Getting the shrimp's share. Mangrove deforestation and shrimp consumption, assessment and alternatives

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Foreword

Due to their ecological richness, tropical forests harbour a large share of the world's biodiversity. This partially explains why these forests are high on the environmental agenda.

Since approximately the mid-2000's, food production, and subsequently food consumption, have increasingly been designated as the main culprits for deforestation in the tropics.

Due to the globalisation of food value chains, consumers' diets are seen as the primary drivers of deforestation. Annual losses of millions of forest hectares globally are now precisely monitored and denounced, and a handful of typical "deforestation commodities" are singled out for their role in this process: (beef) meat, soy (principally used to feed livestock, including poultry and pork), maize, palm oil, coffee and cocoa indeed bear the largest responsibility in tropical deforestation.

This has led to mounting attention from environmental NGOs, and from environmentally sensitive consumers. Spurred by NGOs and by research displaying how globalised value chains "trade deforestation", and aware of a growing demand for more sustainable food products, agri-food businesses and public policy-makers have made commitments and undertaken actions to reduce "embedded deforestation" in importation policies (including, notably, the Amsterdam Declaration "Towards Eliminating Deforestation from Agricultural Commodity Chains with European Countries"[1], France's National Strategy to Combat Imported Deforestation [2] , and a European Commission strategy in preparation…).

This mobilisation, however, tends to neglect a dramatic deforestation process: that of mangroves, i.e. forests which grow alongside tropical coasts.

Deforestation of mangroves is occurring at an alarming pace of approximately 150,000 ha per year. This figure is, *in absolute terms*, rather modest in comparison with inland deforestation (e.g. the Amazon, the Congo basin and the Indonesian/Malaysian inland forests), where annual deforestation affects approximately 20 M ha per year.

This overshadows the fact that mangroves are linear forests. Their ecological, social and economic importance is less proportional to their surface than to their length (see figure 1 below). More than 35 % of mangroves have disappeared during the last two decades, and more than 70 % in some regions. Mangrove deforestation happens at an even more rapid pace than continental deforestation; however, it is much yet less targeted by campaigns and policy responses. Mangroves are of crucial importance for many ecological, social and economic reasons, from their uniqueness to their role in protecting coastal areas from storm surge.

Aquaculture, and, singularly, shrimp farming, bears the largest responsibility in the mangrove deforestation process by far.

It was therefore a perfect subject for the *Biodiversity Values and Policies* class at Sciences Po, third-ranked university for policy studies worldwide, within the *Environmental Policy* master of the *Paris School of International Affairs (PSIA)* [3], where we teach. A group of 13 of its 2017-2018 students have written their final essays on this subject.

This is a collection of these essays, altogether forming a comprehensive report aiming to present evidence on mangrove depletion, the role and responsibility of shrimp farming and shrimp consumption with regards to this issue, and the potential offered by policy instruments as well as alternative consumption patterns. We chose to

[1]https://www.euandgvc.nl/documents/publications/2015/december/7/declarations

[2]https://www.gouvernement.fr/en/ending-deforestation-caused-by-importing-unsustainable-products

[3] http://www.sciencespo.fr/psia/

display these essays in their original form, with their imperfections, notably with respect to English, most of the students (and ourselves…) being non-native English speakers, and we intend to do so each year from now on, on a subject related to global value chains and biodiversity. The role of global value chains in the collapse of biodiversity worldwide is indeed a major subject for IDDRI, the French think tank devoted to better environmental policies, and a partner of Sciences Po[4]. IDDRI's biodiversity and ecosystems programme[5] devotes attention to the governance of agri-food commodities global value chains, and their relation with biodiversity depletion.

With this report, we hope to shed light on these yet overshadowed issues, and to bring shrimp consumption and mangroves onto the "embedded deforestation" agenda, and more generally to the biodiversity protection agenda.

Yann Laurans and Aleksandar Rankovic, 15 January 2019

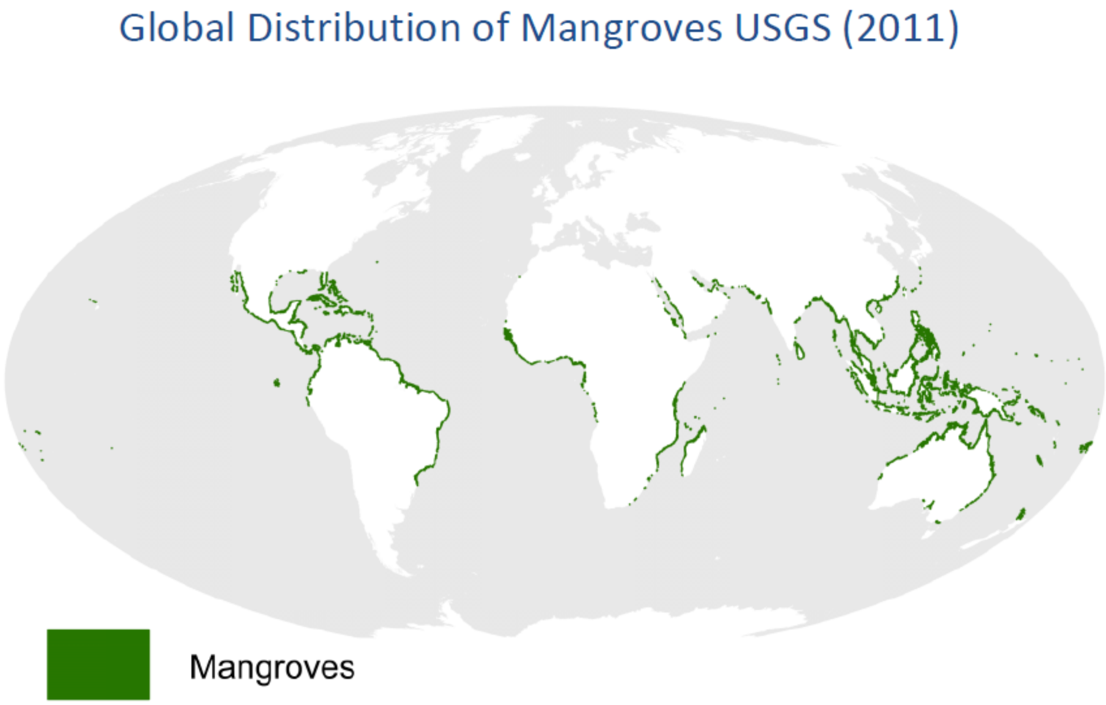

Figure 1. Source: Giri C, Ochieng E, Tieszen LL, Zhu Z, Singh A, Loveland T, Masek J, Duke N (2011). Status and distribution of mangrove forests of the world using earth observation. satellite data (version 1.3, updated by UNEP-WCMC). Global Ecology and Biogeography 20: 154-159. Paper DOI: 10.1111/j.1466-8238.2010.00584.x; Data URL: http://data.unep-wcmc.org/datasets/4

[4] www.iddri.org

[5] https://www.iddri.org/en/programme/biodiversity-and-ecosystems

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1. Mangrove depletion: what is the problem?

By Ana Deligny and Katarina Homolova

Mangroves are a unique ecosystem. These lush tidal forests are perfectly adapted to live and thrive in the intertidal zones of tropical and sub-tropical coastlines and warm temperate waters. Mangroves' diversity and ability to cope with changing salinities, near-permanent inundation of their roots by the sea, and shifting composition of coastal sedimentation (M. Spalding, Kainuma, and Collins 2010) have endowed them with a natural resilience and made them a central pillar of a dynamic environment, a sentinel where the land meets the sea. Mangrove forests are home to a rich and even exceptional biodiversity and provide essential goods and services to coastal communities. In-between submerged shrubs provide ideal nurseries for many species of fish and crustaceous, protruding aerial roots are used as hunting ground for crocodiles and snakes and molluscs simply settle their home on and among the pneumatophores, while higher up in the luxurious canopy birds roost and many mammals like monkeys, deer, bats and even kangaroos, and insects rely on mangroves for their sources of food. For coastal communities, mangroves present many benefits by preventing the loss of coastline, soil erosion and attenuating the damage from extreme weather events as storms surges and tsunamis. They also sustain abundant fishing grounds, provide firewood, act as stormwater filters and sequestrate more carbon from the atmosphere than other types of forests (Donato et al. 2011). In all, their economic values range from US$2,000 to US$9,000 per hectare per year (UNESCO 2017). People and mangroves have been living together many thousands of years. In the Orinoco Delta of Venezuela, the Warao tribe made mangrove forests their home 7000 years ago. Ever since, their life was undiscernible from the rhythm of the ecosystem. Practicing horticulture and deriving their protein from fish and crabs, the "boat people," in their name, live among the mangroves (M. Spalding, Kainuma, and Collins 2010).

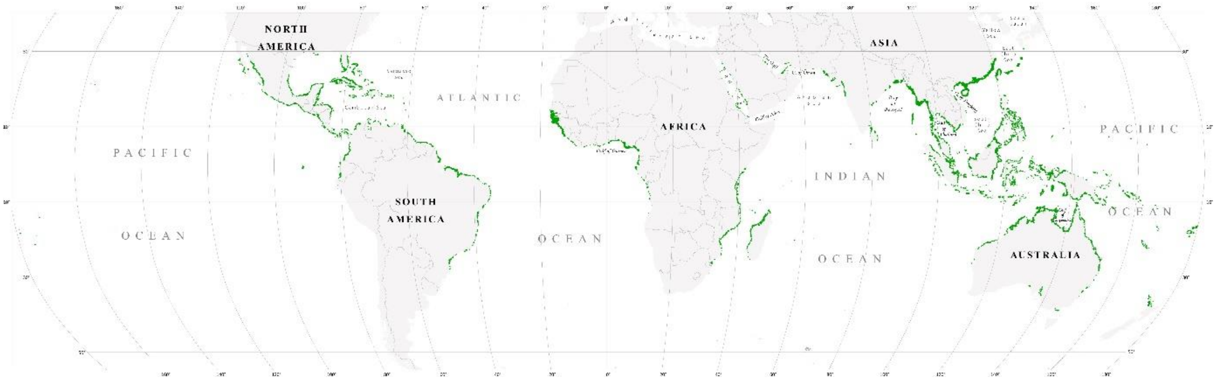
Mangrove forests once lined three-quarters of the world's tropical coastlines, often sharing their habitat with coral reefs, but over half of their area extent has now been destroyed, mostly due to coastal developments, aquaculture expansion, pollution and over-harvesting in the last fifty years (Dear and Kemp 2005; Donato et al. 2011). Today, mangroves cover less than 1% of all tropical forests worldwide and 0.4% of global forest areas, and they are disappearing at rates 3-5 times greater than average rates of forest loss thus becoming a rare and increasingly fragile ecosystem (FAO 2005; M. Spalding, Kainuma, and Collins 2010; UNEP 2014; van Lavieren et al. 2012).

Although all forests are dynamic ecosystems that have evolved and adapted through many epochs, the current challenges they are facing are mostly far from natural and of accelerated impact. Mangroves depletion is one of the most important losses to global biodiversity and the effects thereof will have a worldwide impact. In order to understand the extent of these effects, this section provides first an overview of global trends in mangrove depletion as well as regional and local dynamics, and the conservation efforts in place. Next, it will explore the particular effects of mangrove forests disappearance in the context of biodiversity loss and global carbon balance and last on human coastal settlements.

Global overview

The worldwide distribution of mangrove forests is very much dependent on suitable climatic variables as warm temperatures, the availability of rainfall and freshwater, and low frequency of extreme cold weather events (Osland et al. 2013; Osland, Enwright, and Stagg 2014; Saintilan et al. 2014). Mangroves are particularly abundant in tropical regions, with iconic ecosystems found in the Sundarbans, Mekong Delta, Amazon, Madagascar, Papua New Guinea and Southeast Asia (Giri et al. 2011). Their overall habitat, nevertheless, spans on coastal lines between 31°22' N in Japan (Satsuma Peninsula in southern Kyushu) and 32°59' N in Bermuda, and 38°45' S in Australia (Corner Inlet, Victoria) 38°59' S New Zealand (Raglan Harbour) and 32°59' S on the eastern coast of South Africa (south to the Bashee River) (Cuff and Goudie 2009; M. Spalding et al. 1997).

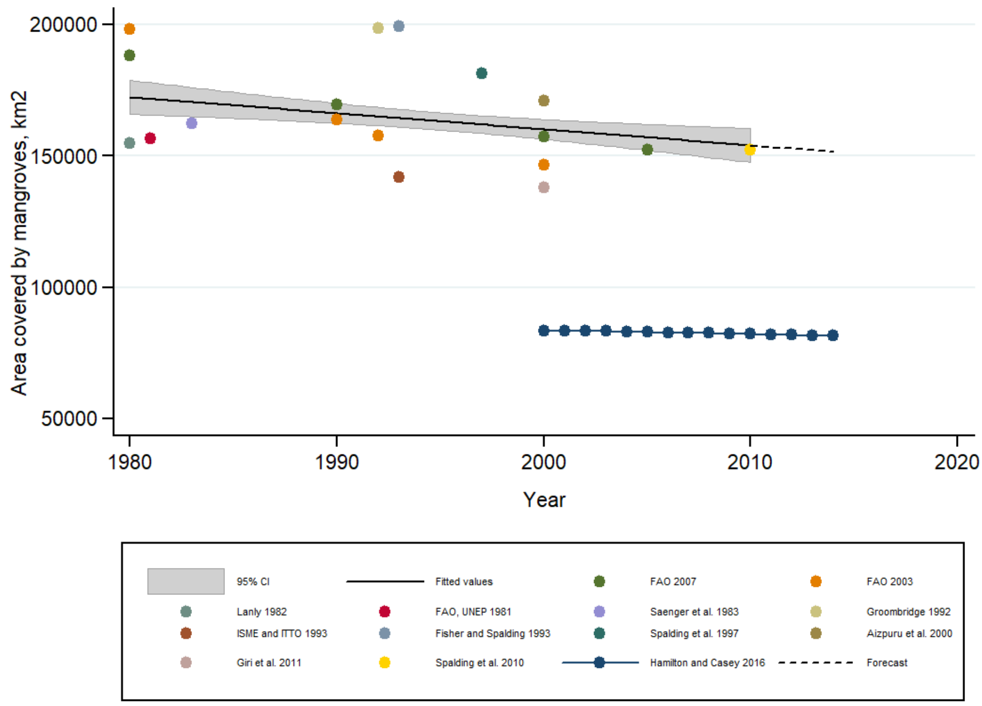
Figure 2: Global geographical distribution of mangroves, 2000



Source: Giri et al., (2011).

The area covered by mangroves has been the subject of many studies, that provided heterogeneous results according to different methodological approaches, varying spatial resolution of satellite imagery, exclusion of countries with negligible mangrove stands and the defining criteria for mangroves used in the study. A meta-analysis of the literature situates the global mangrove forest extent between 151,500 and 81,485 km^2 for the year 2014, see *Figure 3*.

Figure 3: Estimates of the global area covered by mangroves (km²), 1980-2014



Note: Hamilton and Casey (2016) adopt a different definition of mangrove in their study resulting in a substantial difference in calculated areas as compared to previous studies. These results have therefore not been included in the regression and do not influence the forecast.

Table 1: Estimates of the global area covered by mangroves (km²) by year and author, 1980-2010

Source	No. of countries	Reference year	Mangrove area, km²					
			Total	Africa	Asia	Oceania	N. and C. America	South America
FAO 2007	124	1980	187,940	36,700	77,690	21,810	29,510	22,220
FAO 2003	121	1980	198,088	36,593	78,565	18,501	26,413	38,016
Lanly 1982	76	1980	154,620					
FAO, UNEP 1981	56	1981	156,427	36,070	55,817	5,530	21,517	37,493
Saenger *et al.* 1983	65	1983	162,210	32,588	51,796	16,980	20,124	40,722
FAO 2007	124	1990	169,250	34,280	67,410	20,900	25,920	20,730
FAO 2003	121	1990	163,615	34,698	66,893	17,039	22,964	22,020
FAO 2003	121	1992	157,630	33,901	66,617	15,780	21,029	20,303
Groombridge 1992	87	1992	198,478	55,498	76,823	14,922	33,099	18,138
ISME and ITTO 1993	54	1993	141,973	29,454	50,919	385	19,317	24,595
Fisher and Spalding 1993	91	1993	199,287	55,664	77,191	15,145	33,149	18,138
Spalding *et al.* 1997	112	1997	181,280	37,383	75,809	18,789	24,794	24,579
FAO 2007	124	2000	157,400	32,180	61,630	20,120	23,520	19,960

FAO 2003	121	2000	146,532	33,508	58,327	15,269	19,684	19,743
Aizpuru et al. 2000	112	2000	170,756					
Giri et al. 2011	118	2000	137,760	27,552	57,859	16,531	20,664	15,154
FAO 2007	124	2005	152,310	31,600	58,580	19,720	22,630	19,780
Spalding et al. 2010	123	2010	152,361	27,957	62,232	15,888	22,402	23,882

There has been a visible decline in the mangroves' extent between 1980 and 2010, accounting for 10.3% of the total area having disappear or having been destroyed during the given period. In the 21st century, however, the rate of mangrove depletion is slowing down at 0.13-0.18% annually (Hamilton and Casey 2016; Stong and Minnemeyer 2015). Yet, while this indicator might be perceived as less depressing, it would still imply forsaking 1,500 to 3,000 km^2 of tidal forest per decade.

At regional level, Asia hosts by far the largest mangrove population (38%), followed by Africa (21%), North and Central America (15%), South America (13%), and, finally, Oceania (11%). Although, regional estimations vary considerably among studies, recent developments in remote sensing technology ensure a higher degree of accuracy and a gradual convergence of the results, see *Figure 4* for the period 2000-2010. Among all regions, Asia equally experiences the most significant percentage of mangroves depletion while the second most important losses of vegetation are observed in North and Central America, see *Table 2*. Mangrove forests can experience natural dynamics due to dieback and natural processes of soil erosion and deposition that would lead to mangrove decline, retreat and colonization/regrowth respectively. Nevertheless, the most substantial areas are being lost to agriculture and aquaculture. In some parts of Asia, mangroves are equally exposed to logging. Overall, the total anthropogenic activity is responsible for 37.8% of mangrove depletion between 1996 and 2010 (Thomas et al. 2017).

Figure 4: Median values and estimates of mangrove area cover per region per decade in dedicated studies published from 1980 to 2010

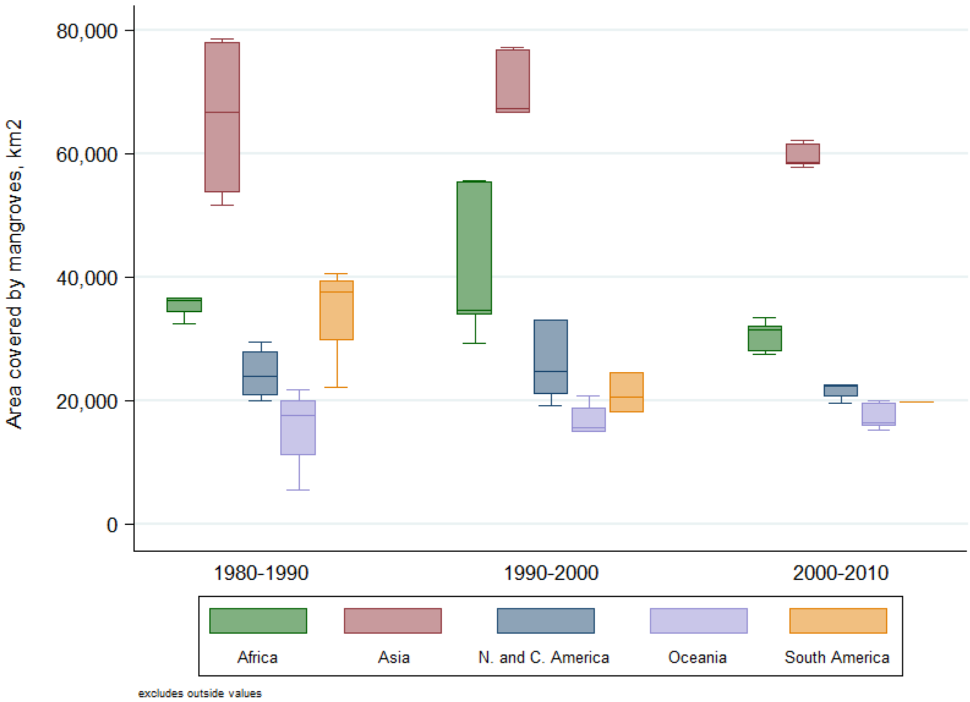


Table 2: Mangrove area cover change per decade, 1980-2014

	Africa	Asia	Oceania	N. and C. America	South America
1980 - 1990	-5.9%	-14.0%	-5.9%	-12.6%	-29.0%**
1990 - 2000	-6.7%	-13.1%	-12.9%	-15.5%	-7.6%**
2000 - 2010	-13.1%	+6.7%*	-3.9%	+8.4%*	+21.0%**
2000 - 2010	-0.3%	-2.9%	-0.3%	-1.3%	-0.5%
2010 - 2014	-0.1%	-1.3%	-0.1%	-0.5%	-0.2%

Note: The values from 2000-2010 and 2010-2014 in the bottom part of the table are calculated from data provided by Hamilton and Casey (2016) and are based on a different definition of mangrove.
*The gains in mangrove forested areas are, most probably, due to differences in methodology throughout studies as well as the inclusion of an increasing number countries and islands, notably in the Caribbean and Southeast Asia, in more recent studies.
**The estimates for South America entail a considerable variance across studies and are therefore not reliable for further analysis.

