Knowledge, evidence and learning for development

Aquaculture and mangroves

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Question

What is the evidence of aquaculture's role in supporting poverty reduction? Where is aquaculture resulting in the greatest loss of mangroves and other environmental harms?

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1. Summary

Aquaculture and poverty

Evidence of the role of aquaculture in supporting poverty is mixed. The diversity of aquaculture systems and the complex pathways of poverty reduction make it difficult to draw conclusions. However, it is recognised that aquaculture generally contributes to poverty reduction. The extent of initial poverty levels may affect the size of the impact although findings on this differ between studies. Access to finance for inputs is important for aquaculture poor farmers to benefit.

Over 20 million people globally are employed in aquaculture, many of whom are in impoverished areas. However, there can be problems with elite capture and power asymmetries. Small-scale farmers need to be able to negotiate in complex value chains.

The evidence on supporting poverty through improved nutrition suggests that the improved supply of fish from aquaculture generally keeps prices low and so benefits access for those on low incomes. Farmed fish, if consumed by the poor, may have greater nutritional benefits with regards to lipids. But farmed fish may be less nutritious than small wild fish which are eaten with the bones inside.

There can be health risks in the physical work involved in aquaculture. And risks involved with contamination of produce making farmers vulnerable to environmental hazards. Poor communities may also be affected when fish they catch for subsistence are reduced in stock as commercial farmers capture them for aquaculture feed. Intensive aquaculture can contaminate and salinize groundwater causing problems for agricultural farmers in surrounding areas.

Ownership issues can be a barrier for women in receiving a fair share of profits from aquacultural farming. Overall, there is a lack of gender consideration among the data.

Aquaculture and mangrove loss

Mangroves are important to preserve as they have biologically rich ecosystems and help to mitigate climate change. Southeast Asia is the region showing the greatest mangrove loss due to aquaculture. For example, between 1977 and 2005 the Andaman sea in Indonesia lost 63% of its mangroves. Studies of data between 2000 and 2016 found six Southeast Asian nations to be responsible for 80% of all human-driven mangrove loss (aquaculture and agriculture).

Total area losses (human and natural) between 2000 and 2012 were highest in Indonesia, 750 kilometres squared. Followed by Malaysia (241 km^2) and Myanmar (235 km^2). Then Thailand (47 km^2) and Brazil (46 km^2).

A study in Southeast Asia looked at mangrove land conversion for aquaculture, rice, and palm between 2000 and 2012 and found aquaculture to account for 30% of loss. The highest proportional losses to aquaculture were in Indonesia, followed by the Philippines and then Brunei. The relative importance of different drivers of mangrove loss varied over time with aquaculture becoming less dominant around 2005 and then becoming more dominant again towards 2012. A mapping of pond aquaculture and mangrove cover in Vietnam, Cambodia, Thailand and Myanmar between 1999 and 2014 shows mangrove growth to have reduced net losses.

A representation of global data on human-driven mangrove loss (aquaculture and agriculture) between 2000 and 2012 shows Indonesia, Myanmar, and Vietnam to have the highest losses. Then Malaysia, Nigeria, Guinea and Madagascar.

The most recent data on mangrove loss shows total loss and does not detail the drivers of the loss. South and Southeast Asia is the region showing the highest annual rate of loss between 2010 and 2020 losing 38,300 hectares of mangrove per year.

Methodological considerations

This report aimed to focus on the impacts of coastal aquaculture on poverty but it was often not distinguished from inland aquaculture in the literature and took extra time to ascertain. Aquaculture reporting was also combined with capture fisheries in some reviews. The initial search aimed to draw on evidence from the past 10 years but key papers emerged that were older and the reviews drew from earlier research. There seemed to be a lack of recent research on the links between poverty and aquaculture.

The tension between environmental protection and economic development is present in the literature with different views being presented depending on either the agenda in grey literature, or the focus of the publisher.

There were data on mangrove loss which did not describe the cause of the loss, data which described human-driven mangrove loss but did not distinguish between different human influences, and a small amount of data which linked aquaculture and mangrove loss directly. Unfortunately, it was not possible to find recent data on aquaculture and mangrove loss to assess latest trends.

2. Aquaculture and poverty reduction

There are a number of potential pathways for fisheries and aquaculture to reduce poverty and improve food security proposed in a World Fish Centre working Paper (Allison 2011). These are the nutritional benefits of consuming fish; income for those employed by the fish sector and spill-over effects in the region and; generation of revenues from exports, taxation and license fees.

