and serious problem in the Philippines (Coastal Resources Center 2021). There is also an increasing concern about the potential negative impact of climate change on Philippine fisheries (e.g., Santos et al. 2011; Muallil et al. 2014b; Suh and Pomeroy 2020; Macusi et al. 2020).

Inland fisheries are essential for food security, especially in landlocked areas, and are also experiencing overfishing, habitat destruction, pollution, siltation, and unreported fishing (Funge-Smith 2018). Addressing these problems could allow inland fisheries to support the food security of landlocked communities and beyond continually.

6. Rebuilding overfished fisheries, addressing overfishing, and restoring degraded marine ecosystems

Improving fish supply in the future requires reforming fisheries by rebuilding the fish population of overfished fisheries, addressing the overfishing issue by managing fishing effort, and restoring degraded ecosystems supporting fisheries productivity. Healthy wild stocks also allow for sustained aquaculture operations, as some aquaculture relies on wild stocks for seeds and feeds.

It is worth noting that fisheries reform has short-term harvest implications that depend on the current status of the fisheries (Costello et al. 2016). Harvest can increase following reform for overfished fisheries by just reducing fishing effort. On the other hand, both catch and fishing effort reductions are necessary in the short term for fisheries experiencing overfishing, particularly those harvested way above MSY. The societal impact of this short-term cost of fisheries reforms will be less if reforms are implemented now versus in the future, where fish demand will be higher. Given the evidence that many of the Philippine fisheries are overfished and are experiencing overfishing (e.g., Gaerlan et al. 2018; Olaño et al. 2018; Candelario et al. 2018), fisheries reforms must therefore be implemented as soon as possible, and pathways to solve the short-term cost of fishery recovery be explored, for instance, by solving illegal fishing by foreign fleets as in the case of Indonesia (Cabral et al. 2018).

It appears that the Philippines was able to sustain marine harvest above the estimated MMSY for several years until recently. It is actually possible that MSY in the multispecies context can increase by modifying the ecosystem structure of the fisheries. A marine ecosystem with a healthy top

predator population generates lower MMSY versus an ecosystem composed mainly of lower trophic levels, as was the case for the Gulf of Thailand, where fishing has modified the marine ecosystem towards highly productive lower trophic level species (Fulton et al. 2022). Although MMSY can be increased by engineering the fisheries to harvest mainly low trophic levels (and fished down top predators), such an ecosystem is less resilient to environmental shocks (Fulton et al. 2022). This engineering towards harvesting lower trophic level species may be happening in the Philippines, as suggested by the declining trend in the mean trophic level of the Philippines catch (Figure 4). There is a tradeoff to be made between desiring higher fish production by “fishing down the food web” versus sacrificing a little harvest for a stable supply of fish.

7. Explore offshore areas

Given their proximity to human settlements, nearshore fisheries in the Philippines have been exploited by both small- and commercial-scale fishers beyond their carrying capacities. The bioeconomic modeling study results of Muallil et al. (2014a) showed that fish biomass levels of several municipal fisheries are overfished. This reflects the declining trends in national fish catch (Anticamara and Go 2016) coupled with declining catch per fisher (Macusi et al. 2020).

The potential yearly fisheries production in offshore areas (e.g., oceanic reefs) is high, ranging from 2-31 MT per km² (Arceo et al. 2020) to 78-105 MT per km² (Alino et al. 1998) in the West Philippine Sea. Arceo et al. (2020) further estimated that the

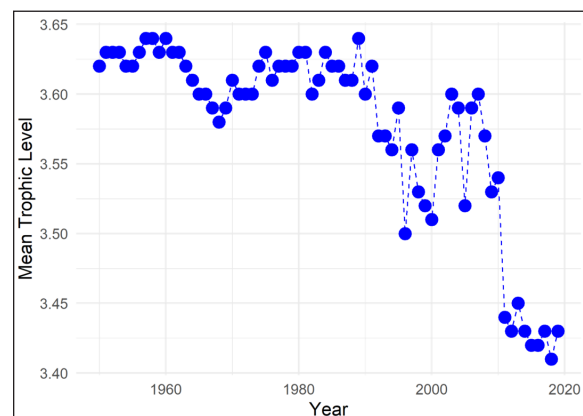


Figure 4. Mean trophic level of the Philippine marine catch. Note that the y-axis starts from 3.40. Data was extracted from the Sea Around Us database (Pauly et al. 2020).

Kalayaan Group of Islands reefs in the West Philippine Sea could produce 61,557–90,850 MT annually. Albeit insufficient to supply the future fish demand for the entire Philippines, this may provide an alternative option for domestic protein sources of nearby coastal communities. However, like its nearshore counterpart, rich fishing grounds in offshore areas may be threatened by overexploitation by foreign fishing vessels. Nighttime fishing activity for vessels that use lure lights has significantly increased in Northern Luzon (Figure 5). Prior to 2015, there were few vessels with lure lights seen in the area.