Of the 118 to 124 countries that are home to mangrove habitats, over 60% of the total area

worldwide is shared between a group of ten countries, see

Table 3. Indonesia's forest richness is the most impressive, containing alone almost a quarter of

global mangroves. Yet Indonesia's stride for development will likely have a devastating impact for local mangroves. Most of them will continue to be transformed into aquacultures, as the expansion of the sector was declared a policy priority in 2010, and palm oil production fields, which are expected to increase in cover by almost 30% above 2012 levels by 2019 (Richards and Friess 2016).

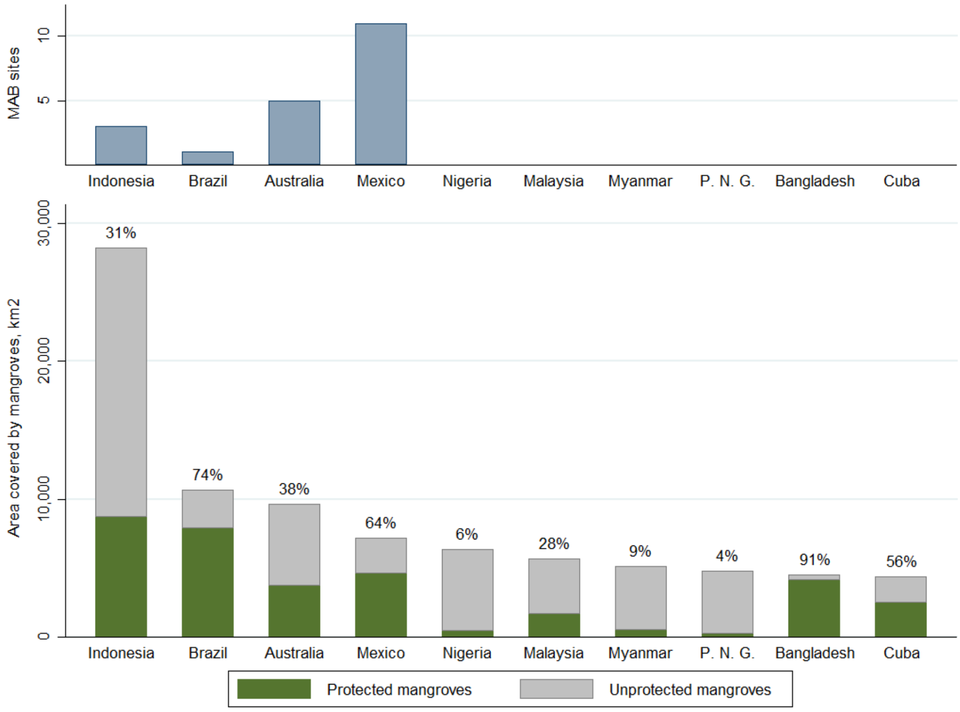
Table 3: The top 10 mangrove-holding countries, their percentage of the global total and their cumulative percentages

2000 (Giri et al. 2011)				**2010** (M. Spalding, Kainuma, and Collins 2010)				**2014** (Hamilton and Casey 2016)			
Country	Area, km²	%	∑%	Country	Area, km²	%	∑%	Country	Area, km²	%	∑%
Indonesia	31,130	22.6	22.6	Indonesia	31,894	20.9	20.9	Indonesia	23,143	28.4	28.4
Australia	9,780	7.1	29.7	Brazil	13,000	8.5	29.4	Brazil	7,663	9.40	37.8
Brazil	9,627	7.0	36.7	Australia	9,910	6.5	35.9	Malaysia	4,691	5.76	43.6
Mexico	7,420	5.4	42.1	Mexico	7,701	5.1	41.0	Papua New Guinea	4,169	5.12	48.7
Nigeria	6,537	4.7	46.8	Nigeria	7,356	4.8	45.8	Australia	3,315	4.07	52.8
Malaysia	5,054	3.7	50.5	Malaysia	7,097	4.7	50.5	Mexico	2,985	3.66	56.4
Myanmar	4,946	3.6	54.1	Myanmar	5,029	3.3	53.8	Myanmar	2,508	3.08	59.5
Papua New Guinea	4,801	3.5	57.6	Bangladesh	4,951	3.2	57.0	Nigeria	2,653	3.26	62.8
Bangladesh	4,366	3.2	60.8	Cuba	4,944	3.2	60.2	Venezuela	2,401	2.95	65.7
Cuba	4,215	3.1	63.9	India	4,326	2.8	63.0	Philippines	2,060	2.53	68.2

Less than a third of Indonesia's mangrove forests are under some kind of protection and the country only established 3 MAB Biosphere Reserves that include mangroves: Komodo, Tanjung Putting and Siberut (UNESCO 2018). Other mangrove rich countries as Nigeria, Malaysia, Myanmar and Papua New Guinea still have a very low share of their mangroves protected, see

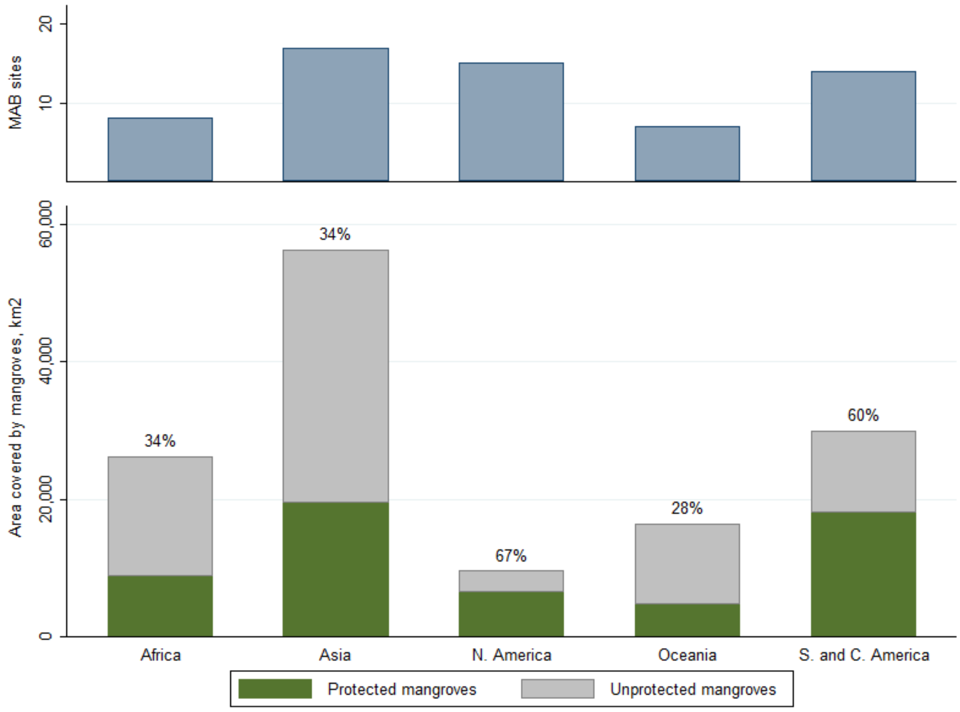
Figure 5. At regional level, Oceania, Africa and Asia have implement very few measures for mangrove conservation. This is particularly alarming in the case of Asia, where mangrove depletion rate is the highest. At the same time, conservation efforts in the Americas are likely to uphold a prospect of decreasing mangrove losses in the future.

Figure 5: Share of protected mangroves of total in 10 largest mangrove-holding countries



Source: UNEP (2014), with modification and inclusion of MAB sites from UNESCO (2018). Note: The percentage of mangroves within protected areas is shown above each bar in the second graph.

Figure 6: Share of protected mangroves of total in in different regions



Source: UNEP (2014), with modification and inclusion of MAB sites from UNESCO (2018).
Note: The percentage of mangroves within protected areas is shown above each bar in the second graph.

Ecological consequences for biodiversity

The specific ecological niche occupied by mangroves and their primary production support numerous forms of land and marine flora and fauna. Consequently, the constant depletion of this valuable resource would have a negative impact on all species reliant on mangroves and also lead to the degradation of the overall ecosystem stability. Tidal forests are home to a rich biodiversity and a total of 69 species of vertebrates (48 birds, 14 reptiles, 1 amphibian, and 6 mammals) have been found to be endemic to mangroves. Of these, 40% are already globally threatened (Luther and Greenberg 2009). Most of these species live in forests throughout Indo-Malaysia and Australasia where the rate of depletion is particularly high and the level of protected mangroves is among the lowest. In Indonesia, 25 mangrove-inhabiting species are listed as endangered or critically endangered and 82 more as vulnerable or near threatened, among them such iconic species as the Long-nosed Monkey (*Nasalis larvatus*) (EN), the Tiger (*Panthera tigris*) (EN), the Leopard (*Panthera pardus*) (VU) and the King Cobra (*Ophiophagus hannah*) (VU). The destruction of natural habitat is the leading cause of species extinctions and even moderate destruction is expected to cause time-delayed but deterministic extinction (Tilman et al. 1994).

Table 4: Mangrove-inhabiting species in Indonesia, included in the IUCN Red List of Threatened Species

	Near Threatened (NT)	Vulnerable (VU)	Endangered (EN)	Critically Endangered (CR)
Mammals	4	13	8	3
Birds	46	13	7	4
Reptiles		2		
Fish	1			1
Insects	1			
Plants		2	2	
Total	52	30	17	8

Source: IUCN Red List of Threatened Species database (2017), last accessed in May, 2018.

Some species, after the loss of their original habitat find shelter in mangroves. The Yellow-shouldered Blackbird (*Agelaius xanthomus*) and the Philippine Cockatoo (*Cacatua haematuropygia*), once living in inland forests, after having lost their habitat to agriculture and development for housing became currently restricted to mangrove areas and are presumed to have gone extinct if there was not for mangroves as a last refuge (Ellison 2004). That is to say that without mangroves providing for natural protection and places to retreat, the dependent species' population would decrease dramatically.

Alongside biodiversity loss in the mangrove forest habitat, coral reefs usually found bordering coastal forests would also face an important threat. Mangrove ecosystems serve as a source but also as a sink for nutrients and sediments that would otherwise inundate the coral reefs. Their complex root system prevents fluvial sediments to be transported to the sea and cover the reef and impede growth of calcifying organisms. The trees and shrubs also provide shade and relief from thermal and photooxidative stress that causes coral bleaching and therefore extensive coral mortality (Yates et al. 2014).

The mangroves themselves are under extensive threat. Out of 70 mangrove species, 16% are at risk of extinction (Polidoro et al. 2010). Restoration efforts often turn out unsuccessful or only result in creating monoculture forests. Experimental conservation projects in Sri Lanka proved 9 out of 23 concerned sites showing no surviving plants and only 3 plantations registering a survival rate higher than 50% (Kodikara et al. 2017). This is due to the fact that mangrove forests are diametrically opposed to terrestrial forests and cannot be restored solely by planting new trees which are often too small to resist high tides and salinity. Therefore, many species cannot be easily and successfully replanted, rare and slow growing species in particular (Alongi 2002), resulting in scanty diversity. While some area restoration is possible in some regions, species and ecosystems cannot be effectively restored (Polidoro et al. 2010).

On a global scale, the deforestation of mangroves, likewise for rainforests, translates to more carbon in the atmosphere and thus contributes to climate change. Considering the quantity of carbon stored in healthy mangrove trees (on average 269-1663 Mg carbon per ha), their depletion would entail a significant effect on the global ecosystem in terms of carbon concentration (Boone Kauffman et al. 2017). With mangroves undergoing conversion into aquaculture or agricultural land, trees are either cut down and burned or removed from the site leaving little to decompose. These processes subsequently lead to a decrease in aboveground carbon stock, and further incapacity of soil organic carbon (SOC) sequestration. It is estimated that mangrove conversion results in GHG emissions of 1067 to 3003 Mg CO_2e per ha, and overall generates as much as 10% of emissions from deforestation worldwide (Donato et al. 2011; Boone Kauffman et al. 2017).

Ecological consequences for human communities

Over 200 million people live near mangrove forest and benefit from their ecosystem goods and services (M. D. Spalding, Brumbaugh, and Landis 2016). Many of them rely on mangroves for support in making their living (construction materials, fuelwood, medicine), for food supplies (fisheries, fodder) and for commercial activities (tannins, fisheries, arts and crafts, ecotourism). This is particularly relevant for poor and vulnerable communities and developing countries. For small island states, mangroves are an important contributor to national economies. In Belize, they add annually US$74-$209 million to the country's GDP (Cooper, Burke, and Bood 2008). The disappearance of mangrove forests will lead to increased food insecurities, deterioration of the livelihoods and the loss of habitable land for coastal communities due to soil erosion and shoreline destabilisation.

Mangroves also have a crucial role in coastal protection, moderating monsoonal floods and windstorms. Empirical studies have proved mangroves' ability to reduce wave energy (Mazda et al. 2006; McIvor et al. 2012; Hashim and Catherine 2013). Field observation, carried out after hurricane Irena, have noted a reduction of surge amplitudes at the back of the 1-km wide mangrove zone by 16-30% and a further gradual decay pattern, when compared to surge amplitudes at the front of the mangrove zone. Within a 3-km mangrove zone, surge amplitudes actually decreased by about 46-57% (Zhang et al. 2012). In addition, surface wind waves are expected to fall in intensity by more than 75% over one kilometre of mangroves (McIvor et al. 2012) while mangrove density offers protection for coastal population against tsunamis (Kathiresan and Rajendran 2005; Tanaka et al. 2007). Without the mangrove forest protecting the coastline, negative effects of sea storms and extreme weather events would be more severe and resulting in larger damage and loss of lives.

Conclusion

In the last four decades, cumulative natural and anthropogenic effects on mangroves have caused visible losses and transformation to this unique ecosystem. The estimates and interpretations of mangrove depletion vary in their extent and urgency of action, yet the reality of global degradation of tidal forests is ubiquitous.

Without mangroves, many marine nurseries, animal sanctuaries, coastal coral reefs and natural fishing ponds, which are vital for coastal communities and contribute to national economies, would be under significant threat. Moreover, coastal dwellings would have their protection from severe windstorms, inundations and extreme weather events significantly reduced. At a global scale, the deforestation of mangrove forests through carbon release adds in magnitude to a complex chain of events that ultimately leads to climate changes at a planetary scale and to rising sea levels which will exert further pressure on the remaining mangroves.

Therefore, more action is necessary to preserve this unique ecosystem but also the services it provides. Sustainable mangrove use is bound to become an imperative to prevent future damages to biodiversity and human communities that depend on these unique habitats, including the development of comprehensive national policies and multilateral agreements for mangrove conservation and adaptation to climate change challenges as well as large scale restoration efforts and appropriate economic incentives to supply alternative or synergetic uses of mangrove ecosystem services.

2. Marking the Groves: Ecosystem services provided by healthy mangroves

By Nandini Agarwal

The land of academic resources offers many arguments highlighting the value that mangroves add to the human society. Different parts of mangrove forests cater to diverse needs and separate sections of the society. Ewel et al (1998) stress that differential characteristics of mangroves attribute different functions to them. Debates about mangrove services are not isolated from recognizing their defining features within individual stands and across geographical regions. In effect, varying functionalities of mangroves necessitate their categorisation at a micro level and across regions, on macro basis. Policy guided by such distinction would efficiently cater to specific challenges brought by mangrove exploitation. Thus, recognition of mangrove services requires a multi-level explanation that couples empirical observations with the array of scientific theories on mangroves categories. The aim is to gain insight on diverse mangrove services such that comprehensive policies are formulated by engaging relevant stakeholders in sustainable forest management. It should be noted that in developing such understanding, no zone has been highlighted as most or least important, rather varying functions of mangroves have been identified to aid policy decisions surrounding mangrove conservation.

Mangroves have been studied widely due to their imminence not only in fish industry or commodities but for their long standing interaction with diverse cultures across the globe. These evergreen forests grow under peculiar conditions creating a distinct environment that is imperative to the survival of certain species. According to the Food and Agricultural Organisation (FAO), the healthiest mangroves that support maximum biodiversity are usually found in estuaries that are characterised by presence of rich organic matter and low amount of sand in well aerated soil (FAO Forest Department , 1994). Health of mangroves not only depends on the natural features such as soil type and amount of rainfall received, but is increasingly dependent on the extent of exploitation these forests encounter in the face of 'contemporary development'.

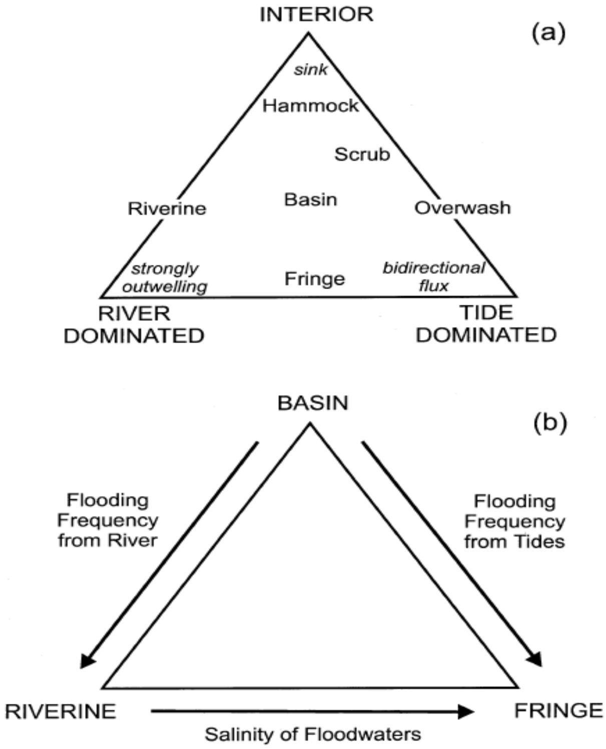
The following sections give a brief definition of healthy mangroves followed by explanation, supported by empirical examples, of varied services provided by different parts of singular forest stand.

Mangroves: A few classifications

Many scholars have classified mangroves on basis of soil structure, interaction with flooding, inundation and self-regeneration abilities (FAO Forest Department , 1994). Frequent inundations by sea-water make them saline, however mangroves across different geographical locations bear distinct features.

Lugo and Snedaker (1951) have used topographic gradient of mangrove forests for categorisation in 6 types namely 1. Overwash 2. Fringe; 3. Riverine; 4. Basin; 5. Hammock; 6. Scrub or Dwarf. The forests have underlying differences in local tide patterns and terrestrial surface drainage. The resulting variation in soil salinity and flushing rates across forests render them different functionalities. This method exposes the differential rates in primary production, carbon export and nutrient recycling in the mangroves (FAO Forest Department , 1994)

Ewel et al (1998) suggest categorisation of mangroves into fringe, riverine and basin (refer to images a and b). They highlight that most variations within a region are observed in basin mangroves due to high and low inter-tidal zones, whereas, inland forests are affected by storm tides. The images clarify the proposed definition.