A rigorous evidence review notes that aquaculture systems are diverse making it difficult to conclude on their impact on poverty (Béné et al 2016). However, it is recognised that “aquaculture generally contributes to poverty reduction directly and indirectly by providing food, income, and employment for both producers and other value chain actor households” (p184).

Mixed evidence

The (Béné et al 2016) review found evidence of commercial aquaculture which has developed rapidly and “had transformational impacts on households and communities supporting a wholesale escape from poverty rather than incremental declines” (p184). This finding does not distinguish between saltwater aquaculture and freshwater aquaculture.

The impacts of introducing aquaculture in impoverished areas may depend on initial circumstances and access to resources for inputs. A review of aquaculture, both inland and coastal, finds greater relative importance in areas with less agricultural opportunities (Little et al

2012). And the horizontal benefits of aquaculture making larger impacts on poverty in areas which have a lower initial income status.

A study in a province in Vietnam modelled household survey data to evaluate the effects of aquaculture on poverty (Nguyen et al., 2016). Results showed no impact of aquaculture on the poorest but improvement in standards of living for marginally less poor populations. Households on less than $1.25 participation in aquaculture showed no or little effect on living standard whereas for those on consumption of higher than $1.25 participation in aquaculture showed improvements in living standards. Poorer farmers are unable to adopt technologies to make aquaculture profitable due to lack of resources for investment and lower education levels.

An empirical study of coastal communities in the Philippines found strong evidence for aquaculture improving poverty (Irz et al 2007). Those on low income were found to receive a relatively larger share of their income from aquaculture than wealthier people. Gini decomposition shows that aquaculture represents a source of income which reduces inequality. Particularly it provided employment to unskilled workers. This study was a number of years old and it is unknown if these benefits have been sustained.

A study in Thailand found that farming grouper made a substantial contribution to household incomes (Sheriff et al 2008). Financial capital and access to credit were required for positive income effects.

Methodological considerations

An expert consultation on the assessment of socio-economic impacts of aquaculture identified a number of positive and negative impacts (FAO 2008). The Consultation debated "land-based habitats, water and wild species, the downstream and upstream industries of aquaculture, infrastructure, incomes, employment, food supply, food quality and safety, food access, food stability, human health, education and training, population and demography, and community and social order, and emphasized that these impacts have profound interdependence and far-reaching socio-economic implications, which makes the task of assessing them difficult." (p. iv). Experts agreed there is no single method which could be used to assess the socio-economic impacts of aquaculture.

There are also different factors to consider for different scales of aquaculture. And national aquaculture statistics are noted to be unreliable (Little et al 2012).

Employment

Employment in aquaculture (both coastal and inland) was estimated to be 20.5 million in 2018 (FAO 2020). 19.6 million of these were in Asia, and 0.39 million in Africa. Béné et al (2016) found national-level data confirming that aquaculture systems generate considerable revenue but there is a lack of evidence on the direct effects of earnings on poverty alleviation.

There can be problems of elite capture. There is evidence from inland practices that better-off farmers are able to adopt new practices and technologies leaving poorer farmers behind (Belton & Little 2011). Power asymmetries in the value chain can mean that small-scale producers may not receive a fair benefit for produce and that certification schemes may help with this issue (Béné et al 2016). Benefits depends on how well fish farmers are connected to markets (Little et al 2012). Farmers need the capacity to negotiate in complex value chains. They also need access to inputs.

The Béné et al (2016) review on the relationship between poverty and aquaculture makes a distinction between ""immanent" systems, whereby aquaculture emerges in response to demand, and "interventionist" systems, in which external agencies support the promotion of predominantly small-scale subsistence aquaculture systems" (Béné et al 2016 p184). A few studies in the review found that donor support to small-scale subsistence aquaculture alleviates poverty.

Nutrition

The Béné et al (2016) review on fisheries and aquaculture finds fish-farming households consume a higher proportion of fish but there is no evidence that this results in higher nutritional status. Improved nutrition may result in the households ability to use cash generated from selling fish to purchase other types of nutrient rich food.

Commercial aquaculture systems keep fish prices low so that it is still affordable for poorer households maintaining access to high quality protein (Béné et al 2016). However, intensification can increase risk of disease and environmental degradation.

A review from Bangladesh analysed changes in fish consumption due to the impacts of aquaculture, looking across inland and coastal farms (Toufique & Belton 2014). The expansion of aquaculture was found to keep fish prices down which resulted in increased fish consumption for the extreme and moderate poor.