Fishing in the area by Filipino fishers is limited close to the shore due to strong wind and waves (NFRDI-BFAR 2022). Local officials in the area have complained about the presence of foreign fishing vessels using powerful lights a few kilometers from shore starting around 2015 (Rappler 2016; Jennings 2017; PNA 2017; Roxas 2017). Increased fishing effort in this area, generally in the West Philippine Sea, is attributed to increased foreign fishing and has contributed to the decline in fisheries production in the West Philippine Sea (Cariaso 2023). The viability of exploring offshore areas in the West Philippine Sea depends on actions that address the illegal fishing issue and the careful and thorough review and adherence to effective management of offshore fisheries.

8. Can we just import fish to fill future fish demand?

It is possible that importing fish from other countries can partially or fully supply the future fish demand. In fact, the Philippines is currently importing fish to fill in the current fish demand gaps. However, other countries may also be challenged by increased fish demand from their increasing and burgeoning human population and climate change. Overfishing in other parts of the world can also mean less surplus of fish for these countries to export. Less reliance on trade for fish supply means more resilience to external fish supply shocks and more control over local resources management and use (Gephart et al. 2016). Reliance on importation to fill in future fish demand is unlikely the path the Philippines will take in the future as the country aims to attain fish sufficiency by locally producing fish (Jocson 2022).

9. Expanding marine aquaculture as a solution

Aquaculture, or the cultivation of aquatic animals, is growing in many other parts of the world. Currently, 33% of the fish production from aquaculture in the Philippines is inland (freshwater fishpond, fish cages, fish pens, small farm reservoirs, and rice fish) (11% if including seaweed), while

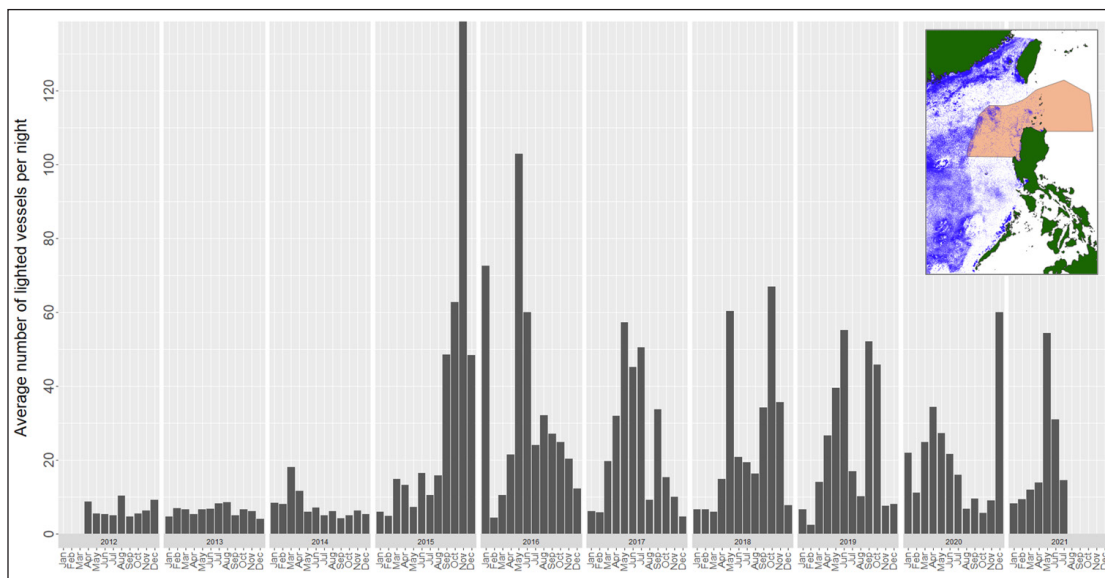


Figure 5. Nighttime-lights boat detections in Northern Luzon in the Philippines from 2012 to 2021. Nightly Visible Infrared Imaging Radiometer Suite (VIIRS) boat detection data was sourced from the Earth Observation Group, Payne Institute for Public Policy (Elvidge et al. 2015).

the rest is from marine and brackish waters (PSA 2023). While the total aquaculture production in the Philippines is increasing (Figure 1), fish production from freshwater aquaculture is decreasing (Figure 3). It is critical to reverse the declining trends in fish production from the inland environment (both capture and aquaculture), as these sectors critically support the food security of landlocked communities and beyond. It is possible that inland aquaculture can expand horizontally, but its growth may be challenged by increasing competition with urbanization and agriculture for space and freshwater resources. As the Philippine human population increases, the land value for housing and recreation will also increase (versus for aquaculture). A possible mechanism for inland aquaculture to secure and increase its production is securing key inland aquaculture space and intensifying and improving aquaculture operations' efficiency.