"Figure (a) depicts the relationships among three functional types of mangrove forests (river-dominated, tide-dominated, and interior) with the associated physical processes (in italics), and six types of mangrove forests described for the Neotropics. Figure (b) shows the proposed relationship among three functional types of mangrove swamps that can be distinguished within any given region (original)" (ONG, 1998)

The definition provided by the scientists is simplistic, yet holistic making it an efficient and practical tool to understand eco-system services by different parts of mangroves. For this reason, and in order to not get lost in only in definitions, this paper adapts their approach and delves into the discussion on mangrove services accordingly.

Services delivered by mangroves

Mangroves have provided numerous ecosystem services over centuries. These can be divided into habitat, regulating, provisional and cultural services (Luke M.Brander, 2012). However, formal categories of ecosystem services have evolved only by contemporary scholars. While some mangrove services are natural, others are produced by human intervention, such as harvesting mangrove trees (ONG, 1998). Most of the services act as 'public goods' meaning that the utilisation of a certain resource by one person does not decrease the pool of that resource for the others. Moreover, the beneficiaries cannot be excluded from receiving these services (Luke M.Brander, 2012).

The TEEB (2010) report presents the following classification - "Mangroves provide a number valuable ecosystem services that contribute to human wellbeing, including provisioning (e.g., timber, fuel wood, and charcoal), regulating (e.g., flood, storm and erosion control; prevention of salt water intrusion), habitat (e.g., breeding, spawning and nursery habitat for commercial fish species; biodiversity), and cultural services (e.g., recreation, aesthetic, non-use)" (UNEP, 2006)

Regulating services such as erosion control and sediment accretion that are a focus of much contemporary research were recognized as early as 1865. Interestingly, multiple ecosystem services like provisioning services for export that represent colonial views of new lands as ripe for economic use, were only discussed in depth by colonialists (Friess, 2016).

This section overlays the classification provided by TEEB on the definition of mangroves provided by Ewel et al (ONG, 1998) to delineate ecosystem services of mangrove forests.

Regulating services

Regulating services encompass stabilization of shorelines, protection from floods and soil erosion, trapping sediments and processing of pollutants. Additionally, marine systems in the mangrove forests are a key factor in climate regulation and maintenance of nutrient cycle (UNEP 2006).

→ Nutrient Cycle: Processing organic matter

Mangroves are proven to be highly productive wetland ecosystems that play an important role in stabilising coastal environment through biochemical cycles. Organic matter is produced in the roots and litter fall of mangroves, which are also a source for carbon and nutrients. A high nutrient availability leads to speedier nutrient cycle – storage, internal recycling and acquisition of nutrients (Luciana de Souza Queiroz, 2017) thereby increasing the pool of phosphorus, nitrogen, potassium and organic carbon (Syed Ainul Hussain, 2008). People in different parts of the world realise the importance of rich mangroves that provide richer life to marine species and high productivity for local communities.

→ Climate regulation

Duarte et al stress the importance of mangroves in climate regulation as they make for huge carbon sinks. Having the largest per hectare global carbon stores mangroves are of particular significance in the context of climate change (Clare Duncan, 2016). Maintenance of global temperatures, precipitation and other biological processes is an important function of mangroves that regulates the greenhouse effect (Luciana de Souza Queiroz, 2017).

→ Sediment trapping

Riverine forests are effective in trapping heavier sediments, whereas basin forests play a role to trap the finer particles. Roots of fringe and riverine forests bind the soil and play a role in preventing erosion of vulnerable soil of the shoreline. Moreover, though in a limited capacity, mangroves also prevent washing off of artificial sediments created by human activities such as road construction. Excess of artificial sediment however kill the mangroves in the long run, as seen in the Pacific island of Pohnpei in the Federated States of Micronesia (ONG, 1998) Trapped sediments stabilise the land against changing sea levels (UNEP, 2006).

→ Protection from floods

Mangroves act as protectors of the shoreline or coastline against wave, frequent tropical storms and wind erosion (FAO Forest Department , 1994). Basin mangroves function as water storage systems in a flood and reduces velocity of water that flows within the forest. (ONG, 1998). High density mangroves have played a role in preventing deaths and loss of wealth in the past. Even 100 m wide mangrove effectively reduces the flow of tsunami wave (Bao, 2011).

Testing the waters

Geubas et al test whether or not mangroves effectively function as a buffer to tsunami by observing Sri Lankan mangroves post-tsunami. They found that protection services that mangroves provide to habitats during storms are undermined in the face of clearance of forests, insufficient regeneration and intrusion of non-mangrove plants in mangrove vegetation. This renders the ecosystem weak and progressively lowers their utility, unless mangrove forests are not protected and revived. The high resilience rates of mangroves observed in Malaysia and East-Africa makes for a good case to invest in mangrove regeneration (F. Dahdouh-Guebas).

Provisioning services

Entire mangrove forests provide wood and non-wood products that are used in industries such as construction, textiles, food and beverages, fishing, agriculture and others. (FAO Forest Department , 1994)

→ Wood products

Wood products include timber which is provided by large adult trees up, to 60 m height, in the forests. Unfortunately, trees are cut off before they can attain reasonably large sizes leading to scarcity in timber (FAO Forest Department , 1994). The appropriate moisture level of some species of mangroves like *Rhizophoras* make it popular source of charcoal in most Asian countries. It is mostly used for cooking purpose in households or by small industries. In economic terms, charcoal does not have as high a return as shrimp farming. Moreover, majority of people living next to the mangroves sustain their lives by fishing. Harvesting mangroves for wood and other plant products is not the primary source of income for them, however it makes for an important supplementary income (Bradley B. Walters, 2008)

Fuel and construction are the most widely used services of wood from mangroves. Though logging is being discouraged due to heavy natural resource loss, relatively isolated coastal communities are still highly dependent on mangrove wood for domestic use (burning, construction of houses, boats, furniture, fishing poles, etc.) and for sale to near-by towns or for customers like bakeries. The availability of and demand for these products however varies across regions, depending on the properties suited to these products coupled with the cultural differences and habits in different communities. Additionally, bark of mangroves are used to make tanning and dyes whereas wood fibre is used to make paper and rayon (Bradley B. Walters, 2008).

→ Non-wood products

Buds and leaves of fringe mangroves are used by indigenous communities for making vegetables, alcohol, and animal fodder. Mangroves also make for a good habitat for some medicinal plants (UNEP, 2006). They are also important for the scientific community for acquisition of genes that are resistant to pests and other scientific materials (Luciana de Souza Queiroz, 2017)

→ Animal habitat and biodiversity

Mangroves act as breeding, spawning and nursery grounds for marine animals within the forests as well as for offshore species. Most species spend critical years of their early lives in mangroves (Alongi, 2002). Commercial fishes form a part of this habitat (UNEP, 2006), among which crabs are mostly found in high inter-tidal locations and are very important in maintaining mangrove functions.

→ Habitat for animals – services to humans

Shrimp is found in high density in fringe and riverine mangroves as well as parts of basin mangroves that are frequently inundated (ONG, 1998). Other crustaceans such as crabs and fresh water prawns utilise the mangroves at some points in their lives. The function of mangroves to trap and assimilate sediments and nutrients acts as a base for coral reefs and fisheries production. Mangroves also provide a suitable habitat for bees and in turn for bee communities making it an attractive place to harvest honey and bee wax. The recent 'utilisers' of traditional *gei wai* ponds in Hong Kong have integrated forestry, fisheries and aquaculture, which urgently calls for development of guidelines for sustainable aquaculture (Bradley B. Walters, 2008) . More than 200,000 hectares of mangrove forests have been destroyed in Vietnam at the hands of agriculture and aquaculture for shrimp farming, as well as for recreational uses (Bao, 2011).

→ Services to animals

As for non-commercial animals, riverine and fringe mangroves provide nesting and feeding grounds for, particularly, migrating birds. Reptiles such as crocodiles, snakes, lizards as well as sea turtles feed in the mangroves. Many mammals like crab-eating rats, monkeys, large cats, deer and otters are also utilise mangrove resources. Mangroves also serve as refuge or resting points for migrating birds (FAO Forest Department , 1994). Additionally, they provide the right environment for biological interactions between organisms allowing biodiversity to flourish animals to thrive (Luciana de Souza Queiroz, 2017). With reduction in biodiversity, ecosystem mangroves can lose resilience and consequently not be able to provide the array for services.

Cultural Services

→ Spiritual and communal

Local communities share a symbolic relationship with mangroves that runs much deeper than material needs of the modern society. For fishermen mangroves are sacred places deemed important for maintenance of societal relationships and guarding ancestral knowledge. Moreover, coastal communities attach pride, liberty and personal satisfaction to mangrove forests (Luciana de Souza Queiroz, 2017) . Since indigenous communities live so closely to these forests, it is important to take account of traditional knowledge and work with these communities to preserve mangroves.

→ Aesthetic value

Mangroves have been attractive sited for tourism industries for decades. They form a part of the coastal scenery and providing spots for leisure activities like fishing, cruises, etc, but also hold inspirational value for artistic creations (Luciana de Souza Queiroz, 2017).

Clearing up of forests and altering ecosystems for construction of hotels, though perceived as "minor alterations" by a few, the cumulative effects of such activities increases their vulnerability to natural hazards. Moreover, the forests have becomes stores for waste, as analysed in the report by Island Resources Foundation that estimated 50 tons of untreated waste on a five-acre mangrove area in Tortola (UNEP, 1996)

The following sections give a brief account of current challenges faced by mangrove forests as they get exploited by multiple stakeholders for the above mentioned services. Not only forests are getting degraded but there is lack of consensus on how they should be valued. These lead to degradation in services they provide and can have cascading effects on nature and dependent human and animal habitats.

Fun fact: At your (dis)service

Mangroves were not always perceived to be the silver basket they are today. In colonial times, an account from the British services in India recollects the gloomy nature of mangroves seen as a “reservoir of disease” such as malaria and area of danger. Moreover, because indigenous people had been using mangroves since centuries in the past, the interactions between the mangroves and the “dangerous habitants who used to mangroves as a hiding place” were viewed as a disservice by the new settlers (Friess, 2016).

Degrading values and changing services

Increased accessibility of fringe mangroves has deteriorated off-site services such as coastal protection and nursery survives. Moreover, more immediate threats such as pollution, deforestation, fragmentation and long term threats like sea-level rise (Giri et al., 2011) are adding to the degradation. Deforestation for construction of roads is understood to be a major factor in fragmentation of mangrove forests (Luke M.Brander, 2012)).

Mangroves are also being converted for other land uses such as aquaculture ponds, urban developments, agriculture and infrastructure. In Asia there has been large scale conversion of mangrove forests to shrimp farms (EDWARD B. BARBIER, 1998) (Bradley B. Walters, 2008).

Valuing mangrove services

The lack of understanding of, and information on, the values of mangrove ecosystem services has generally led to their omission in public debates. In academia, some opine that the importance of mangroves as natural capital tends to be ignored when the ecosystem services are directly compared to the economic value of alternative public investments (Luke M.Brander, 2012). Costanza has worked on economic valuation of mangroves and given it a value of \$194,000 ha^{-1} yr^{-1} for humans (Clare Duncan, 2016). Though the underlying principle of setting a price to services fills the gap for discussion and provides a tool to advocate for their protection for modern society, this also creates the risk of commodification of nature and goes against cultural values of people closest to the forests. Studies that focus on valuation of mangroves using geo-spatial analysis show that value of individual mangroves is enhanced when the mangroves are surrounded with larger patches (Luke M.Brander, 2012). These studies could act as an effective tool for conservation policies in place of economic tools of valuation.

Valuation of ecosystem services is another gambit of debate. In any case it can be safely suggested that in order to estimate specific threats to mangroves, including sea-level rise, the entire mangrove forests all over the globe need to be modelled. This would aid in making targeted policies for improving the forests (ibid).

Conclusion

"Recognition of environmental and economic trade-offs in the coastal zone are now evident and lack of knowledge regarding ecosystem service loss or degradation is no longer a justifiable excuse for coastal development." (Shay Simpson, 2016)

We see that a wide account has been maintained for healthy mangroves and studies that highlight their importance in maintaining natural cycles and supporting plant and animal habitats. However currently, power and legitimacy of stakeholder groups guide policies and decisions in coastal areas that constrain or encourage the expression of these accounts (ibid). In the face of increased development, different stakeholders like tourism and fisheries are over-exploiting mangroves for economic reasons. This not only harms crucial biodiversity in the region but also disrespects the spiritual and traditional value attached to these forests. Many scholars have developed different theories to value these services either in order to protect them or for 'sustainable exploitation'. Among these, the argument that economic valuation provides the appropriate tools to preserve mangroves and ecosystems in general has taken a sweeping stance for decades now. Unfortunately, only a few question this argument and have given alternate theories like spatial analysis and valuing socio-cultural aspects of mangroves to promote sustainable use. However, these debates are ever-evolving with no single answer. What is important is to understand all perspectives of understanding mangroves and their services for varied communities in order to frame effective policies for their management.

3. The drivers of mangrove depletion, and the relative responsibility of shrimp farming

By Ilyia Kurtev

Introduction

At dawn on the morning of Sunday 26th of July 1998, hundreds of men, women, and children gathered on the island of Muisne, in the west part of Esmeraldas province of Ecuador, to protest against the growing spread of illegal shrimp farms within the mangrove forest[6] With the aid of Greenpeace activists who had just arrived for the occasion, using picks, shovels, bits of wood, and their own bare hands, they breached the dikes of one of the farm ponds and let the shrimp escape into the sea. Then, they proceeded to replant the pond with mangrove seedlings. The message was clear: this was the first time such a radical act of sabotage had been carried out against a shrimp farm in Ecuador, but if the industry did not change its ways, it was not going to be the last.[7]

To make that promise real, a national network for the defense of the mangrove ecosystem of Ecuador (C-CONDEM) was formed on the same day.[8] Its main objectives were to participate in creating policies for the recovery and conservation of the mangrove ecosystem of Ecuador, and to guarantee that the human rights of the communities inhabiting it – *los Pueblos Ancestrales del Ecosistema Manglar* – are fully taken into account. .

A year after the Muisne campaign, its capacity to fulfil that promise was put to the test. The Ecuadorian government introduced a proposal to legalize shrimp farms on state-owned mangroves as property of their operators, which was a move C-CONDEM drastically opposed. But instead of publishing a detailed policy analysis outlining the unfair and potentially devastating aspects of the government's proposal, the network opted for something rather unexpected: it shared with the people of Ecuador – and with the international community at large – a simple unfiltered statement of a *conchera*[9] living in the mangroves. It read as follows:

"We have always been ready to cope with everything, but now they want to humiliate us […] We are struggling for something which is ours, our ecosystem, and not because we are professional ecologists, but because we must remain alive. Because if the mangroves disappear, we all disappear… I do not know what will happen to us if the mangroves disappear [...] What I know is that I shall die for my mangroves."[10]

[6] Environmental Justice Atlas (n.a.): Shrimp Farming in Muisne, Ecuador. Online resource. Retrieved 6 may 2018 from: https://ejatlas.org/conflict/shrimp-farming-in-muisne-ecuador

[7] Warne, Kennedy (2011): Let Them Eat Shrimp: The Tragic Disappearance of the Rainforests of the Sea. Island Press / Shearwater Books, Washington | Covelo | London. p. 60.

[8] C-CONDEM (2008): '¡10 años junt@s! 1998 – 2008'. Online magazine, anniversary edition. Retrieved 5 May 2018, from: http://www.ccondem.org.ec/imagesFTP/5036.10anos_2008.pdf

[9] A woman who collects mussels for a living.

[10] Warne, Kennedy (2011): Let Them Eat Shrimp: The Tragic Disappearance of the Rainforests of the Sea. Island Press / Shearwater Books, Washington | Covelo | London. p. 63.

Shrimp and mangroves, mangroves and shrimp – the two are intertwined: ecologically, socially, economically, and politically. As Kennedy Warne puts it, "*they are like a pair of orbiting stars, though one shines at the expense of the other.*"[11] The story above expresses the underlying problem in the mangrove-shrimp relationship: over half of the world's mangrove forests have already been destroyed and the shrimp farm industry has been the driving force behind the devastation.[12] Although exact statistics on the matter remain disputable, one fact is not: despite the advances in technology and legislation, irresponsible shrimp farming continues to be among the principal causes for the disappearance of mangrove wetlands globally. As a result, many other mangrove-dependent communities throughout the world – in the Americas, in Africa, in South-East Asia, and Oceania – share the fears of *los pueblos del manglar,* and are similarly willing to risk their lives if that is what it takes to stop the advance of the shrimp behemoth.

But how did these resilient trees, able to withstand tsunamis and survive conditions in which other plants would languish within minutes, suffer so much damage and devastation, and how, in the words of Warne, did shrimp become the mangroves' nemesis?[13] In an attempt to answer these two questions, the remainder of this paper proceeds as follows: first, it examines what the mangrove forests are and why they are important; next, it identifies the main anthropogenic causes of mangrove loss worldwide; then, it proceeds to trace the origin and development of the shrimp farming industry and analyze its contribution to mangrove depletion; and lastly, it concludes with a brief reflection on the possible way forward.

Mangroves- the Rainforest of the sea

Mangroves – to the unexperienced observer, they appear as little more than an impenetrable coastal thicket that clings to the edge of solid land and blocks the access to the sea. Partially, that is understandable, for many of the species thrive in repulsive, fowl-smelling swamps; range in size from dense small bushes to 60-meter giants[14]; and share the annoying feature of spreading their root systems in complex, dense, wide-ranging webs that make traversing nearly impossible. That, perhaps, is why it often comes as a surprise to hear that mangrove forests are among the most productive, diverse, and valuable ecosystems on the planet, constituting an endless reservoir of natural wealth: they provide roosting sites for birds and attachment sites for shellfish; hunting grounds for tigers, snakes, and crocodiles; nurseries for fish and shrimp; a nectar source for bats and honeybees; and a food source for monkeys, deer, and tree-climbing crabs.[15] In addition, they protect the coasts by acting as land stabilizers and breakwaters against tsunamis and water surges; represent a major contributor to the global carbon balance; and provide homes, resources, work, and physical protection for millions of people living on the coast.[16]

[11] Ibid, p. 29.

[12] Mangrove Action Project (n.d.): Mangrove Issues: Deforestation. Online resource. Retrieved 6 may 2018 from: https://mangroveactionproject.org/mangrove-issues/

[13] Warne, Kennedy (2011): Let Them Eat Shrimp: The Tragic Disappearance of the Rainforests of the Sea. Island Press / Shearwater Books, Washington | Covelo | London. p. 30.

[14] American Museum of Natural History (n.d.): What's a Mangrove? And How Does It Work? Online journal, retrieved 6 may 2018 from: https://www.amnh.org/explore/science-bulletins/bio/documentaries/mangroves-the-roots-of-the-sea/what-s-a-mangrove-and-how-does-it-work/

[15] Warne, Kennedy (2011): Let Them Eat Shrimp: The Tragic Disappearance of the Rainforests of the Sea. Island Press / Shearwater Books, Washington | Covelo | London. p. XVII.

[16] Ibid, p. XVII.

And yet, statistics reveal that in the past several decades, between a third and a half of the world's mangrove coverage has been ravaged. These saltwater rainforests have now become one of the most endangered ecosystems on the planet, disappearing, as some accounts suggest, with a rate of three to five times faster than global forest loss on average.[17] They continue to be uprooted, torched, and bulldozed to create clearings for housing, roads, ports, tourist resorts, golf courses, and aquaculture ponds, and they may die from a thousand lesser cuts: oil spills, chemical pollution, sediment overload, overexploitation, and disruption of their water balance. [18] According to some observations, they are critically endangered, or approaching extinction, in 26 out of the 123 countries that have them, and the outlook for the next half a century and beyond looks no brighter.[19] In addition to these existing threats, there looms a problem of potentially even more disastrous consequences: climate change and sea level rise. Standing as they do at the land's frontiers, mangroves will be the first to face the encroaching tides and spreading inland will not be an option in many places as human development behind the mangrove fringe is cutting off the line of retreat. As Warne puts it, "the *mangroves have become hemmed in on all sides and the walls are closing in.*"[20]

But how did these valuable ecosystems, which provide a livelihood for millions of people worldwide, become among the most vulnerable, overlooked, and abused environments on Earth? What are the causes that have led to this dramatic, absurd outcome? The next section attempts to find the answer to these questions.