Farmed fish tend to be higher in lipids which is advantageous for protein-energy malnutrition (Little et al 2012). Although unsaturated fatty acids decline and become less optimal with intensively farmed fish. It is also noted that wild small indigenous fish are generally consumed whole, including bones, so may be more nutritious than farmed fish which are grown larger and filleted (Béné et al 2016).

Negative effects

Aquaculture can present health risks. Béné et al (2016) found risks relating to prevalence of communicable diseases (including HIV and AIDS). And physical risks associated with fishing and fish-processing although this is a larger risk with capture fisheries. Research in Zanzibar, Tanzania, found seaweed farmers to have poor health due to working conditions (Fröcklin et al 2012). Income was also reported to be below the poverty line.

Risks to aquaculture livelihoods, and therefore poverty alleviation, include pathogens, parasites and pests. These risks have increased in the last 20 years with the intensification of production and increased integration in supply chains (Naylor et al 2021).

The poor may be worse off if the establishment of privately-owned aquaculture interferes with areas which previously had common-fishing access (Little et al 2012). Small wild fish caught by local people for subsistence may be threatened as they are caught instead for feed ingredients for cultured fish raising a potential threat to food security. More recently developments are being made to reduce the reliance on the fish oil and meal sourced from wild fish resources (Naylor et al 2021). These include growth in omnivorous species production; improved feed conversion ratios; use of alternative protein and oil ingredients; and increased production of fishmeal and oil from fish processing waste and by-catches. Movement towards alternative plant-based diets for farmed fish alters immune functioning and increases disease risk (Naylor et al 2021).

An article in *Ocean & Coastal Management* suggests aquaculture is negative for poor coastal communities. van Wesenbeeck et al (2015) warn of the issues of groundwater pumping for aquaculture causing subsidence compounded by mangrove removal in South East Asia and Latin America. The authors suggest that often profits from aquaculture end up with large-scale investors. Intensive aquaculture contaminates and salinizes surrounding surface and groundwater which collapses both aquaculture productivity and inland agricultural crops. Large companies abandon the ponds once the profits decrease leaving communities with devastated landscape and employment loss. Loss of mangroves contribute to decline of fish stocks and exacerbated sea level rise leaving coastal communities vulnerable.

Gender

Issues of gendered ownership of aquaculture ponds in Bangladesh put women at greater risk of poverty in a study of inland and coastal fish farming (Choudhury & McDougall 2018). Development practitioners are recommended to recognise joint ownership as a barrier for women and subsidise women with ownership opportunities. "Women's knowledge of aquaculture influences their ownership, so transferring knowledge and building skills in aquaculture can have positive impacts on women's control over ponds and men's willingness to trust women with aquaculture resources" (Choudhury & McDougall 2018 pp15-16). It should be recognised that younger women are more vulnerable to ownership gaps than older women.

The Béné et al (2016) rigorous evidence review found a lack of gender disaggregated data.

3. Aquaculture and mangrove loss

Historically

Onshore aquaculture was the leading cause of mangrove deforestation between 1950 and 2000, particularly the late 1970's and early 80's (Friess et al 2019). It is estimated that 28% of mangroves deforested since 1970 were converted to commercial aquaculture. And aquaculture accounts for 30% of mangrove loss in Southeast Asia between 2000 and 2012. Table 1 present varying data on the proportion of mangrove losses attributed to aquaculture in different time periods for a number of regions.

See: Table 1: Mangroves lost to aquaculture, Source: Friess et al 2019 p.96, https://www.annualreviews.org/doi/pdf/10.1146/annurev-environ-101718-033302

Southeast Asia

A study assessing mangrove loss between 2000 and 2016 estimated that 62% of global mangrove loss was attributed to land-use change, primarily aquaculture and agriculture

(Goldberg et al 2020). Up to 80% of the human-driven loss was in six Southeast Asian nations[1]. Both human and natural losses declined between 2000 and 2016 globally.

Another study of mangrove loss between 1996 and 2010 found 12% were deforested by humans over the time period (Thomas et al 2017). The greatest was observed in Southeast Asia where 50% of mangroves had been lost during that time (18.4% of global loss). The drivers of man-made loss were again identified to be aquaculture and agriculture.

Bryan-Brown et al (2020) find Southeast Asia to be the area for greatest mangrove loss and fragmentation with 50% of the destruction due to conversion for aquaculture, rice fields and palm plantation. Data for the ten countries with highest mangrove loss presented in table 2.