10. Ensuring sustainable mariculture expansion: Lessons and policy recommendations

Through the Bureau of Fisheries and Aquatic Resources (BFAR), the Philippines implemented the Mariculture Park Program in the early 2000s to boost fisheries production and improve food and livelihood security. This program aims to promote mariculture development by designating economic development areas where infrastructures and support services are available, and technology innovation, skills development, and economic efficiencies across the supply chain of mariculture operations can be pursued (Rosario 2008; Ferrer 2017). However, unsustainable development of some mariculture parks in the Philippines has led to the displacement of fishers from their traditional fishing grounds, mariculture creating minimal local jobs (as jobs were exported from outside the locality), minimal participation of local fishers in mariculture due to high capital and skills requirement, and increasing waste inshore and offshore from mariculture operations affecting adjacent activities such as tourism and recreation (Ferrer et al. 2022).

The Philippine government recognizes the need to sustainably expand mariculture, as evident in the establishment of the National Mariculture Center in 2015, which aims to “develop and promote an integrated and sustainable mariculture industry in the country to ensure available and affordable food for the Filipinos and improve the lives of fisherfolk” (<https://www.bfar.da.gov.ph/national-mariculture-center/>), and the filing of the House Bill No. 5531 in 2022 creating the National Mariculture Program that aims to expand mariculture in the Philippines further (Reganit 2022).

The experience to date from mariculture development in the Philippines, particularly from the Mariculture Park Program, guides ways current and future policies and programs can improve the sustainability outcomes of mariculture intensification in the country:

a. Managing risks and environmental impacts of mariculture through strict regulatory measures, marine spatial planning, monitoring and evaluation, adaptive management, and good governance

There are environmental and social risks associated with mariculture expansion, but they can be mitigated by mainstreaming good governance through transparent and accountable siting, monitoring, and permitting of mariculture operations (Verceles et al. 2000; Cabral and Aliño 2011; Salayo et al. 2012; David et al. 2014; Ferrer et al. 2022). The Philippines is home to several sensitive marine ecosystems, such as coral reefs and seagrass beds. Unregulated mariculture development can be catastrophic, as what the Philippines have experienced with respect to brackish water aquaculture expansion (Primavera 2000). Furthermore, the ocean is also used for several purposes, such as fishing, recreation, and navigation, and introducing mariculture in already crowded ocean spaces can potentially create more conflict.

Strictly enforcing best practices on the limits on the number of mariculture cages, cage spacing, stocking densities, feeding, pollution management, and environmental monitoring and evaluation can help avoid and minimize pollutant accumulation, fish diseases, and other ecological and economic costs associated with poorly regulated mariculture (Salayo et al. 2012; Suyo et al. 2020; Ferrer et al. 2017). This requires better formulation and strict enforcement of leasing, permitting, certification, and operation policies (David et al. 2014; Ferrer et al. 2017; Salayo et al. 2012) and short and long-term planning for mariculture in local government units (Salayo et al. 2012).

Mariculture siting should follow rigorous scientific criteria, i.e., complete assessments of the sites' carrying capacity and flushing rates, ensuring adequate water depth below the cages and sufficient water movement to disperse waste (Ferrer et al. 2017; David et al. 2014). Marine spatial planning and trade-off analysis could inform the siting of mariculture areas that optimize benefits from mariculture while minimizing risks to other ecosystem services and conflicts with other industries.

Environmental monitoring, information sharing, and management should be adaptive, dynamic, and collaborative to respond effectively to changing environmental conditions. A regular state of mariculture report that feeds to governmental, industrial, and other local stakeholders will foster collaboration and efficiencies across multiple sectors (David et al. 2014).

b. Investments in input (seeds and feeds) and output optimization

The variable supply and declining availability of seeds sourced from the wild and the high feed cost limit mariculture's wider adoption and expansion. For example, Salayo et al. (2021) estimated that commercial feeds comprise ~70% of total operating costs in cage culture operations.

Investment in scalable hatcheries, nurseries, and breeding programs is needed to produce high-quality and high-output local fish seeds (Salayo et al. 2012; Ferrer et al. 2017; Suyo et al. 2020). Less reliance on seeds from the wild or imports from neighboring countries can enhance the stability of mariculture production in the face of greater global uncertainties (Salayo et al. 2021). Also, less reliance on wild seeds can help ensure that mariculture expansion actually reduces (or minimizes) pressure on wild stocks.