[17] UNESCO (2016): International Day for the Conservation of the Mangrove Ecosystem. Online resource at the *Did you know* section. Retrieved 5 may 2018 from: http://www.unesco.org/new/en/unesco/events/prizes-and-celebrations/celebrations/international-days/int-day-for-the-conservation-of-the-mangrove-ecosystem/mangrove-ecosystem-2016/

[18] Warne, Kennedy (2011): Let Them Eat Shrimp: The Tragic Disappearance of the Rainforests of the Sea. Island Press / Shearwater Books, Washington | Covelo | London. pp. XV-XVI.

[19] Ibid, p. XVI.

[20] Ibid.

Table 3. Human use of mangrove area leading to loss of habitat, by continent.

Activity	Area affected by each activity (10^3 km^2) Asia	Americas	Africa	Australia	World total	Percentage of total[1]
Shrimp culture	12	2.3	–	0.005	14	38
Forest use	4.6	4.9	–	–	9.5	26
Fish culture	4.9	–	–	–	4.9	14
Diversion of freshwater	4.0	–	0.09	–	4.1	11
Land reclamation	1.9	–	–	–	1.9	5
Herbicides	1.0	–	–	–	1	3
Agriculture	0.8	–	–	–	0.8	1
Salt ponds	0.02	–	0.03	–	0.05	–
Coastal development	0.05	–	–	–	0.05	–
Total area	29	7	0.12	0.005	36	
Percentage of mangrove area represented	85	75	2	100	66	

Source: Data from Linden and Jernelov 1980, Saenger et al. 1983, Ong 1995, Fortes 1988, Jory 1997, Stonich et al. 1999.

1. Does not total 100% because of rounding.

Mangrove trees can endure almost anything. These botanical amphibians have mastered the art of survival in extreme environments and thrive where almost any other plant would fail. And yet, they cannot withstand the destructive force of man. As already indicated, by some estimates less than 50 percent of the world's mangrove forests were still intact at the end of the 20th century, and of the remaining mangrove stands, it is estimated that 52% are degraded due to shrimp/fish aquaculture, 26% due to forest use, and 11% due to freshwater diversion.[21] As a result, mangrove forests are among the most threatened habitats on the planet: Thailand has already lost over 87 percent of its original mangroves, the highest rate of mangrove loss of any nation, while India follows closely behind with 85 percent loss, and Bangladesh, Pakistan, Singapore, Djibouti, Guinea Bissau, Kenya, Liberia, and Somalia are all among the longer list of countries which each has lost more than 70 percent of their mangrove marshlands.[22] This trend continues to be rampant across the globe, with an estimated rate of 1-2% of global annual decline in mangrove coverage.[23]

From a root-cause perspective, several anthropogenic factors can be identified as contributors to that reality:[24]

[21] Valiela, I., Bowen, J. L. & York, J. K. (2001): Mangrove Forests One of the World's Threatened Major Tropical Environments. Bioscience Journal. Vol. 51, No. 10, p. 807.

[22] Lewis, R.R. III, Phillips, M.J., Clough, B. and Macintosh, D.J. (2003): Thematic Review on Coastal Wetland Habitats and Shrimp Aquaculture. Report prepared under the World Bank, NACA, WWF and FAO Consortium Program on Shrimp Farming and the Environment. Published by the Consortium. p. 11.

[23] FAO (2003): Status and Trends in Mangrove Area Extent Worldwide. By Wilkie, Mette Løyche and Fortuna, Serena. Forest Resources Development Service, FAO Forestry Department. Resources Assessment Working Paper No. 63. Retrieved 6 May 2018 from: http://www.fao.org/docrep/007/J1533E/J1533E02.htm

[24] Group on Earth Observations (2017): Earth Observations 2030 Agenda for Sustainable Development. Global Mangrove Watch – Mapping Extent and Annual Changes in the Global Mangrove Cover. p. 13. Retrieved 6 May 2018 from: https://www.earthobservations.org/documents/publications/201703_geo_eo_for_2030_agenda.pdf

→ Tourism

Ecotourism is a booming industry and an important source of income in many developing nations. If practiced irresponsibly, however, it can destroy the very nature on which it depends. Tourists bring with them garbage, sewage, noise, fumes, lights, and other disturbances that can damage mangroves and the surrounding ecosystems, and walking off paths, lighting fires, feeding wildlife, anchoring on reefs, and collecting flora and fauna can also have harmful effects on the environment. Yet it can also have a positive impact. If practiced sustainably, it can help the recovery of mangrove wetlands by providing a valuable source of funding for initiatives aimed at protecting them.

→ Agriculture

Mangrove forests have been and continue to be destroyed to make way for rice paddies, rubber trees, palm oil plantations, and other forms of agriculture in countries like Myanmar, Malaysia, and Indonesia.[25] In addition, farmers often resort to using fertilizers and chemicals which can contaminate surrounding waters and kill mangrove trees in spite of their resilience. Moreover, waterways are often diverted for irrigation or paved over for roadways, which alter the natural flow of water and can also have detrimental effects: each mangrove species has evolved to adapt to the specific tidal fluctuations of their environments and can perish as a result of major changes in the water currents.

→ Wood exploitation

For many coastal communities, mangrove wood, especially the denser species like *Rhizophora* and *Cerops,* represent an excellent, high-energy firewood and charcoal source; and in some deficit but over-populated areas even small branches and saplings are often removed for domestic fuel.[26] In addition, the cottage industries of many coastal populations depend on mangroves for the highly-valuable timber they provide, which is naturally resistant to saltwater decay and constitutes an ideal building resource. However, in many places where fishing has declined below subsistence levels, locals turn to chopping down mangroves as source of income instead, which furthers the adverse cycle of habitat loss and biodiversity decline.

→ Coastal development

Human activity is altering the mangrove ecosystems in many other ways. From ports and docks to golf courses and hotels, the wheel of coastal development takes different forms and the pressures coming from tourism, industry, and trade make sure to keep it turning. And yet, as streams and wetlands become drenched by roads, concrete, and urbanization, and resources dwindle from overexploitation by offshore dredging, mining, and bycatch, the natural processes of these habitats get interrupted and their ability to regenerate and propagate diminishes. That is why, considering the present rate of global mangrove loss (1-2% per year on average), as well as the possible adverse effects of climate change and sea level rise, the world appears to be facing a real risk of losing its

[25] Richards, D. R. and Friess, D. A. (2016): Rates and Drivers of Mangrove Deforestation in Southeast Asia, 2000–2012. PNAS, vol. 113, no. 2, pp. 344-349. Retrieved 6 May 2018: https://dx.doi.org/10.1073/pnas.1510272113

[26] FAO (1994): Mangrove Forest Management Guidelines. FAO Forestry Paper, n. 117, p. 1.

mangrove ecosystems entirely in the next 100 years.[27]

The biggest cause of mangrove depletion, however, remains to be discussed in detail. The past contribution of this relatively novel industry exceeds that of all of the above factors combined[28], and what is more, it appears to continue constituting the greatest threat to mangrove forests globally in the years to come[29]. Because of that, it deserves a section of its own.

Shrimp and mangroves, mangroves and shrimp

Although aquaculture has been practiced by humanity for thousands of years – the oldest known guide was written in 475 BC by a Chinese administrator on how to get rich by cultivating carp[30] – the origin of shrimp-farming as a commercially viable industry is much more recent. It all began when the Japanese ichthyologist Motosaku Fujinaga, after decades of laboratory experimentation between the 1930s and the 1960s, finally succeeded in mass producing the esteemed *kuruma* sushi shrimp – *Penaeus japonicus* – in captivity.[31] Word of his success spread like wildfire, and breakthroughs in hatchery techniques, feeding, disease control, and pond management followed one after the other. And so, by the 1970s, shrimp farming – the 'pink gold' – became one of the fastest growing and most commercially profitable aquacultural activities worldwide, establishing itself as the rising star of the 'Blue Revolution'. This new industry attracted the attention of scientists, entrepreneurs, and politicians alike, experiencing a boom in productivity and scale, and from constituting just 7 percent of global seafood harvest in 1974, by 2014, captive farming grew to represent more than half of the world's seafood market.[32]

That was how, and why, with little regulation against it, and with governments seduced by sizeable profits and inclined to cooperate, the mangrove forests began to fall like matches as the shrimp industry expanded. Major contributions towards it, unwillingly, came from the ground-breaking research of another scientist, Jurgenne Primavera, a leading expert in fisheries from the Philippines named 'Hero of the Environment' by *Time Magazine* in 2008.[33] Her research on the growth and survival of the world's largest species of shrimp – the giant tiger shrimp, *Penaeus monodon* – helped transform it into the most widely cultivated shrimp in the world

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[27] Duke, N. C. *et al*. (2007): A world without mangroves? Science Journal. Article. Vol. 317, pp. 41–42.

[28] Mangrove Action Project (n.d.): Mangrove Issues: Deforestation. Online resource. Retrieved 6 May 2018 from: https://mangroveactionproject.org/mangrove-issues/

[29] American Museum of Natural History (n.d.): Mangrove Threats and Solutions. Online resource. Retrieved 6 may 2018 from: https://www.amnh.org/explore/science-bulletins/bio/documentaries/mangroves-the-roots-of-the-sea/mangrove-threats-and-solutions

[30] FAO (2005-2018): Cultured Aquatic Species Information Programme. Hypophthalmichthys molitrix. Cultured Aquatic Species Information Programme. Text by Yang, N. In: *FAO Fisheries and Aquaculture Department* [online]. Rome. Retrieved 5 may 2018 from: http://www.fao.org/fishery/culturedspecies/Hypophthalmichthys_molitrix/en

[31] Fujinaga, Motosaku Hudinaga (n.d.): Kuruma Shrimp (Penaeus japonicus) Cultivation in Japan. FAO E/44: Personal account of the discovery. Retrieved 8 May 2018: http://www.fao.org/docrep/005/ac741t/AC741T15.htm

[32] FAO (2016): The State of World Fisheries and Aquaculture: Contributing to Food Security and Nutrition for All. Rome. Part 1: World Review, p. 76.

[33] Time Magazine (2008): Heroes of the environment 2008: Jurgenne Primavera. Online Article. Retrieved 6 May 2018 from: http://content.time.com/time/specials/packages/article/0,28804,1841778_1841782_1841792,00.html

for over a decade.[34] But as Primavera witnessed the industry grow beyond anyone's wildest expectations, she realized she had a tiger by the tail.[35] The industry she had helped foster bit her own country hard, wreaking havoc on its mangroves which, for centuries, had been a source of food and livelihood for millions of coastal dwellers. As a result, between 1950 and 1990, the Philippines lost an estimated two thirds to three quarters of its original mangrove forests, and more than half of that was through government-assisted conversion to aquaculture ponds.[36]

A similar trail of depletion followed in Thailand and Vietnam, and the damage from irresponsible shrimp farming did not stop in Asia. As developing counties in the Americas and Africa staked their claim in the pink-gold bonanza, the global loss of mangroves accelerated, and at the dawn of the new millennia, the latest studies revealed the true scale of the destruction: estimates suggest that the aquaculture industry had been responsible for 52 percent of the global mangrove loss, with shrimp farming alone accounting for 38 percent of the decline.[37] And so, Warne's observation appeared to be confirmed: shrimp and mangroves, mangroves and shrimp – they are indeed like a pair of orbiting stars, though one radiates brightly at the expense of the other.[38]

Shrimp farming and mangrove depletion

There is a myriad of human-induced factors that contribute to the loss of mangrove coverage worldwide. Yet all major attempts to estimate the impact of human activity on mangrove ecosystems suggest that shrimp farming alone has been, and still remains, the most detrimental of all. But how exactly, as Warne put it, did shrimp become the mangroves' nemesis?

The main source of the imbalance in the mangrove-shrimp relationship arises from a simple geographical fact: the prime location for shrimp ponds has traditionally been in the shore zone occupied by mangrove forests. The reason for that is simple: in its most basic form, as still practiced in many developing countries today, shrimp farming employs an extensive method consisting of building ponds in the upper intertidal zone, where the mangrove forests live, letting the tide fill them with water while the moon acts as a pump and the sea as a hatchery.[39] The attractiveness of this method is obvious: there are little costs involved and the returns are immediate and sizeable. But the problem is that the productivity of extensive farming is generally low. If aquafarmers want to scale up their profits, they need to either build more ponds or

[34] Ackefors, Hans (World Aquaculture Society, 2009): The evolution of a worldwide shrimp industry. World Aquaculture Journal, p. 56. Retrieved 6 May 2018: https://www.was.org/magazine/ArticleContent.aspx?Id=592

[35] Warne, Kennedy (2011): Let Them Eat Shrimp: The Tragic Disappearance of the Rainforests of the Sea. Island Press / Shearwater Books, Washington | Covelo | London. p. 31.

[36] Spalding, M., Blasco, F. and Field, C. (eds., 1997): World Mangrove Atlas. International Society for Mangrove Ecosystems. WCMC, National Council for Scientific Research. Paris. p. 61.

[37] Valiela, I., Bowen, J. L. and York, J. K. (2001): Mangrove Forests: One of the World's Threatened Major Tropical Environments. Bioscience Journal, vol. 51, n. 10, p. 812, reproducing data from Linden and Jernelov (1980), Saenger *et al.* (1983), Ong (1995), Fortes (1988), Jory (1997), and Stonich *et al.* (1999). Also, see Warne, Kennedy (2011): Let Them Eat Shrimp: The Tragic Disappearance of the Rainforests of the Sea. Island Press / Shearwater Books, Washington | Covelo | London. p. 32.

[38] Warne, Kennedy (2011): Let Them Eat Shrimp: The Tragic Disappearance of the Rainforests of the Sea. Island Press / Shearwater Books, Washington | Covelo | London. p. 29.

[39] Ibid, p. 32.

find a way to intensify the process, both of which may have adverse effects on the environment. More ponds entail more clearcutting of the forest, while more sophisticated, intensive farming methods introduce additional elements into the process, increasing the risk and gravity of incidents such as chemical pollution and soil contamination.

These elements of intensification include the practices of stocking ponds with hatchery-spawned larvae; nurturing them with high-energy fishmeal, supplements, and growth hormones; filtering, circulating, and aerating the water; and countering disease outbreaks with chemicals and antibiotics.[40] But while these additives may increase the productivity of ponds, the effect is only temporal and carries one major setback – an expiration date of 5-10 years.[41] After a long period of exploitation, without effective management, the productivity of ponds declines as the nutrients become exhausted, and the chemical residue and toxins accumulate in the water, which may filter through the soil and contaminate underground streams and reservoirs with grave consequences for the environment. Faced with this reality, aquafarmers have only two options: either to rehabilitate the pond and manage it responsibly, or to move to a new one elsewhere and continue to 'rape and run'. And since rehabilitation takes time and money, and since the shrimp industry seems to have shown little inclination to address, let alone repair, past damages[42], the second choice has generally been the preferred one. That is how pond abandonment has become a double tragedy for mangrove forests: not only are additional trees sacrificed for the construction of new ponds, but the old ones, instead of being rehabilitated for productive use, often end up as completely useless toxic dead-ends.

And there lies the bitter irony. The technology to solve these problems already exists. In fact, it is not even necessary to build the ponds within the mangrove forests anymore, as modern closed-circulation methods allow farms to be built far away from the ocean and the coastline. But while the technology is there, it is not cheap nor readily available for everyone. Most producers in developing countries do not have the access nor resources to buy the latest aquacultural equipment, nor to practice the most efficient farming techniques, and that is important because it is in developing countries where the vast majority of the world's cultivated shrimp continues to be produced. And regardless of technological breakthroughs, with mangrove land undervalued, concessions cheap, and governments supportive or compliant, many shrimp farmers still find it easier to cut and run rather than to stay and manage.[43] And the proximity to the sea, likewise, regardless of the technological advancements, continues to represent an asset: it reduces costs by allowing seawater to be pumped into non-intensive ponds from short distance away, and continues to provide a significant practical and economical advantage when it comes to transport.

This is the challenging reality which environmentalists and legislators have to face. Shrimp farming, contrary to wild-catch in open waters, is an industrial activity performed within the territory of a state. As such, it falls under the sovereignty of each individual country to regulate against or in favor of it, and regulations from one country to another differ ostensibly. Moreover, even though there are laws in place that already denounce the negative impacts of irresponsible shrimp farming, there is often a lack of political will to enforce them. And the same is true when it comes to the attempts to regulate shrimp farming internationally. For instance, the *'FAO Code of*

[40] Ibid, p. 33.

[41] Valiela, I., Bowen, J. L. & York, J. K. (2001): Mangrove Forests One of the World's Threatened Major Tropical Environments. Bioscience Journal. Vol. 51, No. 10, p. 812.

[42] Warne, Kennedy (2011): Let Them Eat Shrimp: The Tragic Disappearance of the Rainforests of the Sea. Island Press / Shearwater Books, Washington | Covelo | London. p. 34.

[43] Warne, Kennedy (2011): Let Them Eat Shrimp: The Tragic Disappearance of the Rainforests of the Sea. Island Press / Shearwater Books, Washington | Covelo | London. pp. 33-34.

Conduct for Responsible Fisheries (CCRF)' [44], adopted in 1998, the seven *'International Principles for Shrimp Farming'* [45] from 2006, and WWF's '*Standards for Responsible Shrimp Farming'* produced in 2011 as a result of its years-long *'Shrimp Aquaculture Dialogue',* have all been steps forward but they have not reached the end of the road. And the fact itself that new such documents continue to be adopted demonstrates that there is no commanding authority behind them capable of implementing their contents once and for all. In other words, international shrimp farming regulations are not binding, and in many regions, shrimp aquafarmers continue to operate as if they had a *carte blanche* in their pockets. As a result, as Marc Gunther points out, although there has been a very slow uptake, an "uphill battle" still lies ahead.[46]

And this is how the shrimp has grown to represent the mangroves' nemesis. Today, the rainforests of the sea continue to be its first and foremost victims, and as the mangroves continue to fall, less and less biodiversity and resources will remain available, and more and more people will be forced to turn to practices like aquaculture for subsistence, propagating the adverse cycle of mangrove depletion and biodiversity loss.

A way forward

One of the explanations of this grim situation, perhaps, resides in the difference of perception of those who live within the mangroves and those who live without them. The feeling towards mud, for instance. To most Westerners, it is something to be avoided. But in the mangrove communities mud is the walls of their houses, the location of their food, and the source of their income. For them mud is life, and the mangroves are their homes.

More and more people around the world are becoming conscious of that reality, and the struggle of '*los pueblos del manglar'* appears to not have been in vain. In honor of their call for justice, in 2015, the 26th of July was declared *'International Day for the Conservation of the Mangrove Ecosystems'*[47], and it has been commemorated ever since. As a result of this growing recognition, more and more people are turning from observers into activists to protect and restore these ecologically, biologically, and culturally unique environments. Heightened awareness of the importance of mangroves has led to projects ranging from small-scale mangrove replanting to large-scale efforts at replumbing the Everglades, [48] and more and more communities around the world are learning how to protect these valuable environments and use them in sustainable ways.

Today, even the shrimp aquaculture industry seems to have put some of its destructive ways behind and to be embracing sustainability and environmental stewardship in its modern approaches. [49] Major

[44] FAO (1998): Towards Sustainable Shrimp Culture Development: Implementing the FAO Code of Conduct for Responsible Fisheries (CCRF). Fisheries Department. Rome.

[45] FAO (2006): International Principles for Responsible Shrimp Farming. FAO, NACA, UNEP, WB, WWF. Rome.