Table 2: Mangrove loss between 2000 and 2012

Country	Sum loss (km^2)
Indonesia	749.90
Malaysia	241.28
Myanmar	235.17
Thailand	47.05
Brazil	46.34
United States	43.44
Mexico	29.46
India	27.22
Cuba	26.90
Philippines	26.81

Source: Bryan-Brown et al 2020, p. 2. Reproduced with permission.

[1] Indonesia, Myanmar, Malaysia, the Philippines, Thailand, and Vietnam

Land use conversion study

High-quality datasets were used to classify mangrove loss and land-use change in Southeast Asia between 2000 and 2012 by Richards & Friess (2016). The annual rate of mangrove loss in in the region over this time is estimated at 0.18% per year. Aquaculture accounts for 30% of the loss. Authors found aquaculture to be less dominant as a pressure on mangroves than expected. Rice agriculture is identified as a leading cause of deforestation in Myanmar, and oil palm plantations in Malaysia and Indonesia. Rice and palm are suggested to be growing in importance for mangrove risk. Table 3 shows what proportions of deforested mangroves are attributed to which land use change.

See: Table 3: Percentage of the total deforested mangrove (2000–2012) converted to different land uses in Southeast Asia[2] (Richards & Friess 2016, p. 346), https://www.pnas.org/content/pnas/113/2/344.full.pdf

29.9% of mangroves were lost due to land conversion to aquaculture in Southeast Asia between 2000 and 2012. 21.7% were lost due to conversion for rice fields and 16.3% were lost to farming for palm oil. The highest proportional losses due to aquaculture (listed in order, starting with highest loss proportion) were identified in Indonesia, Philippines, Brunei, Cambodia, Malaysia, and Thailand.

The relative importance of the different drivers varied over the study time period. The percentage of mangrove converted to aquaculture across the region decreased from around 39% in 2000 to 20% in 2005 to around 35% in 2012. Aquaculture was more dominant as a driver of mangrove loss in the 1980s and 1990s. Mangrove conversion to aquaculture is currently occurring mainly in Kalimantan and Sulawesi in Indonesia. This is suggested to have driven the increase back up to 35% in 2012.

A detailed mapping of pond aquaculture and mangroves in Vietnam, Cambodia, Thailand and Myanmar between 1999 and 2014 records percent change in pond farming compared to percent change in mangrove cover in subdivisions in each country (Eastman et al 2018). The totals for each country are presented in table 4. New mangrove growth has reduced net losses and some mangrove loss is attributed to other land use cover, particularly transition to cropland.

See: Table 4: Change in area of pond aquaculture and change in area of mangrove cover in Vietnam, Cambodia, Thailand and Myanmar between 1999 and 2014 (Eastman et al 2018, p.7), https://clarklabs.org/wp-content/uploads/2019/01/Aquaculture-and-Coastal-Habitats-Report-No5.pdf

Individual countries

NASA Earth Observatory data depicted on a choropleth map[3] shows the extent of human-driven mangrove loss (in total km^2) between 2000 and 2012 in different countries. The greatest losses

[2] Data for Singapore were 0

[3] https://www.nasa.gov/feature/goddard/2020/nasa-study-maps-the-roots-of-global-mangrove-loss

shown are in Indonesia, Myanmar, and Vietnam. Malaysia also shows high loss but to a lesser extent.

The next most severe losses are in Nigeria, Guinea, and Madagascar. Human-driven losses are apparent but to a lesser extent again in Mexico, Philippines, and Thailand. Human-driven mangrove loss is shown, but to the least extent, in Cambodia, Sierra Leone, Liberia, Cote d'Ivoire, Ghana, Benin, Gabon, Angola, Kenya, Somalia, Eritrea, Djibouti, Oman, United Arab Emirates, Sri Lanka, Jamaica, Guatemala, El Salvador, Honduras, Nicaragua, Peru, Ecuador, New Zealand.

Note that these are categorised according to total area of mangrove lost, not a scale relative to the area of coastline. And the totals are over a relatively large timespan ending in 2012 so not indicative of the most recent trends. The areas that have been worst hit may be areas to focus restoration and the areas with minor losses may be areas to look out for greater future risk of further deforestation and where sustainability efforts should be focussed.

A study using satellite images of Hainan China from 1966 to 2009 recorded that 72% of mangroves had been lost and 76% of this was as a result of pond creation for aquaculture (Herbeck et al 2020).