Investments in cost-effective feed formulation (e.g., plant-based ingredients and insect meals (Hua et al. 2019)) to reduce reliance on fish-based meals, more efficient feeding techniques, and innovative production methods, such as polyculture and integrated multi-trophic aquaculture as bio-mitigation strategy and harvest improvements should be encouraged (Salayo et al. 2012; Ferrer et al. 2017; Suyo et al. 2020).

Furthermore, partnerships between hatcheries, backyard nurseries, and grow-out farmers should be encouraged to foster collaboration and efficiency (hence, cost reduction) within the value chain (Ferrer et al. 2017).

c. Improving local participation of fisherfolks and women in mariculture

Despite earlier efforts to encourage investors to participate in mariculture in the Philippines, uptake is slow, and mariculture parks are underperforming in terms of intended fish production (Salayo et al. 2012). Local participation in mariculture in the Philippines, particularly fisherfolks and women, is

low. For instance, Ferrer et al. (2017) found that only 24% of local households in areas hosting mariculture participate in mariculture despite huge interest among locals. Reasons for low participation include high capital requirements that are rarely affordable to poor fishing households, inadequate technical skills for the mariculture industry, and the preferential hires of non-local operators to non-local employees (Ferrer et al. 2017).

Improving local participation of fisherfolk and women in mariculture ensures that mariculture expansion is equitable and just, which are key components of sustainability. Furthermore, increased local participation, particularly from fisherfolk, contributes to increasing total fish production while simultaneously providing opportunities for fishers to switch from fishing to mariculture. Local communities hosting the mariculture are directly exposed to potential negative impacts of poorly managed mariculture. Therefore, they must be integral in decisions regarding mariculture development, from planning to implementation, and must benefit directly from mariculture development.

Increasing local participation in mariculture will require a combination of improving access to capital via low-interest loans, improving the cost efficiency of input and processes along the mariculture value chain (as discussed above), and strict guidance towards preferential employment of local fishers and women, and the provision of training required for mariculture industry. Mariculture can further boost the local economy and support and improve women's participation by mandating a fraction of mariculture output to be designated in the local market/retailers/processors—sectors that are highly participated by women (Ferrer et al. 2017).

d. De-risking mariculture investments

A major catastrophe to mariculture, like those caused by a major typhoon and fish kills, would halt the mariculture operations of low-income coastal communities. Small investors are also sensitive to changes in prices of input items such as seeds, feeds, and fossil fuel and to uncertainties in farm gate prices of mariculture products. Mariculture expansion should include plans for de-risking investments, such as implementing a socialized insurance system favoring marginalized local fisherfolk and women. Facilitating the establishment of a portfolio of mariculture product markets, which includes exports, local distribution, and processing, can stabilize revenue from mariculture

products. Siting of mariculture in areas sheltered from typhoons or preferential use of fish cages and technologies that can withstand typhoons also reduces possible disruptions to mariculture operations.

11. Final thoughts

Meeting the expected increase in fish demand from the growing number of Filipinos in a sustainable manner will be one of the grand challenges the Philippines will face in the 21st century. Rebuilding overfished fisheries, restoring critical habitats, and addressing existing threats to fisheries sustainability that enable optimal wild fisheries production from inland and marine environments are necessary but insufficient actions for meeting the future fish demand in the Philippines. Even if inland and marine capture fisheries are managed well, there will still be a gap in the supply of fish of 2.77 million MT per year by 2050. Because there is not much space for increasing wild fisheries' catch to meet future fish demand, expansion and intensification of fish production from aquaculture, especially in the marine space, is necessary and should be done sustainably to avoid environmental externalities negatively affecting adjacent communities. The declining fish production trends in inland capture fisheries and inland aquaculture are alarming, and the Philippines should pursue efforts to reverse the trends as inland fisheries and aquaculture critically support the food security of landlocked communities and beyond. Mariculture production can expand, and sourcing most of the fish required by additional Filipinos in the future from this sector is possible but requires major technological, infrastructure, research, and policy investments.

ACKNOWLEDGMENT

This policy brief is the product of the address delivered by RBC during the 44th Annual Scientific Meeting of the National Academy of Science and Technology, Philippines, last July 2022, with the theme Foresight 2050: Science for a Sustainable Future. We dedicate this work in memory of our friend, Lito Mancao, who championed good governance in the Philippine fisheries and has generously supported numerous fisheries researchers and practitioners.

AUTHOR CONTRIBUTIONS

Cabral RB: Conceptualization, Formal analysis, Writing - Original Draft, Writing - Review & Editing. **Geronimo RC:** Conceptualization, Formal

analysis, Writing - Review & Editing. **Mamauag ASS:** Conceptualization, Writing - Review & Editing. **Silva JA:** Formal analysis, Writing - Review & Editing. **Mancao RH:** Conceptualization, Writing - Review & Editing. **Atrigenio MP:** Conceptualization, Writing - Review & Editing.