[46] Gunther, Marc (2012): Shrimp Farms' Tainted Legacy Is Target of Certification Drive. Yale School of Forestry & Environmental Studies. Online resource. Retrieved 6 may 2018 from: https://e360.yale.edu/features/shrimp_farms_tainted_legacy_is_target_of_certification_drive

[47] UNESCO (2015): PROCLAMATION OF THE INTERNATIONAL DAY FOR THE CONSERVATION OF THE MANGROVE ECOSYSTEM. 38th Session of the General Conference, 38 C/66. Item 4.19 of the provisional agenda. Retrieved 5 May 2018 from: http://unesdoc.unesco.org/images/0023/002353/235350e.pdf

[48] Stevens, William K. (1994): *Everglades: Paradise Not Quite Lost. New York Times: Article. Retrieved 6 may 2018 from: https://www.nytimes.com/1994/03/22/science/everglades-paradise-not-quite-lost.html*

[49] Cheang, Michael (2010): Eco-friendly shrimp farming. Online article. Retrieved 6 May 2018 from:

efforts are being undertaken to transition away from fishmeal and towards sustainably produced feeds, and to incorporate standardization and traceability of good practices into the supply chain of shrimp production. Ultimately, this could lead to the complete shifting out of the mangrove zone and to the establishing of closed water-circulation as industrial standard, ending the use of antibiotics and hazardous chemicals, towards becoming a fully green, organic, and community and environmentally-friendly industry.

Yet while the head may be moving in the right direction, the snake drags a long tail behind it.[50] Codes of best practices have been around for twenty years, yet their adoption remains marginal and largely optional. Industry leaders may vocally condemn ditch-and-switch pond abandonment, but along the remote coastlines of less developed countries, far from the eyes of the consumer watchdogs, the practice continues. As early as 1978 it was made illegal for shrimp farms to be sited in mangroves in Ecuador, yet there they are still found today, operating despite everything. And there are many regions of the world where the situation is similar, and where mangrove wetlands continue to be degraded from a multi-use public resource, to a single-use private asset, to ultimately a ruined wasteland.

Despite the many setbacks, however, hope remains. Aquaculture may yet become an asset rather than a liability for those who dwell within the mangroves. At an appropriate scale, and with appropriate technologies, investment, and regulation, shrimp-farming can redeem itself and help pave the path towards sustainable development. Many coastal dwellers remain skeptical that this tiger can change its stripes, but some scientists, activists, and mangrove advocates, like Jurgenne Primavera, are working hard to make this happen. Having helped lay the foundations of the industrial shrimp culture, she now looks for ways to make mangrove-friendly, community-oriented aquaculture a commercial reality. Can she make it? That remains to be seen. Yet if more decide to join her efforts, and if none stand in the way, 'no' will be the unlikelier answer.

https://www.thestar.com.my/lifestyle/features/2010/03/29/ecofriendly-shrimp-farming/

[50] Warne, Kennedy (2011): Let Them Eat Shrimp: The Tragic Disappearance of the Rainforests of the Sea. Island Press / Shearwater Books, Washington | Covelo | London. p. 35.

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4. Three case studies: Bangladesh, Madagascar and Ecuador

By Alexandra Oliveira Pinto and Ana Kunh-Velásquez

Introduction

In recent years, consumers have become increasingly concerned with the impacts of their eating habits as their negative consequences, both for health as well as for the environment, have appeared in the public arena. We can mention for example the rising concern regarding meat consumption and its impacts in global warming. Despite this, other products lack the same attention.

In 1970 the phenomenon known as the "blue revolution" started, consisting in the exponential growth of aquaculture all around the world. Aquaculture can be defined as the cultivation of species in salt water, fresh water and brackish water for the purpose of direct or indirect consumption. One of its branches is shrimp farming, which has seen an increase due to growing international demand (Salgado, 2014). Nowadays, farmed shrimp represents 55% of global shrimp production, surpassing fishing (WWF, 2017), and is mostly carried out in developing countries which see it as an opportunity for economic growth.

According to Salgado (2014) the worlds' boosters of shrimp farming were the local governments in parallel with agencies like the World Bank, the Inter-American Development Bank and the International Monetary Fund. Accordingly to Greenpeace (2002) important loans were given to private firms in countries like India, China, Bangladesh, México, and Ecuador under the slogan of "a world without poverty". These institutions subsidized shrimp farming disregarding the presence and importance of mangrove ecosystems directly threatened by this activity. Indeed, shrimp farming found the mangrove ecosystems to be ideal for the development of its industry given its particular characteristics. Mangroves are a unique ecosystem that only can develop in tropical and subtropical areas of the Earth. Located in flooding lands with brackish water, mangroves are crucial nursing and feeding grounds for numerous species, making them one of the richest ecosystems along with coral reefs. This in turn provides important support for coastal livelihoods. Other services they provide are protection from natural disasters as well as carbon storage (IUCN, 2010).

In order to have a concrete understanding of the multiple impacts of shrimp farming, we decided to explore the issue through three case studies: Bangladesh, Madagascar, and Ecuador. These were selected as they illustrate different approaches taken to shrimp farming, representing -to an extent- the characteristics of their respective continents. We will start with the case of Bangladesh, presenting the multiple challenges it faces regarding both human and environmental impacts, followed by Madagascar and it´s attempt to integrate global markets. Thirdly, the Ecuadorian approach, known for its environmentally friendly practices will be detailed. The approach chosen allows us to conduct a down-to-Earth analysis, unveiling differences and similarities in the ways these three countries carry out the same activity.

Bangladesh

General context: social and environmental characteristics

Bangladesh has the world's 2nd largest delta only after the Amazon, 32% of the country's total surface consisting of coastal areas and harboring the world's biggest compact mangrove in the Sundarban forest (Afroz & Alam, 2013). These areas are important biodiversity hotspots, with over 334[51] plants species and 49 mammals documented in the Bangladeshi delta (IUCN). This rich ecosystem has proven to have the perfect conditions for cheap shrimp production, which is mostly carried out in the Cox's Bazar, Khulna, Bagerhat, and Satkhira districts, with the first two districts mentioned representing 95% of the country's total shrimp farming area (Hossain & Uddin, 2013). As a result, an ever expanding area of mangrove forest is being cleared and replaced by shrimp ponds, transforming a space where we used to find a complex ecosystem, with all of the services it provided, into one dedicated to the production of a single resource.

The gravity of the situation and the responsibility of the shrimp sector in mangrove depletion has been signaled as early as the 1980s. According to Connor, by 1988 almost 75 km2 of mangrove forests had already been cleared out in the Chakaria Sundaban area due to this activity (Afroz & Alam, 2013). And since then, it has only increased as the activity expands from East to West in the search for appropriate climate conditions and cheap labor, passing from occupying 108,280 ha in 1991 to 217,877 ha in 2008 (Hossain & Uddin, 2013). It is important to mention that shrimp farming isn't the only force driving mangrove deforestation, as agricultural practices —notably rice production— play an important role, as well as salines.

There are multiple factors explaining the impressive rise of shrimp farming, both local and international. On what concerns internal factors, besides the already mentioned appropriate environmental conditions, cheap labour and poverty also play an important role in making shrimp farming attractive both for the population and State. Given these two factors, shrimp farming positions itself as a possible income source for the local population as well as interesting for investors given its low production costs and resulting market competitiveness. This makes the industry a precious source of employment and foreign currency for the country. Numerous external factors also contributed to its development, starting with the increasing demand for shrimp in the international scene, the decline of marine catch and the role of international agencies, such as the Asia Development Bank (ADB) and the WB, giving financial and technical support to the sector.

Since its beginnings the shrimp farming industry has been motivated by exports, as opposed to national consumption, and was seen as a possibility for important economic growth. This had led to the creation of regulations supporting its expansion — through subsidies or tax rebates for example— and caught the attention of international development agencies, further supporting the sector. According to Afroz and Alam, the will to render the activity as lucrative as possible is one of the factors explaining its disorganized and unregulated growth. While there are many regulations linked to aquaculture, there is a strong lack of coordination among them weakening their application. We can mention for example the opposition between protection measures such as the 1927 Forest Act, the 1992 National Environment Policy, or the 1950 Protection and Conservation of Fish Act, to the Export Policy 1997-2002 calling for the expansion of the sector, without mentioning the conditions under which it should be carried out. Another example would be the incongruence between the 1995 National Environment Policy, stating that inland salinity shouldn't be increased, and the Shrimp Mohal

[51] « *Sonneratia griffithii* is found in India and Southeast Asia, where 80 percent of all mangrove area has been lost over the past 60 years." (IUCN, 2010)

Management Policy which points out land in which shrimp farming can take place, which in practice would lead to inland salinization. This confusion of laws is only one of the motives why they aren't respected, as it very often happens. Other factors such as corruption add up to the lack of sanctions and bending of laws in favor of the political and economic elites.

In spite of its lack of control, the government has tried to impulse regulations in the recent year in order to improve the quality of the shrimp produced, for example the Fish and Animal Food Act (2010) and the Fish Feed Rules (2011). These tackled the issue of the shrimp feed, which has largely been unregulated leading to unhealthy practices where antibiotics and chemicals are overused to compensate for the bad sanitary conditions. Indeed, one of the mains problems Bangladeshi production is facing is disease outbreaks.

Despite this maze of regulations and corruption, or maybe thanks to it, the shrimp industry has been able to expand in a considerable way.

Economic factors, social and environmental consequences

The shrimp farming industry is one of the fastest growing in the country, with an impressive increase of 32% between 2002 and 2008 (FAO, 2008), and with the share of cultured shrimp in the national shrimp production more than doubling from 1990 to 2008. This places it just behind the readymade garment sector as the second main source of export income, shrimp earning over 445 million US dollars per year (Hossain & Uddin, 2013). Its main buyers are the US —passing from 26% of Bangladesh's total exports in 2002 to 46% in 2008— followed by the UK, Belgium, Germany and Japan.

The sector is one of the major employment sources for the country, involving directly and indirectly, around 0.7 million people (Afroz & Alam, 2013).

The type of production carried out has been divided into four categories depending on its intensity: traditional, extensive, semi-intensive and intensive. The factors taken into account are inputs, production density, species diversity, seed source, water quality management and production cost. Following this criteria, it has been estimated that 70% of shrimp farms are either traditional or extensive, 25% semi-intensive and only 5% intensive (FAO, 2006). To this we must add the numerous illegally established farms, mostly found in coastal areas owned by the government and occupied by political leaders and local authorities.

The unregulated growth of the shrimp sector has had many negative outcomes, either by being the direct cause or by aggravating the existing inequalities, as some of the most affected by them have been the already dangerously weak coastal communities.

The most visible direct negative outcomes are linked to the environmental performance of the farms, starting by mangrove deforestation and all of its consequences, notably coastal changes due to erosion and sedimentation, loss of biodiversity, and overall ecological imbalance. Other factors linked to the practice are water pollution, inland salinization, and disease outbreaks due to inappropriate management and lack of regulation. Local biodiversity may also be affected by the introduction of new species with which they'll have to compete as well as the practice of collecting wild spawn as seed for the farms. This has caused a decrease in native shrimp population, with river depletion rates of 10% in the last decade (Paul & Vogl, 2011). Adding to this, the creation of the ponds disrupts the natural flow of waters and may prove detrimental to fish migration routes.

Local communities have also been directly affected by the farms. While some positive social impacts are present, such as increased income, most of it hasn't been captured by locals but by urban businessman and authorities. The reason for this is that while in theory peasants could benefit from increasing job opportunities, in practice shrimp farming has resulted in important changes in land holding patterns with the progressive exclusion of small farmers. As mangroves started to be converted into shrimp farms, these areas became attractive to investors whom either bought out small farmers or simply took their land by force. Between 1994 and 2000 the value of the land skyrocketed, increasing 18%, further excluding economically weak communities (Hossain & Uddin, 2013). The same authors state that given this situation, farmers progressively lost access to the basic resources they used to obtain from the mangroves, losing an important income and food source, as well as a way of life. Some became part of the cheap workforce employed by the shrimp farms, becoming daily labourers, while other simply became jobless, and in the most extreme cases had to leave to go find job elsewhere, very often in urban centers where they engrossed the unemployed ranks. It has been estimated that only in the Satkhira region, over 120,000 people have been displaced (Hossain & Uddin, 2013). One of the reasons why the farming industries weren't able to provide enough jobs for the communities is that the activity is less labour intensive than rice cultivation, an activity that not only granted people job but also food (Islam, 2008). But even for those who did find jobs in the farms, many human rights abuses have been documented to happen there, notably against women. In the SSNC 2011 short documentary, we can hear many testimonies of women whom have been raped or suffered other physical abuses in the shrimp farms, commonly by the owners or other powerful figures.

Other threats to the physical security and health of local people are linked to the contaminating practices of the farms and salinization, which negatively affects freshwater supplies both for irrigation, animal raising and direct human consumption, and has provoked a rise in gastrointestinal infections (Ali, 2006). Furthermore, this directly endangers food security, as traditional food sources disappear and marginalized populations grow increasingly poor. One of the reasons for this is found in the underlying motivations behind shrimp farming which isn't to increase food security but economic growth, and given the complicated state in which Bangladeshi politics find themselves, this additional income often doesn't arrive to those whom need it the most.

Environmental Laws and Certifications

As we've seen until now, Bangladesh presents important problems concerning the sustainability of its shrimp farming. However, there has been a smooth increase on the preoccupations on the way this production is carried out. Mostly in the Southern part of the country, organic shrimp aquaculture has started to develop. The Swiss Import Promotion Program started in 2005 the Organic Shrimp Project (OSP) (Paul & Vogl, 2011) and quickly some German organizations followed the wave. OSP farms are certified by a private association of German organic famers: Naturland. To have this certification OSP organic farms must be inspected by the Institute of Market Ecology (Paul & Vogl, 2011). Despite the increasing consumer awareness, the extent of the concept of organic shrimp aquaculture remains small, touching only a few thousand farmers in Bangladesh.

There are several suggestions to the improvement of sustainability of the shrimp farms and big exporter countries, like Ecuador, are already putting them into place. However, to transform shrimp farming in Bangladesh into a sustainable sector, the changes have to come from above. Firstly, the government should not be tempted to corruption and produce tougher laws concerning environmental and human rights and regulating the management practices of shrimp farming. Then, NGOs should become more active in this field and denounce to consumers the reality behind the cheap shrimp they are eating. Additionally, Afroz & Alam (2013) recall the need to put in place an Integrated Coastal Zone Management as a way to offer a holist approach to respond to the impacts of this sector on the ecosystems.

Madagascar

General context: social and environmental characteristics

Madagascar is located in the Indian Ocean, and is known to harbor 5% of the world's biodiversity, 80% of it being endemic to the island. Among its ecosystems, mangrove forests cover 25% of the country's 4,000 km2 coastline, representing in 2005 over 2,797 km2 (Giri & Muhlhausen, 2008). These are mostly found in the western coast where the climate conditions are more favorable, notably in Mahajamba Bay, Bombekota Bay, Cap St Vincent, and Mahavavy. The East side on the other hand is characterized by stronger storms and less freshwater availability.

The country is known for its high poverty levels: over 70% of its population in 2012 according to the WB (2017). On the other hand, its demographic growth is of about 3% per year, and problems such as malnutrition and insufficient health and education centers are still current. Adding to this, given that most of the country's economy depends on the primary sector current deforestation and soil degradation puts it in a fragile position. It has been estimated that between 1950 and 2000 forest coverage decreased by 40% (Harper, 2002). Mangrove forests are also facing degradation, even though their deforestation rate is slower than world trends. The causes responsible for more than half of its deforestation are: agriculture representing 35%, logging 16%, aquaculture 3%, and urban development 1% (Giri & Mahlhausen, 2008).

The systemic poverty problems have impulsed the search for economically promising activities with aquaculture positioning itself as an interesting opportunity given the availability of resources and the growing world market. Shrimp fishing has only been found to be carried out traditionally in the Toliara region, most traditional activities being either agricultural or pastoral. It is only in the 1960s that aquaculture starts to develop as an answer to increasing poverty and the will to profit of this unexploited resource. Indeed, Madagascar has ideal environmental conditions for shrimp farming: the natural presence of *Penaeus monodon* shrimp (which is considered as one of the most performing species) and suitable habitats for its industrial farming, notably in the western side if the island, between the Saint-André cap and the Saint-Sébastien cap, where ample mangrove forests are located (Chaboud et al., 2002).

The first shrimp farming projects are relatively recent, appearing in the 90s after the success of the « Pilot Shrimp Farm » project conducted in Cratère de Nosy Be financed by the PNUD/FAO. The production started in 1994 with the Malagasy AQUALMA farm in Mahajamba producing 406 tons of shrimp, leading the way for other farms (GAPCM, 2018). In order to further enable local operators to access this market, in 1998 and with the support of the Japanese government, the Center for the Development of Shrimp Culture was created in Mahajanga. It had as a mission to train and give technical support to small scale shrimp producers. But due to lack of funding and the low quality of the shrimp produced, the associations created under this initiative dissolved shortly after their creation. This was also the fate of the short-lived «Groupement des Aquaculteurs Artisanaux de Madagascar» created in 2002. Nowadays, it is mostly semi-intensive farms which subsist.

Between 1999 and 2001 the government started the «Malagasy Shrimp Aquaculture Planning Scheme» under the EU's support, which led to the implementation of the Law n° 2001-020 concerning sustainable shrimp farming practices. This legislation forces the companies to carry out environmental impact studies and promote reforestation practices (GAPCM, 2018).

Economic factors

In recent years, the shrimp farming industry passed from its initial 406 tons to over 7,000 in 2003 (FAO). One of the main drivers behind shrimp farming is the rising demand for this product in the European and Japanese markets, largely responsible for fixing shrimp market prices. Another aspect worth mentioning is the development of infrastructure, notably collecting networks.

The impulsion of these shrimp farms has had considerable effects for the mangrove forests in which they are located, we can mention, for example, the conversion of 600 hectares in the Baly Bay since 1998, as well as in other coastal areas for instance Mahamba Bay. Furthermore, the areas in which shrimp farming takes place are those in which the mangrove are denser and biodiverse, as these present the most favourable conditions. This increases the negative impacts of the practice, not only due to direct deforestation but also coastal sedimentation. Despite legislation promoting sustainable practices, given the availability of adequate land for this activity we can expect it to increase considerably. It has been estimated that: « For shrimp/prawn culture, only 4,928 ha (41.7%) of a total available area of 11,938 ha is being used » (FAO). Other studies such as the 2004 Report on Aquaculture Shrimp Farming carried out by the MAEP UPDR, estimated that approximatively 30,000 ha are still available for shrimp farming.

While Madagascar does not position itself as one of the main world shrimp exporters, it has an important role at the regional scale, placing itself before Nigeria and Mozambique, and distinguished itself by the rapid initial growth of its industry. Indeed, since the 90s shrimp is one of the country's main exports alongside raw nickel, vanilla and clove, crustaceans representing 3.5% of the country's exports (OEC, 2018). This makes shrimp an important source of foreign currency —particularly important for the country, under structural adjustment since the 80s. This made it an important source of revenue not only for the State but for the local population, either directly employed in the sector or benefitting from indirect effects linked to shrimp farming, we can mention for instance the legal requirement of the companies to provide certain social services in the villages close to their farms (GAPCM, 2018). The main destinations of the Malagasy shrimp are Europe (70%) and Japan (30%), representing in 2004 7 million shrimp, the equivalent of 62 million US dollars and represents 5,2% of the country's PIB (MAEP UPDR Ocean Consultant, 2004).

On what concerns the general farming characteristics, they are summarised by the FAO (2018) as:

> *"Marine aquaculture is dominated by giant tiger prawn farming behind the mangrove areas on the north-west coast which were previously identified by the Madagascar Shrimp Aquaculture Development Master Plan. These are comprehensive production systems composed of breeding ponds, a hatchery, a processing and packaging factory and storage facilities, as well as facilities for the company staff. All the aquaculture feed is imported, even though trials have been conducted using local feed, but these have not been conclusive."*

Most of the farming is done following the same methods which have been found to have the best results given the Malagasy environment, meaning a semi-intensive model working with pumping and without aeration, mostly raising the *Penaeus monodon* specie.