Recent data

The most recent data on mangrove loss does not detail cause of loss (FAO 2020b). Table 5 shows regional data between 2010 and 2020. Showing South and Southeast Asia to be demonstrating the highest rate of change losing 38,300 hectares per year between 2010 and 2020. The Caribbean and North and Central America show positive change in mangrove area.

Table 5: Annual change in mangrove area (1000 ha/year) between 2010 and 2020

Region/sub region	Annual change in mangrove area
Eastern and Southern Africa	2.2
Northern Africa	-0.1
Western and Central Africa	-4.5
Africa total	-2.3
East Asia	0.7
South and Southeast Asia	-38.3
Western and Central Asia	-0.7

Asia total	-38.2
Caribbean	11.7
Central America	-1.8
North America	0.5
North and Central America total	10.5
Oceania	-5.9
South America	14.8
World	**-21.2**

Source: FAO 2020b, licensed under the Creative Commons Attribution-NonCommercial-ShareAlike 3.0 IGO licence (CC BY-NCSA 3.0 IGO)

Further findings

In Indonesia, aquaculture production is expected to grow by 7% per year between 2012 and 2030 (Tran et al 2017).

Bryan-Brown et al (2020) look at fragmentation of mangroves, which reduces the capacity for ecosystem service provision. They note that Cambodia and the Caribbean had relatively low mangrove loss but a large amount of fragmentation which threatens future mangrove cover.

Net loss of global mangrove carbon stocks between 1996 and 2006 is estimated to be 158.4 metric tonnes (Richards et al 2020).

Other environmental harms from aquaculture can result in water quality issues and nutrient build-up through fish waste emissions (Healey et al 2016). Whether this issue is greatest simply where there is the greatest amount of aquaculture activity was not identified within the scope of this review.

Positive findings

There are reports of positive results of mangrove replanting where aquaculture has been abandoned in for example Bali, Indonesia (Proisy et al 2018). Conservation and efforts have been found to have reduced mangrove loss in Senegal with only 0.1% of mangrove loss attributed to human activities (Goldberg et al 2020). In Southeast Asia shrimp and rice production declined by 77%, some of which could be attributed to regional policies encouraging aquaculture intensification instead of expansion (Richards & Friess 2016).

Global deforestation rates are declining (Friess et al 2019) and mangrove destruction for shrimp farming is declining (Naylor et al 2021). Decline in mangrove losses globally are also thought to be a result of limited mangrove resources left, with “a lack of remaining mangroves viable for conversion to aquaculture” (Goldberg et al 2020 p. 5844).

4. Aquaculture and conservation

Results from a rapid search for literature on aquaculture supporting or minimising mangrove loss include:

- A technical guideline on Building with Nature has been published by Ecoshape for integrating aquaculture and coastal restoration (Bosma et al 2020). A case study in Java, Indonesia is described where innovative ‘Associated Mangrove Aquaculture (AMA) systems’ restored mangrove greenbelts and protected fish ponds.
- Ahmed et al (2017) suggest making aquaculture more green by translocating shrimp culture from mangrove swamps to offshore Integrated Multi-Trophic Aquaculture[4].
- Anh et al. (2011) look at international, national, and community initiatives on standards and certification to promote sustainable shrimp and pangasius aquaculture in Vietnam. The authors find potential and challenges.
- Certification schemes can provide a useful framework for sustainable aquaculture. See Best Aquaculture Practices (BAP) Aquaculture Facility Certification (BAP 2021).
- Mangrove-based aquaculture has been shown to be sustainable on stable or progradational coasts where ponds are protected by mangrove belts at least 700 meters wide in Kien Giang, Mekong Delta (Luom et al 2021). Aquaculture ponds developed on erosional coasts fail or accelerate coastal retreat.
- Zhu et al (2020) explore the potential effects of aquaculture farm structures to dissipate coastal erosion. These are nature-based structures which consist of natural aquatic vegetation and can hold systems for kelp and mussels.
- Primavera (2006) makes recommendations for sustainable aquaculture including “emphasis on herbivorous and omnivorous species, polyculture, integration with agriculture and mangroves, and self-regulation in the form of codes of conduct and best management practices” (p. 531).
- Not on mangrove conservation but a note on water quality management - Molluscan aquaculture is attractive as they do not require feed inputs and they have a positive impact on water quality (Naylor et al 2021). Although they can also absorb viruses, bacteria and pollution making food safety risks high.

[4] https://www.aquaculturealliance.org/advocate/look-at-integrated-multi-trophic-aquaculture/

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