CONFLICT OF INTEREST

Authors declare that they have no competing interests.

ETHICS STATEMENT

The authors carried out no animal or human studies.

REFERENCES

- Aliño PM, Nañola Jr CL, Ochavillo DG, Rañola MC. 1998. The fisheries potential of the Kalayaan Island Group, South China Sea. *The Marine Biology of the South China Sea III. Proceedings of the Third International Conference on the Marine Biology of the South China Sea.* Hong Kong, 28 October - 1 November 1996. pp. 219-226.
- Anticamara JA, Go KT. 2016. Spatio-temporal declines in Philippine fisheries and its implications to coastal municipal fishers' catch and income. *Frontiers in Marine Science.* 3:21. <https://doi.org/10.3389/fmars.2016.00021>
- Arceo HO, Cabasan JP, Luciano RMA., Heyres LJD, Mamauag SS, Aliño PM. 2020. Estimating the potential fisheries production of three offshore reefs in the West Philippine Sea, Philippines. *Philippine Journal of Science.* 149(3):647-658. <https://doi.org/10.56899/149.03.16>
- Asian Development Bank. 2014. *State of the Coral Triangle: Philippines.* Mandaluyong City, Philippines.
- Barut NC, Santos MD, Garces LR. 1997. Overview of Philippine marine fisheries. In: Silvestre G, Pauly D, editors. *Status and management of tropical coastal fisheries in Asia.* ICLARM Conf. Proc. 53. pp. 62-71.

- Barut NC, Santos MD, Mijares LL, Subade R, Armada NB, Garces LR. 2003. Philippine coastal fisheries situation. In: Silvestre G, Garces L, Stobutzki I, Ahmed M, Valmonte-Santos RA, Luna C, Lachica-Aliño L, Munro P, Christensen V, Pauly D, editors. *Assessment, Management and Future Directions for Coastal Fisheries in Asian Countries*. WorldFish Center Conference Proceedings 67. Penang: WorldFish Center. pp. 885–914. <https://hdl.handle.net/20.500.12348/2159>
- BFAR. 2014. Bureau of Fisheries and Aquatic Resources - Philippine Fisheries Profile 2014; [Accessed 5 May 2023]. <https://www.bfar.da.gov.ph/wp-content/uploads/2021/05/Philippine-Fisheries-Profile-2014.pdf>
- BFAR. 2015. Bureau of Fisheries and Aquatic Resources - Philippine Fisheries Profile 2015; [Accessed 13 September 2022]. <https://www.bfar.da.gov.ph/wp-content/uploads/2021/05/Philippine-Fisheries-Profile-2015.pdf>
- BFAR. 2018. Bureau of Fisheries and Aquatic Resources - Philippine Fisheries Profile 2017; [Accessed 13 September 2022]. <https://www.bfar.da.gov.ph/wp-content/uploads/2021/05/Philippine-Fisheries-Profile-2017.pdf>
- BFAR. 2020. Bureau of Fisheries and Aquatic Resources - Philippine Fisheries Profile 2019; [Accessed 13 September 2022]. <https://www.bfar.da.gov.ph/wp-content/uploads/2021/05/Philippine-Fisheries-Profile-2019.pdf>
- BFAR. 2021. Bureau of Fisheries and Aquatic Resources - Philippine Fisheries Profile 2020; [Accessed 13 September 2022]. <https://www.bfar.da.gov.ph/wp-content/uploads/2022/02/2020-Fisheries-Profile-Final.pdf>
- BFAR. 2022. Bureau of Fisheries and Aquatic Resources - Philippine Fisheries Profile 2021; [Accessed 13 September 2022]. <https://www.bfar.da.gov.ph/wp-content/uploads/2022/11/2021-Fisheries-Profile-FINAL-FILE.pdf>
- Cabral RB, Aliño PM. 2011. Transition from common to private coasts: Consequences of privatization of the coastal commons. *Ocean & Coastal Management*. 54(1):66–74. <https://doi.org/10.1016/j.ocecoaman.2010.10.023>
- Cabral RB, Geronimo RC. 2018. How important are coral reefs to food security in the Philippines? Diving deeper than national aggregates and averages. *Marine Policy*. 91:136–141. <https://doi.org/10.1016/j.marpol.2018.02.007>
- Cabral RB, Mayorga J, Clemence M, Lynham J, Koeshendrajana S, Muawanah U, Nugroho D, Anna Z, Ghofar A, Zulfainarni N, Gaines SD, Costello C. 2018. Rapid and lasting gains from solving illegal fishing. *Nature Ecology & Evolution*. 2(4):650–658. <https://doi.org/10.1038/s41559-018-0499-1>
- Candelario MB, Gonzales LM, Jardin JA. 2018. Status of fisheries resources of Honda Bay (2003–2013). *The Philippine Journal of Fisheries*. 24(1):52–61. <https://doi.org/10.31398/tjpf/25.1.2017C0006>
- Carioso B. 2023. BFAR: Foreign vessels curtailed Philippine fish catch in 2022. *The Philippine Star*; [Accessed: 18 August 2023]. <https://www.philstar.com/headlines/2023/06/17/2274503/bfar-foreign-vessels-curtailed-philippine-fish-catch-2022>
- Coastal Resources Center. 2021. *Quantifying the Prevalence and Impact of Illegal, Unreported and Unregulated Fishing in the Philippines Workshop Report*. USAID Fish Right Program. Narragansett, RI: Coastal Resources Center, Graduate School of Oceanography, University of Rhode Island. 32 p.
- Costello C, Ovando D, Clavelle T, Strauss CK, Hilborn R, Melnychuk MC, Branch TA, Gaines SD, Szuwalski CS, Cabral RB, and others. 2016. Global fishery prospects under contrasting management regimes. *Proceedings of the National Academy of Sciences*. 113(18):5125–5129. <https://doi.org/10.1073/pnas.1520420113>
- Costello C, Cao L, Gelcich S, Cisneros-Mata MÁ, Free CM, Froehlich HE, Golden CD, Ishimura G, Maier J, Macadam-Somer, and others. 2020. The future of food from the sea. *Nature*