Despite the rapid growth of the sector during the decade of its appearance, in 2008 the production started to decrease mostly due to external factors such as international competition as well as the rise of the petroleum prices. The situation worsened in 2012 when the World Organization for Animal Health confirmed that Malagasy shrimp farms had been infected by the White Spot Syndrome Virus. The first case was detected in May in the AQUAMEN

FILIERE AQUACOLE	2001	2002	2003	2004
Captures (en tonnes eqc*)	5 195	5 916	6 800	6 176
Chiffres d'affaires crevettes (en millions d'Ar)	55.913	71.458	77.947	104.612

Source : Observatoire Economique de la Pêche et de l'Aquaculture de Madagascar, 2015 farm, and by September of the same year three other farms were infected. Following this episode, only three societies were able to keep their operations (GAPCM, 2018).

Environmental laws and certification

At the time when shrimp farming started to develop in Madagascar, the first attempts to limit the negative effects of overfishing and promote more responsible practices emerged, notably following Rio 1992 (Chaboud, Courtois, & Feltz, 2002). Despite its limited resources, Madagascar tried to follow this path, rapidly regulating shrimp farming. Nowadays, companies are required to monitor their production by analyzing water quality before and after their farms, respect sanitary norms, carry out mangrove reforestation programs, and respond to the National Office for the Environment. Adding to this, they are required to consult the local population and actively participate in the development of the area, for example by fulfill social measures such as building schools and health centers as well as roads, water points and markets.

Besides the national government, international organisms such as the AFD and WWF have participated in trying to promote environmentally friendly practices. We can mention for example the creation of the first document relative to eco-certification of shrimp farms in Madagascar or the participation of Malagasy shrimp farmers to the 2008 Shrimp Aquaculture Dialogue, both with the support of the WWF and the AFD. On what concerns certification, Malagasy farmers have tried to obtain « bio » labels in order to comply with market exigencies and become more competitive: for example the Ikizuki Japanese label or the Bio label of the LGA/OSO society.

Overview and conclusions

Madagascar's case illustrates the difficulties as well as the opportunities linked with shrimp farming for a developing country. Despite the fact that shrimp isn't a significant part of the traditional culture, they have come to play an important role in the country's economy, representing a significant part of its exports. The sector has faced numerous drawbacks, both linked with the country's overall economy as well as to diseases.

Nonetheless, the shrimp production is expected to rise, which would increase mangrove deforestation rates. So far, Madagascar's mangroves haven't disappeared as quickly as in other regions, mostly due to the fact that the shrimp farming hasn't been as intense. But this situation could change, especially if regulations aren't effectively implemented.

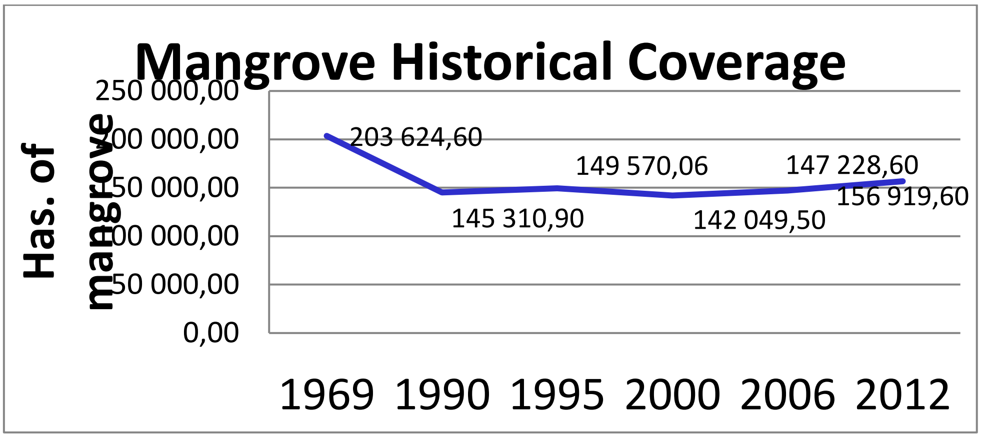
General context: social and environmental characteristics

Ceviche is an iconic Ecuadorian dish known around the world and millions of people eat it every day. It's possible to cook it with different ingredients but shrimp is the most coveted one. Ecuador is the second producer of shrimp in the world and this crustacean represents more than 3% of the countries' GDP (CNA, 2018). 60% of America's shrimp production comes from Ecuador, who exports to more than 50 countries around the world (CNA, Más de 900 millones de camarón ecuatoriano se exportaron en el 2017, 2018).

According to Andersen (2014), South America contains 15.7% of the world's mangroves, from which 157 094, 28 ha are in Ecuador and from those 73 071ha are protected (MAE & FAO, Árboles y Arbustos de los Manglares del Ecuador, 2014). Ecuadorian mangroves are goods belonging to the State and they are out of the market (García, 2015). However, in previous years, despite the 1974 law interdicting the deforestation of mangrove, there has been a decrease on the area of mangrove; and for Andersen (2014), "a significant portion of the mangrove deforestation that has occurred in Ecuador can be directly attributed to shrimp aquaculture development". Since the 80's around 80.000 ha of mangrove have been deforested due to different drivers, being the construction of pools for shrimp farming the main one. The mangrove loss is also related to its wood exploitation, coal production and the use of its bark as a source of tannins for the tannery industry (Gaibor, 2014).

The impacts on such a biodiversity are inegable as we are depleting an habitat of 52 species of birds, 15 of reptiles, 14 of shrimp, 3 of crabs, 79 of moluscs and 100 of fishes (Bravo, 2003). Accordingly to the Instituto Geográfico Militar Ecuatoriano, the country once had 362.862ha of mangrove. Since 1940 the mangrove area is used for housing, crops, cattle raising and uncrontroled shrimp farming, which lead to a mangrove depletion of 27,7% (a decrease of 56.395,9 ha) between 1969 and 2006 (MAE & FAO, Árboles y Arbustos de los Manglares del Ecuador, 2014). Shrimp farming is considered as the main cause for this depletion, authors as Bravo (2010) blame the unsustainble and unregulated expantion of these sites, for which no studies took place to analyse the consequences of such activity. In addition to the environmental impacts, within the social one's we can observe a decrese on quality of life and emigration of ancestral mangrove users (MAE & FAO, Árboles y Arbustos de los Manglares del Ecuador, 2014).

Between 1981 and 1995, a package of laws was decreted to declare mangroves as the State proprety. In 1997, the Instituto Ecuatoriano Forestal de Áreas Naturales y Vida Silvestre informed that around 70% of shrimp farming was illegal. This led to the promulgation of the Executive Decrete nº1102 in 1999 and the Miniterial Agreement 172 in 2000 creating agreements for the sustainable use of mangrove in favor of communities and ancestral users and determining technical requirements and the administrative procedures for the creation of this "concessions". Thus, in 2008 an Ejecutive Decrete (1391) (*Expedición del DE 1391 de 15 de octubre de 2008, RO. No 454 de 27 de octubre de 2008 referente a la Regulación de Camaroneras*) was published, reforming the Fishing Law and regularizating all fishing farms built before 1999, if they compensate by reforesting the quantities of mangrove determined by the Ministry of Environment (MAE). Acording to their data, 559 new farms were recorded after this law passed. Now, for each hectare depleted, theres' a fine of USD 89 273,01. The President of the National Aquaculture Chamber (CNA) in 2016 stated that 3 000 ha were reforested by shrimp farmers since 2009 (Sorgato, 2016). Moreover, according to MAE (2017), 1 556,90 ha of mangrove have been reforestated after the recuperation of shrimp farm consessions. This data can be illustrate by the graphic below from the Ministry of Environment (2015).

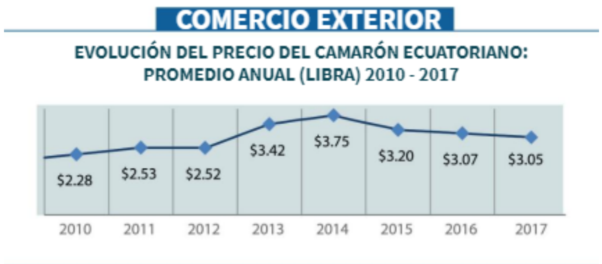


Source: (García, 2015)

Shrimp production is dominated mainly by cultivation of the whiteleg shrimp, but also by the blue shrimp (FAO, 2017). However, artisanal fishing methods are used by Ecuadorians in the Coast Region, ancestral users go fishing crabs, shells and shrimp on the mangroves. According to the FAO, todays' Ecuador shrimp production has mainly low environmental impacts (semi-intensive) and is undertaken by small and large producers. According to Machado (2013) citing the Subsecretariat of Aquaculture, 263 000 ha of the country's cost is occupied by shrimp farms. This is why is complicated to recuperate the spaces of mangrove and do the reforestation expected as there is no space to do it (García, 2015).

Economic factors

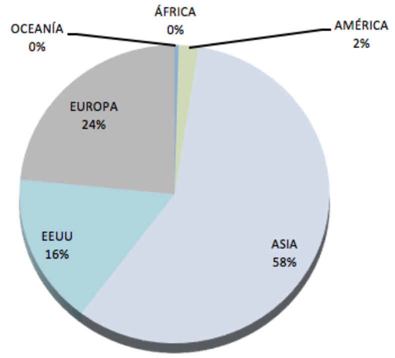
According to the FAO (2006?) report "until 1998 (the last period for which statistics on the subject area available), the Under-Ministry of Fisheries Resources registered 2 006 shrimp industries, 312 larvae hatcheries, 21 feed manufacturing plants and 76 processing plants". Shrimp farming emerged in Ecuador at the end of the 60's, at first on salines and crop lands but rapidly expanded to mangrove areas due to the increasing and important profits made on this field. (Salgado, 2014). The decade between 1984 and 1995 is considered the country's boom on the shrimp industry, doubling its hectares of production and saw an exponential increase on the foreign direct investments. This growth of 600% positioned Ecuador on the world top of shrimp exporters (Machado, 2013). However, during the 90's there was a big decrease in production due to the white spot syndrome virus and they were only able to recover in 2006. The 2013 decrease on Thailand's exports created an opportunity for the industry in Ecuador who benefited from an increase in the shrimp' market price and, due to the multiplier effect, it made the sector grow (as we can see on the graph "Evolution of the Ecuadorian shrimp price per year").



Source: CNA, 2018

In Ecuador, shrimp farming generates, direct and indirectly, more or less 200 000 jobs whereas mangroves have been estimated to have a value of USD 89 273, 01 per hectare (MAE, 2017). There's been an exponential increase since the 80's on crustaceans' production, and those represent 95% of the aquaculture production (FAO, 2006?). Crustaceans are the group who brings more revenues on aquaculture exportations, since its very beginning. If the banana had the leadership on Ecuador's exportations for 40 years, the shrimp industry just broke this tendency in 2017 (Mendoza, 2018). There's been a boost on the exportations mainly due to Asian markets that represented 58% of Ecuador's shrimp exportations as we can see on this graphic.

Exportaciones de Camarón Ecuatoriano: % por mercado (Libras / ene-dic 2017)



Source: CNA, 2018

Since 2017, shrimp became the non-oil product more exported, according to the Ecuador's' Central Bank, representing a revenue of USD 3 038 millions (Mendoza, 2018) corresponding to 426 thousand tons (CNA, Más de 900 millones de camarón ecuatoriano se exportaron en el 2017, 2018). This boom in exportations causes a boom in production: Ecuador's shrimp industry growth for next year is expected to be around 6 to 8%, according to the president of CNA, José Antonio Camposano, against the growth of countries such as India or Vietnam with an increase of 18 or 30%. Camposano argues that any growth rate above 10% can't be sustainable and Ecuador's main goal is to increase efficiency and not the area exploited. The manager of a shrimp farm (Aquatropical) from Santa Elena Álex El Ghoul recalls the importance of the progresses made on the past years: now within 100 days the shrimp can grow until 20 to 25 grams against the 12 grams obtained before. In addition, the average survival went from 40-60% 10 years ago to 60-80% today (Mendoza, 2018). This is reflected in numbers, both in the weight of the exportations and its' revenues. Camposano, cited by Machado (2013) mentions that the productivity per hectare in Ecuador in 1998 was about 545 kg of shrimp and thanks to the investment of labs investigation in 2013 is was about 1090 kg for the same hectare.

Certifications, environmental and social impacts

In 2014, the Ministry of Environment created the *Socio Manglar* (*Acuerdo Ministerial No 198 de 9 de julio de 2014*) as part of the National Program of Incentives *Socio Bosque* to the sustainable use and conservation of the natural heritage. The goal of *Socio Manglar* is to promote mangrove protection through direct economic incentive to the organizations and associations who signed, with the Ministry of Environment, the agreements of sustainable use and mangrove custody ("mangrove concessions") (Gaibor, 2014). Thanks to the *Socio Manglar*, the artisanal fishing associations and of collectors of crabs and shells are voluntarily engaged to conserve the mangrove forests against an economic retribution. The incentive is given by the Ministry of Environment and depends on the size of the conserved Surface. It allows enhancing the local organizations to the implementation of the management plans of the concessioned areas, which includes control and surveillance activities, environmental education, reforestation and sustainable use of biological mangrove resources (García, 2015). This program empowers the artisanal fishers against the exploitation of the areas by shrimp farmers and gives an alternative to the shrimp consumption at a local level, being substituted by crabs or shells, as well for the consumers but also for the sellers.

Concerning certifications and labeling, Ecuador is considered an example to the world. Since 2016, Ecuador has the leadership of sustainable aquaculture with the Sustainable Shrimp Partnership (SSP). They constantly recall the importance of the absence of antibiotics on shrimp production and more generally they want to comply with the highest standards, producing a "healthy, nutritious and pure [shrimp] cultivated in a sustainable manner" to respond to the demand of consumers each day more concern by this facts (CNA, 2018). They promote better practices hoping the other producers will follow the example of excellency. Rodrigo Laniado, the founder of SSP, explained this March in Boston, that they've [learned a few years ago that the environment is the shrimp' best friend and today we are producing more shrimp and we are more and more sustainable] (CNA, 2018).

Nevertheless, Ecuador shrimp farmers seem to have some problems lately. They are frequently accused of closing access to mangrove with electrified fences, making it impossible for artisanal fishers who go after crabs, shells and mollusks to realize their activities safely. Several people died electrocuted by these fences, and most of the time those people are accused for been trying to steal from the farms. This happened in 2011 to the father of Jorge Luís Jara Abril, an artisanal fisherman from the province of El Oro, who died at 49 years-old while recollecting crabs on the mangrove near to a private property dedicated to shrimp farming. Other murders took place either by shooting or dogs attacks. In addition to this, some survivors went claiming to the authorities who neglected the cases (Machado, 2013). Moreover, innumerous families who lived from decades in these areas, have been displaced with no previous agreement. Organizations like Ccondem (Corporación Coordinadora Nacional para la Defensa del Ecosistema Manglar) argue that this kind of mangrove exploitation goes against the Ramsar Convention, signed by Ecuador. They argue that the increasing violence around this subject is due to the fact that shrimp farm owners considered themselves as owners of the area and don't look at it as a concession by the government (because mangrove is considered a public good by law in Ecuador) (C-CONDEM, 2013).

From the shrimp farmers point of view, the concern is other. They complain about the increase in organized delinquency and the necessity to invest huge amounts dedicated to the security of their workers, merchandises and goods in general. According to Mendonza (2018) in 2017 USD 60 million were invested in security. Only this year already one person was killed by organized groups who steal the shrimp to sell illegally (CNA, 2018).

In a personal experience visiting a shrimp farm in Salinas in August 2016, it was possible to observe the different procedures and stages of shrimp production. It seemed to follow all the rules required by the national government and international institutions and complied with all certifications. The manager explained to us that they want to produce a high quality product to attain sustainable luxury markets and that to achieve this they needed to comply with all the sanitary requirements as well as the environmental and social norms.

Pictures taken in 2016 in the Salinas shrimp farm (Ecuador). Here we can see shrimp at an earlier stage of development.

Conclusion

The situations faced in Bangladesh, Madagascar and Ecuador illustrate how a single industry impulsed by the same drivers can have such different outcomes. Indeed, our research leads us to the conclusion that for the three countries it isn't national consumption but the increasing international demand that is behind the rise of shrimp production. One of the outcomes of this approach is that, rather than reducing social problems, the industry seems to exacerbate inequalities. Marginalized and local farmers are among the most negatively affected, both from environmental and social repercussions, for instance in terms of access to land and resources.

Unfortunately, despite the warnings of different organizations to protect mangroves, those seem to be more and more attacked by the consumption's vicious circle. This makes mangroves, which are known to be one of the most resistant ecosystems to natural events, one of the most vulnerable habitats due human exploitation. This is why strong regulation and its proper application is required not only to protect mangroves as an iconic habitat but also to ensure that shrimp farming practices are sustainable and respond to the high environmental and social criteria. Notably, due to the fact that mangroves ecosystems aren't only threatened by deforestation, but also by the consequences of unregulated shrimp farming, for example pollution. To reduce these negative impacts, there's an urgent need for research dealing with the impacts of this practices on the ecosystems, but also research to diminish the negative consequences of this sector. Research and different policies are though directly linked to another of our conclusions: the three countries had to face the same disease (white spot syndrome virus) but had different results on production levels.

After some readings and a small field research analysing consumer behaviours, we've arrived to the conclusion that there's an urgent need to increase awareness. Most consumers, located away from the origin of the product, totally ignore the supply chain. Besides not knowing the conditions in which shrimp farming takes place, the majority doesn't know what mangrove is nor its value. Even though difference in prices and labeling reflect disparities on the way shrimp was produced, providing consumers the possibility of choosing between cheaper products or ones produced under higher standards, this isn't enough to decrease pressure on mangrove ecosystems. Importer governments need to take stronger actions and acknowledge their part of responsibility in driving demand. One of the leviers we could think of, is highlighting the imported mangrove deforestation linked to shrimp consumption as well as strengthening their importation standards.

Finally, we can ask ourselves if an easier solution wouldn't be to reduce tropical shrimp consumption? In order to answer this question, further research is needed to analyze possible diversification pathways for the exporting countries.

5. Products and markets related to mangrove-depleting shrimp farming

By Luisa El Berr

"In America and Europe, it was a slow, barely noticeable change. In the 1950s a fancy meal might start with shrimp cocktail, four or five shrimp arranged around the rim of a cocktail glass filled with sauce. It was country club food, it cost more than steak, and you turned up your pinkie as you ate it and got to think of yourself as sophisticated in the bargain. Unless you happened to be near the Gulf of Mexico, those fresh little shrimp would have been rushed over a long distance at enormous cost. Adjusted for inflation, those five little shrimp around a cocktail glass in 1950 cost over a dollar each. Today three dollars will buy you a whole pound of shrimp brought all the way from Bangladesh to your refrigerator"- (Bales, 2016).

Introduction

The first documented reference to mangroves was written by Admiral Nearchus, an admiral of Alexander the Great who travelled "along the coast, through the Persian Gulf, to the Euphrates from 326 to 324 BC." Later, Greek philosopher Theophrastus transformed Admiral Nearchus' reports into his extensive botanical writings. Theophrastus portrays that the trees are "'held up by their roots like a polyp'; the leaves and flowers were clearly *Rhizophora* [52] ; while he also discussed the mangrove habitat with its complex creeks (Macnae, 1969 quoted from Spalding, Kainuma, & Collins, 2010, p.23). Humans have settled around mangrove coastal lines for a very long time: "timber and fisheries benefits from the mangroves are probably as old as the history of human settlement in mangrove areas; but as societies became more structured, so larger-scale and industrial uses of mangroves spread" (Spalding et al., 2010).

Since then, the economic interest in mangroves has increased immensely, especially in the last decades this development has led to conversion, destruction and pollution of these "highly productive forests built by a small group of trees and shrubs that have adapted to survive in the harsh interface between land and sea" (Spalding et al., 2010, p.xv). The clearing of mangroves for shrimp[53] production is one of the main drivers for the loss of mangroves. Mangroves are vital for fisheries worldwide, since some species demand on mangroves for their reproduction.[54] Mangroves are as well necessary as a natural buffer against storms and its loss is mostly effecting coastal communities, and "salt flats, mudflats, estuaries, tidal basins and coastal marshes can also be affected by shrimp farming" (World Wildlife Fund, 2018).

This paper will give and overview about products and markets related to Mangrove-Depleting Shrimp (MDS) in order to map their relative importance in the shrimp world and regional markets. This paper's concentration lays on MDS markets and products and not on solutions. It will, however, give a short introduction on effects and problems related to MDS. After this introduction, this chapter will give some basic definitions in Section (2.1.) and will then present a short history of shrimp farming in the

[52] *Rhizophora* is a genus (means: below a family and above a species) of a Mangrove tree (See Leechman, 1918).

[53] Shrimp means all type? of shrimp and prawn (Leung & Engle, 2008).

[54] Mangroves are essential areas for "hunting, nesting, breeding and migratory homes to millions of coastal inhabitants, including fish, invertebrates, and migratory birds" (World Wildlife Fund, 2018).

background section (2.2.). In Section (3), this paper focusses on products and in Section (4) on regional markets of MDS.

In section (5), This paper will conclude that the most harmful shrimp farming to Mangrove forests are producing two types of Warm-water shrimp: *Paneaus vannamei* (Pacific white shrimp) and *Paneaus monodon* (giant tiger prawn) that are produced in Asia and Latin America (World Wildlife Fund, 2018). Shrimp is one of the favourite seafood and is consumed all over world while the largest markets are the United States of America (USA), Japan and European Union (EU) (Leung & Engle, 2008, p.3).

Background: What are Mangrove–Depleting Shrimp (MDS)?

History & Techniques of Shrimp Farming

Mangrove-Depleting Shrimp (MDS) farming has increased since the beginning of the 'Belize Aquaculture Limited concept' that was initially developed to hinder the aggressive virus that occurred in the 1990's from spreading even further. Sir Barry Bowen was one of the most famous shrimp famers and owned Belize Aquaculture, Ltd., a shrimp farm in Belize, Central America. Together with Robins McInosh, Vice President at Charoen Pokphand Foods Public Co., Ltd., who ran Belize Aquaculture, Ltd, for five years, Bowen developed a new way of shrimp farming in 1997, when Belize Aquaculture began its commercial operations.

When in 1990 the Taura virus[55] lead to the failing of countless shrimp farms, Bowen began to investigate shrimp farming and started to re-think the way shrimp farming was done on a commercial level and he developed the so called 'Belize Aquaculture Limited concept' (Shrimp News International, n.d.). The now more effective and efficient intensive shrimp farming has been causing the loss of mangroves worldwide, since it decreased production costs while there was a booming demand for shrimp leading more and more shrimp farms (Primavera, 1998) (See Figure 3).

[55] Taura Syndrome (TS) of peneid shrimp (a family of shrimp) was described in Penaeus vannamei (type of shrimp, also known as Whiteleg shrimp or King Prawn) harvested from shrimp farms near the Taura River in Ecuador (Liu, 2016, p.17).

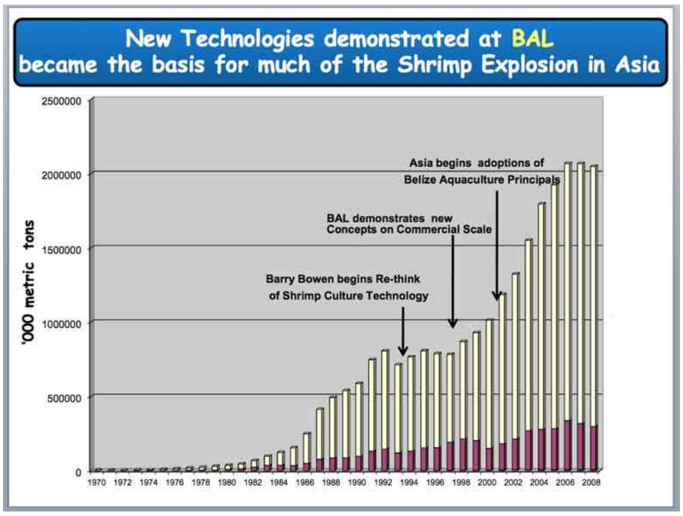


Figure 1 New Technologies of Shrimp Farming[56]

Findings:
Products and Markets of mangrove-depleting shrimp

Since the demand for cheap fish and shrimp increased, there was a "gold rush" in Bangladesh, Southern India, Indonesia, Thailand, Burma, and Sri Lanka (Food and Agriculture Organization of the United Nations, 2018). According to Spalding et al. (2010, p.33), overfishing in general

"is a problem in many areas, both locally within mangroves, but also in some offshore fisheries that depend on mangroves. The combined annual captures of wild-caught penaeid shrimp from all countries with mangroves showed a peak in captures during the early 1980s, with a gradual decline since then: the 2006 catch was some 30 per cent lower than that of 1980. Although it is not possible to disaggregate the mangrove independent shrimps from these statistics, these are a minority, so it is reasonable to assume that this may indicate growing over-exploitation."

It is striking that "shrimp is the most valuable traded marine product in the world today." With an estimated value of 10.6 billion USD in 2005, the farmed shrimp industry has experienced a "growing production (and) an approximate rate of 10 percent annually—one of the highest growth rates in aquaculture" (World Wildlife Fund, 2018). Shrimp is one of the favourite seafood and is consumed all over world while the largest markets are the United States of America (USA), Japan and European Union (EU) (Leung & Engle, 2008, p.3).

Supply: The Shrimp as a Product

It is important to understand the different types of growing techniques used to farm shrimp in order to get an overview, where the main regional markets are. The increasing international value of shrimp in the market have led to massive clearance of mangroves and "many such ventures have suffered disease and pollution, or from market volatility. Unfortunately, the rich provisioning services of the original mangrove cover are also lost in the conversion" (Spalding et al., 2010).

56 Shrimp News International (2018).

There are two broad types of shrimp:

(1) **Cold-water shrimp** that comes from fisheries in the Northern Hemisphere (small-sized and not farmed).[57] The Cold-Water shrimp is captured in Greenland, Canada, Iceland, Norway and he USA (Leung & Engle, 2008, p.5).

(2) The **Warm-water shrimp** (captured and aquaculture) has experienced a high increase in supply since the aquaculture of shrimp has been booming. The main Warm-water shrimp are Black Tiger (*Panaeus Monodon*) and White Shrimp (*Panaeus Vannami).* Black tigers are farmed and produced in Thailand, Vietnam, Indonesia and India and White Shrimp are produced in China Thailand, Brazil, Ecuador Mexico, and Vietnam. It is evident that "especially Asian countries such as China and Vietnam, have increased their farmed Shrimp production in recent years, but also Brazil has boosted its output (Leung & Engle, 2008, p.4).

This means the market for Warm-water shrimp, where shrimp is gown in tropical coastal lines, is the shrimp market that cause the decline of mangroves, since the regional markets for Warm-water shrimp need mangroves for their farming.

[57] The most important Cold-water species is the Northern prawn or pink shrimp (*Pandalus borealis)* (446,000 tonnes), Northern white shrimp (57,000 tonnes) and Common Shrimp (Crangon crangon) (37,000 tonnes); numbers for 2004 *(Leung & Engle, 2008).*

The life of a *Penaeus Vannamei* until Harvest

This section will give a deeper insight in the market for White-leg shrimp, since it is has the most relative importance for markets that produce MDS. Almost 80 % of the farmed shrimp are just two species: *Paneaus vannamei* (Pacific white shrimp) and *Paneaus monodon* (giant tiger prawn) (World Wildlife Fund, 2018). Leung & Engle (2008, p.4) point out that" of total aquaculture production of 2.5. million tonnes, 722,000 tonnes were Black Tiger and 1, 386,000 tonnes were White Shrimp." As one of the most important species of shrimp that are farmed commercially, the *Penaeus Vannamei's* production has increased immensely (See Figure 4).

The so called 'whiteleg shrimp' can be found in the "Eastern Pacific coast from Sonora, Mexico in the North, through Central and South America as far South as Tumbes in Peru, in areas where water temperatures are normally >20 °C throughout the year" (Food and Agriculture Organization of the United Nations, 2018) and it is mainly farmed in China, Thailand, Brazil, Ecuador Mexico, and Vietnam, since "in tropical climate where most farmed shrimp are produces, it takes approx. three to six months to raise a market-sizes shrimp" (World Wildlife Fund, 2018).[58]

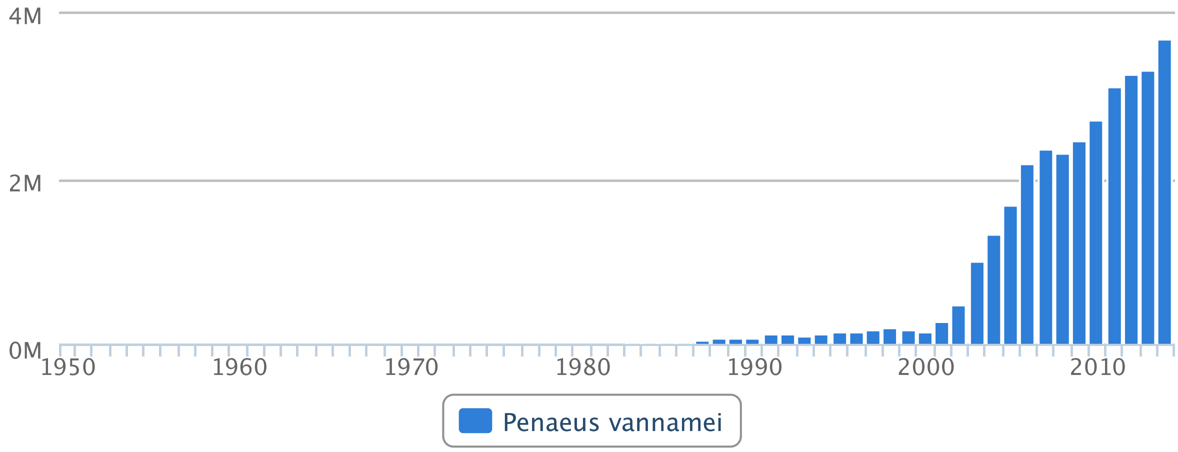


Figure 2 Global Aquaculture Production for Species (Tonnes)[59]

There are three sources for broodstock *P. vannamei* (Food and Agriculture Organization of the United Nations, 2018):

Where they occur naturally, broodstock are sea-caught (usually at 1 year of age and weighing >40 g) and spawned.

Cultured shrimp harvested from ponds (after 4–5 months at 15–25 g), are on-grown for 2–3 months and then transferred to maturation facilities at >7 months of age when they weigh 30–35 g.

Purchased from tank-reared SPF/SPR broodstock from the United States of America, (at 7–8 months of age and weighing 30–40 g).

[58]The FAO point out that "Production costs vary depending on many factors. Operational costs for seed production averages USD 0.5–1.0/1 000 PL, whilst sales prices vary from USD 0.4/1 000 PL8–10 in China and USD 1.0–1.2/1 000 PL12 in Ecuador to USD 1.5 3.0/1 000 PL12 around Asia. Lower feed costs and higher intensity levels result in mean production costs for growing of approximately USD 2.5–3.0/kg for *P. vannamei*, compared to USD 3.0–4.0/kg for more extensive *P. monodon* culture" (Food and Agriculture Organization of the United Nations, 2018).

[59] Food and Agriculture Organization of the United Nations (2018).

Figure 5 shows the life of a *P. vannamei.* The Post-larvae lives inshore to spend their lives until they are full-grown. This time is spent in coastal estuaries, lagoons or mangrove areas and "males become mature from 20 g and females from 28 g onwards at the age of 6–7 months" (Food and Agriculture Organization of the United Nations, 2018).

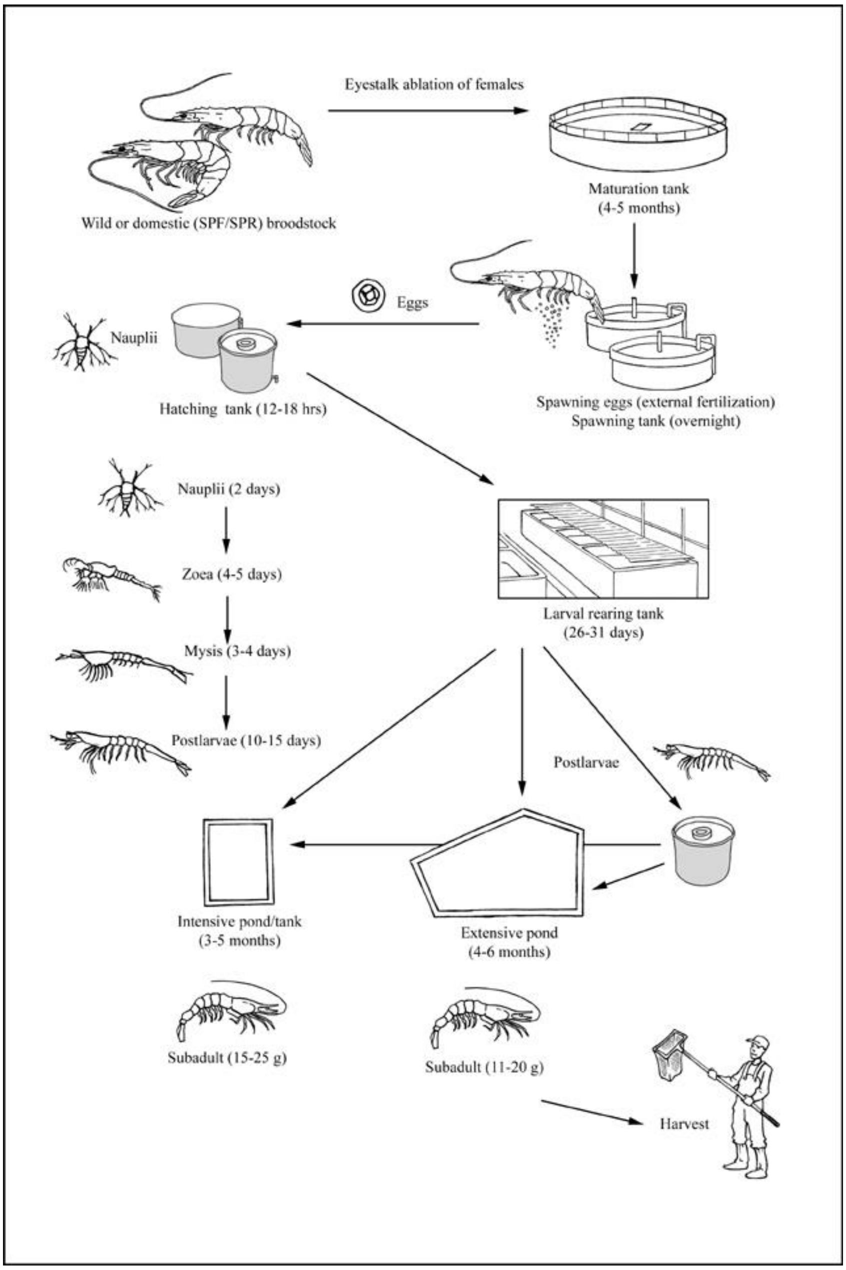


Figure 3 The life of a White-Leg Shrimp[60]

[60] Food and Agriculture Organization of the United Nations, (2018).

There are four techniques (See Table 1) of shrimp growing that can be sub-divided in: Extensive, Semi-extensive, Intensive and Super-Intensive (for a more detailed overview, see Appendix I). These techniques are specific to regional markets.

Table 1: The Four Main Shrimp Growing Techniques by Region[61]

Type	Technique	Region
Extensive	Extensive grow-out of P. vannamei is conducted in tidal areas where minimal or no water pumping or aeration is provided.	Latin American
Semi-intensive	Semi-intensive ponds (1–5 ha) are stocked with hatchery-produced seeds at 10–30 PL/m². Regular water exchange is by pumping, pond depth is 1.0–1.2 m and aeration is at best minimal. The shrimp feed on natural foods enhanced by pond fertilization, supplemented by formulated diets 2–3 times daily. Production yields in semi-intensive ponds range from 500–2 000 kg/ha/crop, with 2 crops per year.	Latin America
Intensive	Intensive farms are commonly located in non-tidal areas where ponds can be completely drained, dried and prepared before each stocking, and are increasingly being located far from the sea in cheaper, low salinity areas.	Asia and some in Latin American
Super-intensive	Recent research conducted in the United States of America has focused on growing *P. vannamei* in super-intensive raceway systems enclosed in greenhouses, using no water exchange (only the replacement of evaporation losses) or discharge, stocked with SPF PL. They are thus biosecure, eco-friendly, have a small ecological footprint and can produce cost-efficient, high quality shrimp.	No specific region, developed in the USA.

One factor of the *P. vannamei* being the dominant species farmed and captured is that the White-leg Shrimp" have a relatively lower feed cost than the *P. mondon*, because it requires less protein. Feed prices for "*P. vannamei* range from USD 0.6/kg in Latin America and Thailand to USD 0.7–1.1/kg elsewhere around Asia; FCRs of 1.2–1.8:1 are generally obtained" (Food and Agriculture Organization of the United Nations, 2018).

When shrimp are sold, specialised teams will handle the harvesting and after the "sorting, shrimp are washed, weighed and immediately killed in iced water at 0–4 °C. Often *sodium metabisulphate* is added to the chilled water to prevent melanosis and red-head. Shrimp are then kept in ice in insulated containers and transported by truck either to processing plants or domestic shrimp markets" (Food and Agriculture Organization of the United Nations, 2018).

[61] Food and Agriculture Organization of the United Nations (2018).

Local Markets of MDS: Market Mechanism or Policy-decision?

Mangroves are found in 123 countries and territories globally, and cover a total of 152,000 square kilometres (equivalent to half the land area of the Philippines or one quarter of Madagascar). This makes mangroves a relatively rare forest type globally (Spalding et al., 2010). The main producer regions for shrimp are the Americas, India, China and Southeast Asia (See Figure 6) (See as well Appendix for more information about specific regions).

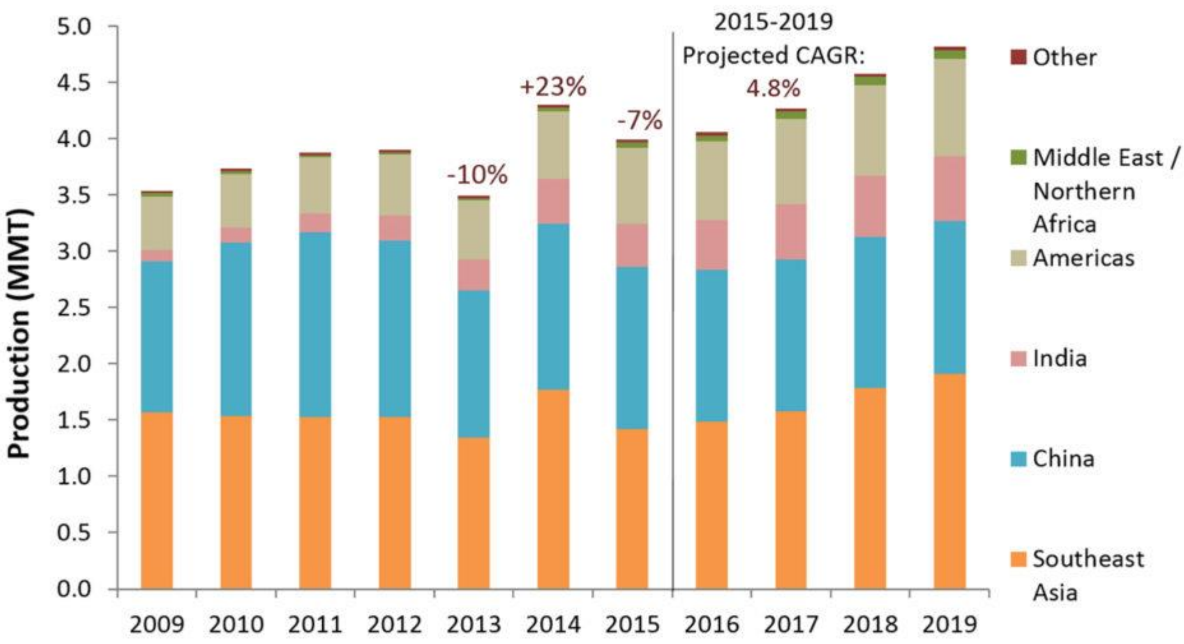


Figure 4 Main Producer Regions of MDS[62]

Shrimp is produced from "wild fisheries in the Northern and Southern hemisphere as well as from aquaculture." Shrimp is one of the favourite seafood and is consumed all over world while the largest markets are the United States of America (USA), Japan and European Union (EU). Figure 7 shows that the output from aquaculture has doubled in the last decades, but the outbreak of diseases in the late 1990's that were spread easily in the large monocultures, have caused supply swings (Leung & Engle, 2008, p.3).