- 588(7836):95–100. <https://doi.org/10.1038/s41586-020-2616-y>
- David LT, Pastor-Rengel D, Talaue-McManus L, Magdaong E, Salalila-Aruelo R, Bangi HG, San Diego-McGlone ML, Villanoy C, Cordero-Bailey K. 2014. The saga of community learning: Mariculture and the Bolinao experience. *Aquatic Ecosystem Health & Management*. 17(2):196–204.
- [DOST-FNRI] Department of Science and Technology - Food and Nutrition Research Institute. 2022. Philippine Nutrition Facts and Figures: 2018-2019 Expanded National Nutrition Survey (ENNS): Food Consumption Survey. FNRI Bldg., DOST Compound, Gen. Santos Avenue, Bicutan, Taguig City, Metro Manila, Philippines.
- Edwards P, Zhang W, Belton B, Little DC. 2019. Misunderstandings, myths and mantras in aquaculture: Its contribution to world food supplies has been systematically over reported. *Marine Policy*. 106:103547. <https://doi.org/10.1016/j.marpol.2019.103547>
- Elvidge CD, Zhizhin M, Baugh K, Hsu FC. 2015. Automatic boat identification system for VIIRS low light imaging data. *Remote Sensing*. 7(3):3020–3036. <https://doi.org/10.3390/rs70303020>
- Ferrer AJG, Francisco HA, Carmelita BM, Hopanda J, Predo C. 2017. Gender Differences in Participation, Roles, and Attitude towards Mariculture Operation: A Case Study in the Philippines. *Asian Fisheries Science Special Issue*. 30S:83–102. <https://doi.org/10.33997/j.afs.2017.30.S1.004>
- Ferrer AJG, Francisco HA, Hopanda JC, Carmelita BMM, Predo CD. 2022. Mariculture Parks in the Philippines Push Small-Scale Fishers Out of, or Far into, the Waters. In: Jentoft S, Chuenpagdee R, Bugeja Said A, Isaacs M, editors. *Blue Justice*. MARE Publication Series Vol 26. Springer, Cham. https://doi.org/10.1007/978-3-030-89624-9_25
- Free CM, Cabral RB, Froehlich HE, Battista W, Ojea E, O'Reilly E, Palardy JE, García Molinos J, Siegel KJ, Arnason R, and others. 2022. Expanding ocean food production under climate change. *Nature*. 605(7910):490–496. <https://doi.org/10.1038/s41586-022-04674-5>
- Fulton EA, Sainsbury K, Noranartragoon P, Leadbitter D, Staples DJ, Porobic J, Ye Y, Phoonsawat R, Kulanujaree N. 2022. Shifting baselines and deciding on the desirable form of multispecies maximum sustainable yield. *ICES Journal of Marine Science*. 79(7):2138–2154. <https://doi.org/10.1093/icesjms/fsac150>
- Funge-Smith S. 2018. Review of the state of the world fishery resources: Inland fisheries. FAO Fisheries and Aquaculture Circular No.C942 Revision 3.
- Gaerlan RSP, Buccat FGA, Ragutero FC. 2018. A Review on the status of small pelagic fish resources in the Lingayen Gulf for the year 2009-2013. *The Philippine Journal of Fisheries*. 25(1):1–14. <https://doi.org/10.31398/tjpf/25.1.2017C0001>
- Gephart JA, Rovenskaya E, Dieckmann U, Pace ML, Brännström Å. 2016. Vulnerability to shocks in the global seafood trade network. *Environmental Research Letters*. 11(3):035008. <https://doi.org/10.1088/1748-9326/11/3/035008>
- Gouel C, Guimbard H. 2019. Nutrition transition and the structure of global food demand. *American Journal of Agricultural Economics*. 101(2):383–403. <https://doi.org/10.1093/ajae/aay030>
- Hua K, Cobcroft JM, Cole A, Condon K, Jerry DR, Mangott A, Praeger C, Vucko MJ, Zeng C, Zenger K, Strugnell JM. 2019. The future of aquatic protein: implications for protein sources in aquaculture diets. *One Earth*. 1(3):316–329. <https://doi.org/10.1016/j.oneear.2019.10.018>
- Jennings R. 2017. The Philippines Is Struggling To Stop Taiwan And Vietnam From Entering A Disputed Sea. *Forbes*; [Accessed 18 August 2023]. <https://www.forbes.com/sites/ralphjennings/2017/04/04/philippines-struggles-to-keep-defense-of-disputed-maritime-claims/?sh=3a52aff5e85>

- Jocson LMJC. 2022. BFAR says fisheries modernization goal is to reduce import reliance. *BusinessWorld*; [Accessed 18 August 2023]. <https://www.bworldonline.com/economy/2022/08/24/470425/bfar-says-fisheries-modernization-goal-is-to-reduce-import-reliance/>
- Macusi ED, Macusi ES, Jimenez LA, Catam-isan JP. 2020. Climate change vulnerability and perceived impacts on small-scale fisheries in eastern Mindanao. *Ocean & Coastal Management*. 189:105143. <https://doi.org/10.1016/j.ocecoaman.2020.105143>
- Muallil RN, Mamaug SS, Cabral RB, Celeste-Dizon EO, Aliño PM. 2014a. Status, trends and challenges in the sustainability of small-scale fisheries in the Philippines: Insights from FISHDA (Fishing Industries' Support in Handling Decisions Application) model. *Marine Policy*. 44:212–221. <https://doi.org/10.1016/j.marpol.2013.08.026>
- Muallil RN, Mamaug SS, Cababaro JT, Arceo HO, Aliño PM. 2014b. Catch trends in Philippine small-scale fisheries over the last five decades: The fishers' perspectives. *Marine Policy*. 47:110–117. <https://doi.org/10.1016/j.marpol.2014.02.008>
- Naylor RL, Kishore A, Sumaila UR, Issifu I, Hunter BP, Belton B, Bush SR, Cao L, Gelcich S, Gephart JA, and others 2021. Blue food demand across geographic and temporal scales. *Nature Communications*. 12(1):5413. <https://doi.org/10.1038/s41467-021-25516-4>
- [NFRDI-BFAR] National Fisheries Research and Development Institute-Bureau of Fisheries and Aquatic Resources. 2022. National Stock Assessment Program (NSAP) Interactive Atlas. Quezon City, Philippines; [Accessed: 18 August 2023]. <https://nsap.nfrdi.da.gov.ph/>
- Olaño VL, Lanzuela NS, Paredes KS. 2018. Assessment of Fishery Resources in Lagonoy Gulf, Philippines. *The Philippine Journal of Fisheries*. 25(1):62–76. <https://doi.org/10.31398/tjpf/25.1.2017C0007>
- Palma AL. 2016. Restoration and enhancement of fisheries in Philippine lakes and reservoirs. In: Kawamura H, Iwata T, Theparoonrat Y, Manajit N, Sulit VT, editors. *Consolidating the Strategies for Fishery Resources Enhancement in Southeast Asia*. Proceedings of the Symposium on Strategy for Fisheries Resources Enhancement in the Southeast Asian Region, Pattaya, Thailand, 27-30 July 2015. Samutprakan, Thailand: Training Department, Southeast Asian Fisheries Development Center. pp. 109–112.
- Pauly D, Zeller D, Palomares MLD, editors. 2020. *Sea Around Us Concepts, Design and Data*; [Accessed 18 August 2023]. www.seaaroundus.org
- Pedrosa III AA, Simbajon R, Rolleda M, Hurtado AQ, Ferrer S, Ramirez PJB, Fernandez FB, Dakay MAR, Yap AY, Bero MC, Togonon DE, Ortiz IF, Capacio I. 2022. *The Philippine Seaweed Industry Roadmap (2022-2026)*. Bureau of Fisheries and Aquatic Resources. ISSN: 2945-4417; [Accessed 18 August 2023]. <http://www.pcaf.da.gov.ph/wp-content/uploads/2022/06/Philippine-Seaweed-Industry-Roadmap-2022-2026.pdf>
- PNA. 2017. Foreign vessels threatens livelihood of fishermen in northern PH. *Update Philippines*; [Accessed 18 August 2023]. <https://www.update.ph/2017/05/foreign-vessels-threatens-livelihood-of-fishermen-in-northern-ph/17699>
- Primavera JH. 2000. Development and conservation of Philippine mangroves: institutional issues. *Ecological Economics*. 35(1):91–106. [https://doi.org/10.1016/S0921-8009\(00\)00170-1](https://doi.org/10.1016/S0921-8009(00)00170-1)
- PSA. 2023. *Philippine Statistics Authority OpenStat*; [Accessed 14 August 2023]. <https://openstat.psa.gov.ph/>
- Rappler. 2016. PH authorities nab suspected Chinese poachers off Batanes. *Rappler.com*; [Accessed 18 August 2023]. <https://www.rappler.com/nation/133311-ph-arrest-suspected-chinese-poachers-batanes/>
- Reganit JC. 2022. House bill creating nat'l mariculture program filed. *Philippine News Agency, Republic of the Philippines*; [Accessed 18

- August 2023]. <https://www.pna.gov.ph/articles/1185939>
- Rosario WR. 2008. The Philippines. In: Lovatelli A, Phillips MJ, Arthur JR, Yamamoto K, editors. *FAO/NACA Regional Workshop on the Future of Mariculture: a Regional Approach for Responsible Development in the Asia-Pacific*. Guangzhou, China, 7–11 March 2006. *FAO Fisheries Proceedings No. 11*. Rome: FAO. p. 225–240.
- Roxas JT. 2017. Governor notes 'respite' in foreign poaching off Batanes. *GMA News*; [Accessed 18 August 2023]. <https://www.gmanetwork.com/news/topstories/regions/606026/governor-notes-respite-in-foreign-poaching-off-batanes/story/>
- Salayo ND, Perez ML, Garces LR, Pido MD. 2012. Mariculture development and livelihood diversification in the Philippines. *Marine Policy* 36(4):867–881. <https://doi.org/10.1016/j.marpol.2011.12.003>
- Salayo ND, Marte CL, Toledo JD, Gaitan AG, Agbayani RF. 2021. Developing a self-sufficient Philippine milkfish industry through value chain analysis. *Ocean & Coastal Management*. 201:105426. <https://doi.org/10.1016/j.ocecoaman.2020.105426>
- Santos MD, Dickson JO, Velasco PL. 2011. Mitigating the impacts of climate change: Philippine fisheries in focus. Secretariat, Southeast Asian Fisheries Development Center. *Fish for the People*. 9(2):101–110.
- Selgrath JC, Gergel SE, Vincent AC. 2018. Shifting gears: Diversification, intensification, and effort increases in small-scale fisheries (1950–2010). *PLoS One* 13(3):e0190232. <https://doi.org/10.1371/journal.pone.0190232>
- Silvestre G, Pauly D. 1997. Management of tropical coastal fisheries in Asia: an overview of key challenges and opportunities. *ICLARM Conf. Proc.* 53:8–25. <https://hdl.handle.net/20.500.12348/2588>
- Suh D, Pomeroy R. 2020. Projected economic impact of climate change on marine capture fisheries in the Philippines. *Frontiers in Marine Science*. 7:232. <https://doi.org/10.3389/fmars.2020.00232>
- Suyo JGB, Le Masson V, Shaxson L, Luhan MRJ, Hurtado AQ. 2020. A social network analysis of the Philippine seaweed farming industry: Unravelling the web. *Marine Policy*. 118:104007. <https://doi.org/10.1016/j.marpol.2020.104007>
- UN. 2022. United Nations, Department of Economic and Social Affairs, Population Division. *World Population Prospects 2022*, Online Edition; [Accessed 18 August 2023]. <https://population.un.org/wpp/Download/Standard/Population/>
- Verceles L, Talaue-McManus L, Aliño P. 2000. Participatory monitoring and feedback system: an important entry towards sustainable aquaculture in Bolinao, Northern Philippines. *Science Diliman*. 12(2):78–87.
- World Bank. 2023a. Population, total - Philippines; [Accessed 6 May 2023]. <https://data.worldbank.org/indicator/SP.POP.TOTL?locations=PH>
- World Bank. 2023b. GDP per capita (current US\$) - Philippines; [Accessed 24 May 2023]. <https://data.worldbank.org/indicator/NY.GDP.PCAP.CD?locations=PH>



© 2023 The authors. Published by the National Fisheries Research and Development Institute. This is an open access article distributed under the [CC BY-NC 4.0](https://creativecommons.org/licenses/by-nc/4.0/) license.