Furthermore, the harvesting of the larvae is an important source of employment in some regions such as the Indian Sundarbans. This work is harvesting of wild larvae and "constitutes as little as 0.25 per cent of the catch, but most of the remainder is considered unwanted bycatch and is discarded, often dead, greatly reducing available stock for other fisheries" (Sarkar and Bhattacharya, 2003 quoted from Spalding et al., 2010, p.32).

[62] Ashton (2008).

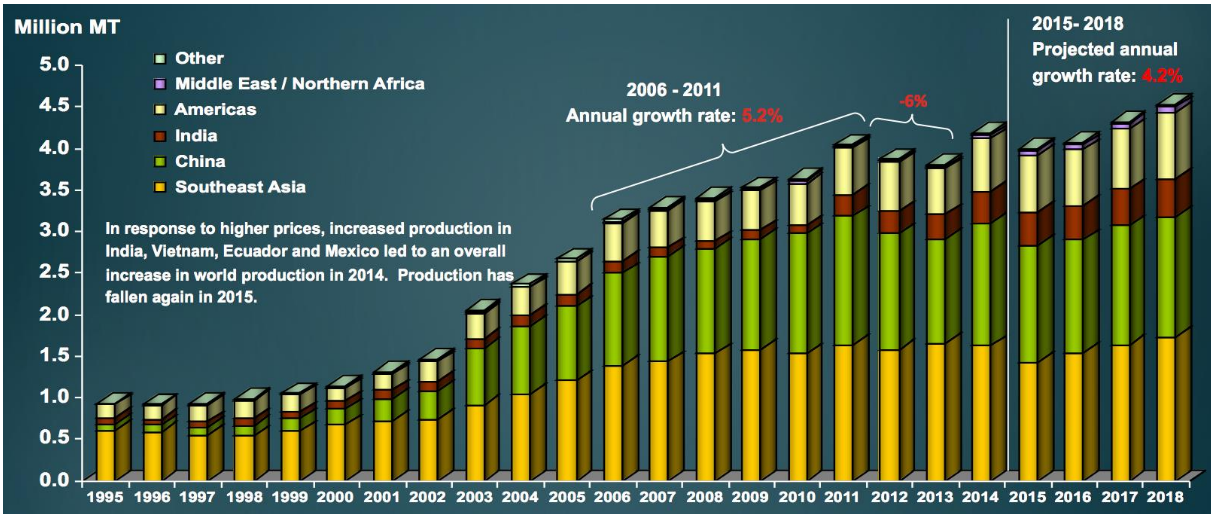


Figure 5 Main Producers of MDS over time

The market mechanism itself is not the only aspect that allowed the sector to grow this quickly and therewith caused the decline of Mangroves. There are

"laws addressing the placement of aquaculture standards or water quality pollution minimization have greatly altered the shape of new aquaculture developments in many countries. New policies and projects have led to widespread mangrove plantation across the Philippines. Policies of mitigation have led to the offsetting of mangrove loss by replanting or restoration elsewhere – for example, in Florida (US) and Australia. Many countries, such as Mexico, Belize, Tanzania and Mozambique, have established general legal protection for mangroves, controlling destructive activities through strict licensing systems. More specific protection is usually achieved through protected or highly managed areas" (Spalding et al., 2010, p.xvi).

The way that mangroves declined are a sum of many local decisions, sometimes driven by "market forces, industrial demand, population expansion or poverty", but in many countries there is a policy behind this market force (Spalding et al., 2010, p.xvi).

Conclusion

This paper showed that it is important to understand which techniques are used to get an overview where shrimp are farmed since Cold- and Warm-water Shrimp are farmed/captured differently. The Cold-Water Shrimp is captured in the Northern hemisphere and the Warm-water shrimp is farmed and captured in tropical coastlines and cleansing for shrimp ponds is causing a rapid decline of mangroves.

Shrimp that are farmed through the most mangrove-depleting systems are Warm-water shrimp. MDS have a large relative importance for the regional markets and the shrimp world, since almost 80 % of the farmed shrimp are just two Warm-water shrimp species: *Paneaus vannamei* (Pacific white shrimp) and *Paneaus monodon* (giant tiger prawn) (World Wildlife Fund, 2018). Leung & Engle (2008, p.4) point out that of a total "aquaculture production of 2.5. million tonnes, 722,000 tonnes were Black Tiger and 1,386,000 tonnes were White Shrimp." This means, that White shrimp (*Paneaus vannamei)* are farmed and captured the most in Mangrove areas.

This paper defined mangroves as a "characteristic intertidal plant formations of sheltered tropical and subtropical coastlines" (Saenger, 2002). Extensive and Semi-Intensive farming systems are typically built in tidal and intertidal areas and are "responsible for the most widespread losses of mangrove coverage," while these systems are found mainly in Latin America (Spalding et al., 2010). The 3rd farming system, 'Intensive shrimp farming' mainly happens in Asia and some in Latin America. Intensive shrimp farming is commonly placed in non-tidal areas.

This paper limited itself to the rather descriptive analysis of MDS related products and markets and it did not aim to analyse possible solution to the obvious problems related to MDS. However, in the process of this research, it occurred that a more detailed analysis of the type of market we deal with when researching MDS would be helpful to understand how and where to address MDS-related problems. The mapping of the actors of the MDS market(s) and the markets' typology (monopoles, oligopoly, a monopsony etc.) would be a valuable insight in the dynamics of the actors involved. Due to the limited resources of this paper, this could not be captured but such an analysis could help future research that might be more solution-orientated to tackle certain problems based on the actors involved.

6. The economics of mangrove-depleting shrimp and their relative importance in the regional economies

By Manon Ghislain

The identification key classifies shrimp as a decapod crustacean that thrives in fresh and brackish water. Historically appreciated for its nutritional value, shrimp has been farmed for centuries, especially in Asia (Rönnbäck 2001) since tropical climates cater for the best conditions for shrimp farming (WWF 2017). More recently, its taste has won Western countries over, thus inducing a rapid expansion of the demand and a splurge of shrimp farms development. Consequently, shrimp is the aquaculture product that has experienced the fastest growth in the world (WWF 2017). Once considered as a special treat, shrimp has grown to be the most valuable traded seafood product worldwide.

However, this growth took a toll on the environment, and especially in Asia where the shrimp business is mainly gathered, particularly in South and Southeast Asia. Indeed, in 2012, Asia produced 80% of global shrimp products (representing 3.5 million tons) with China, Thailand, Vietnam, Indonesia and India being the top five producers (Shamsuzzaman et al. 2017). At the same time, mangrove is mainly found in Indonesia (22%), Bangladesh (4%), Malaysia (4%) and India (3%) (FAO 2003)[63], countries where shrimp farming has skyrocketed since the 1970s. Therefore, it is reckoned that since 1980, a fifth of mangrove worldwide has been lost due their transformation into shrimp ponds (Doyle 2012). Others assess the role of shrimp farming in this depletion at up to 60% (Akhter, 2010).

Nonetheless, one could think that the rapid growth of farmed shrimp in South and Southeast Asian countries would improve the livelihoods of their communities and trigger a significant socio-economic trickle-down effect. Yet many interviews and research have concluded that the profits and benefits were short term because of the *'rape and run'* (Shang et al. 1998, Primavera 1997, Miao et al. 2012) and '*cash crops*' (Miao et al. 2012) practices that it encouraged. Even if the yields of the first years were promising, environment degradation and market pressure have been proven detrimental to regional environment and economies.

Given this context, this chapter will mostly focus on shrimp farms in South and Southeast Asian coastal areas, as they represent a booming economy for these regions since the 1970s, as well as they are widely involved in mangrove depletion (Alauddin et al. 1999).

This paper seeks to argue that despite a potential short-term increase in the economy, the damage done to the environment at the expense of local communities is a major drawback that outweighs the financial revenues. Nevertheless, the importance of the shrimp business makes for the local communities difficult to pull out of it, as external factors such as regional and national governance provide few incentives in that direction.

[63] While acknowledging that Brazil also accounts for a big share of global mangrove

The importance of shrimp farming in Asian coastal areas

A booming economy since the 1970s

Shrimp culture is ancestral in South and Southeast Asian coastal areas and is known as '*bheri-culture*' or '*gher*' (Akhter 2010). Initially, this culture was part of a holistic use of the swamps: during dry season, shrimp was cultivated and when the monsoons came, farmers cultivated rice on the same patches of land. Thanks to the nutrients of both cultures and the respecting of the seasons, no artificial fertilizer was needed and the shrimp and the rice provided food for the farmer as well as for the whole community through local markets. Historically, shrimp culture was local, sustainable and catered for the nutritional needs of those who cultivated it (ibid).

However, during the 1970s the demand from Western countries (especially the USA and Western Europe) for shrimp started growing rapidly and continuously. Many countries that already had the historical knowledge of shrimp farming, such as Thailand, the Philippines, India, Taiwan, Indonesia, started exporting their production to Western countries (see table 2) (Akhter 2010). Between 1998 and 2008, the world production increased from 500,000 metric tons to 3.1 million, a growth that mostly came from China, Thailand and Indonesia (Doyle 2012). These countries are among the leading producers alongside India, Vietnam, Brazil, Ecuador and Bangladesh (see table 1) (WWF 2018). This growth is mainly due to the rapid expansion of farmed shrimp that accounts for 55% of the global production, representing 4.3 million tons in 2017 (ibid), while in 1995, the volume of 712,000 tons of farmed shrimp stood for 27% of the global shrimp production (Primavera 1997). Comparatively the growth of wild catch shrimp increased steadily of 2-3% per year while farmed shrimp was booming.

Since its development in the second half of the 20th century, the shrimp farming industry has taken a significant part in the livelihoods of South and Southeast Asian communities. It is reckoned that shrimp production accounts for almost 70% of the average household income (Baumgartner et al. 2016). Added to the income from crab farming and other fish production, the share goes up to 90% of overall household incomes (ibid).

One could assume that the growing shrimp market is a boon for South and Southeast Asian economies, where the rural labour force in coastal areas is idle. And yet, divergent studies have been led on the improvement of the livelihoods of shrimp farmers. While a minority of them conclude that most farmers have increased their income as well as their general standards of living (Ahmed et al. 2018), others highlight the inequitable distribution of the benefits of the globalized economy that farmed shrimp has become, as it will be further developed.

→ The pursuit of profitability, albeit effective, has led to mangrove-depleting farming methods

Several production modes exist, which have different impacts on livelihoods and on the local environment. In general, three main methods can be found: traditional extensive, modified traditional, and semi-intensive. While the first one has been explained above (alternating rice and shrimp), the second one is inspired by the traditional method and involves more technology (e.g. electric pumps, saline controls, etc.). In this case, there is no alternation of rice and shrimp, but instead a combination, which at times even includes other fish and crustaceans. High productivity can be expected with this method, although it induces significant upfront costs to set up the required equipment. The last method is the most intensive one, including a lot of high-end material that local farmers cannot usually afford (thus it is more coveted by foreign investors). It yields seven times more than the traditional extensive method and three times more than the modified traditional method (Miao et al. 2012).

Modified traditional and (semi-) intensive methods are equally involved in mangrove depletion since the shrimp farms that emerged after the 1970s have been constructed on brackish water swamps, for which mangrove has been uprooted. Shrimp farmers took advantage of the good conditions left by mangrove. Moreover, the evolution of traditional methods has allowed farmers to increase shrimp yields. Therefore, both increases of yield and shrimp value have transformed shrimp farming into a highly profitable business. However, it does not necessarily benefit local communities.

However, shrimp farming is no silver bullet for Asian coastal communities

A rapid overview of the shrimp economy on socio-economic aspects

In spite of all the assumed economic benefits of shrimp farming, the living standards of shrimp farmers have not evolved much, and some studies shed light on the persevering rates of under-nutrition, low food availability and lack of food diversity (Miao et al. 2012). Actually, half of the Southeast Asian youth is still suffering from under-nutrition although their countries are known worldwide for their food production (ibid). Paradoxically, while shrimp used to be a great source of protein for coastal communities, its new heightened market value has made it inaccessible to them, thus threatening diet diversity and food security (Miao et al. 2012). It is worsened by the loss of rice paddies due to shrimp farms development. It deprives farmers of a staple food that represents more than half of their caloric intake (FAO/WFP 2008 in Miao et al. 2012). Another study concludes that the recurring practice of '*cash for crops*' led by foreigners and by local communities does not translate into increased food security and diversity (Negin et al. 2009). Therefore, shrimp farming is ironically one the main causes of food insecurity in these coastal areas.

Furthermore, shrimp farming creates new dynamics and interactions on a regional level. In that way, violent rivalries emerged in tense socio-economic climates: several cases of theft, poaching, poisoning, and vandalizing have been reported by farmers (Ahmed et al. 2008). These field surveys show that economic benefits do not necessarily translate into improved social conditions.

→ The emergence of new threats for local farmers

In addition to jeopardizing the local environment, mangrove depletion induces fisheries loss, which is a significant part of coastal populations' livelihoods, up to one fifth in some areas (Miao et al. 2012). Studies reckoned the decrease of catches due to mangrove depletion up to 80% (Swapan et al. 2010 in Miao et al. 2012).

Moreover, the commodity being standardized, many cases of illness and spreading diseases have occurred. Monoculture of only two main species64 (white leg shrimp and black tiger shrimp account for 80% of the market, FAO 2009) makes for a poor biodiversity and therefore a greater vulnerability (WWF 2018). For instance, in 2013, a disease episode halved shrimp production in Thailand, driving considerable loss in revenue (on average $5,000 per crop) as well as in jobs (WWF 2017).

On the environment level, cost-benefit analyses showed that the harm done to the environment is financially much costlier than the turnover of shrimp farming as well as it is significantly more persistent (Miao et al. 2012). The ratio between damage and benefits in some Southeast Asians areas is reckoned to be up to 4 to 1 (Primavera 1997)65. The

[64] Although there are about 2,000 different species of shrimp, only 14 are farmed among which two stand out from the crowd in terms of volume and value (WWF 2017).

[65] The report specifies: "63 billion rupees vs. 15 billion rupees annual earnings"

reasons mentioned are mangrove depletion, soil salinization and most surprisingly, unemployment.

→ The trickle-down economic effect is only short-term

Shrimp farming has become a dually constraint market where operational costs increase continuously, while at the same time the strong demand for shrimp pull the prices downwards (Miao et al. 2012). Thus, although most of energy and commodities prices rose during the beginning of the 20th century, the wholesale price of shrimp declined from $15/kg in the 1990s to $11/kg in 2017 (WWF 2017). When illness and environmental events take a toll on shrimp harvests, farmers are compelled to reduce their margins in order to remain competitive.

The first study on the trickle-down effect (more employment, increased livelihoods, better living standards) led in 1989 in the Philippines concluded that the profits of farmed shrimp did not benefit the local communities but rather the investors and traders, quickly steering local living standards back to their pre-farmed shrimp level (Amante et al. 1989). Another study conducted in Bangladesh led to similar results, emphasizing the fact that fishers lost their jobs to shrimp farms (Choudhury et al. 1994 in Primavera 1997). Even if shrimp farming may have increased livelihoods in some coastal areas, many research papers disprove the trickle-down effect.

Besides, numerous cost-benefit analyses demonstrated that the productive life of an average shrimp farm is five years, leading to '*rape and run*' practices where lands are exploited during a small amount of time and left abandoned (Sathirathai et al. 1995, Primavera 1997). The short high-yield timeframe encourages investors and farmers to find new locations quickly, especially by converting mangrove forests into commercial shrimp farms, thus taking part in the depletion of mangrove (ibid). Moreover, the upfront costs are generally too high for local farmers: 43% of the respondents to a survey led in Bangladesh mention that the lack of capital is their "*single most important constraint*" (Ahmed et al. 2008). In addition to the costs, the fact that ponds deplete ecosystems forces farmers to use more fertilizers, more feeding, etc. adding up to the overall operation costs. This is why foreign investors with more financial means overrun most shrimp farms.

The growing shrimp economy benefits mainly to outsiders, at the expense of local communities

→ The stranglehold of foreign investors on farmed shrimp economy

It appeared in the literature that most farm owners are actually foreign investors. They manage the biggest (and the most intensive) shrimp ponds, sometimes remotely, hiring local or outside farmers to manage the ponds on site (Akhter 2010). A field study led in coastal areas of Bangladesh found that only 1% of the entire shrimp-farming region was owned by local communities while outside businessmen owned the rest (ibid). Comparatively, in the early 1990s, outsiders represented 75% (Shultna 1994 in Primavera 1997), and earlier in 1985, outsiders controlled 20% of all farms (while occupying 43% of the total shrimp area) (Alauddin et al. 1999). In addition, since the 1990s, most of them have been developing integrated production chains through which they also own hatcheries, feed production, processing plants, etc. Conversely, local farm owners are dependant both on their suppliers and their buyers (ibid). The growing economy lured numerous foreign investors that drove a splurge in the market: during the last two last decades of the 20th century, the shrimp market grew at an annual rate of 80% (ibid). As a result, opportunities in the shrimp farming industry for local communities are often limited to low-paying, unskilled, effort intensive jobs, while upper positions are monopolised by outsiders, thus economic benefits rapidly get away from local communities (Primavera 1997).

→ Despite the drawbacks, it remains difficult for South and Southeast Asian communities to pull out from the shrimp business

Countries such as the US, many in Europe and in Asia (to a lesser extent) import a lot of shrimp products, maintaining an enormous demand on the market. It is noticeable on table 2 that all the major importers are more and more demanding, the US leading the way with an annual consumption per capita of almost 2 kg (WWF 2018). This ever-increasing demand makes shrimp the most valuable traded marine product in the world, the value of the market experiencing on average an annual growth of 10% since 2010 (ibid). Thus, it remains difficult for local farmers to pull out from the shrimp business. It is even tougher for countries such as Bangladesh, for which shrimp production is the second largest economy after garment, as it would put in jeopardy many livelihoods, especially in coastal areas.

Banks and specific programs also largely sustain this business. Indeed, many loans, microcredits, NGO programs, moneylenders and investors provide local farmers with financial support with a view to developing local activities. In some coastal areas, up to two thirds of farmers receive financial support of that kind (Ahmed et al. 2008). A bank from Bangladesh well known for its developing shrimp farming loans was even given the Nobel Peace Prize in 2006[66]. Although these financial supports help some farmers, others suffer from unplanned events, emphasized by the lack of biodiversity resilience, that destroy their culture. They find themselves not being able to pay back their loans, circling back to a cycle of debt.

→ Although shrimp farming is a threat for environment, the lack of awareness amongst coastal communities remains challenging

Even though local communities do not benefit from shrimp farming at their maximum potential, they would benefit even less from mangrove protection. Indeed, as long as farmers' lands are covered in mangrove, it is considered as a governmental property. As a result, local communities cannot take full advantage of those mangrove-covered land since they cannot claim ownership. Conversely, when farmers turn swamps into shrimp farms, they are allowed to receive the benefits of those (Ha et al. 2012, Baumgartner et al. 2016). Besides, a study led in Bangladesh reported that more than two thirds of the interviewees did not believe that farmed shrimp was harmful for the environment (Ahmed et al. 2010). Environmental issues cannot be solved as long as shrimp farmers are not aware of them and as long as it is more interesting financially to uproot mangrove.

Nonetheless, it is possible to have mixed mangrove-shrimp systems that in addition to being more sustainable could provide households with a variety of products from aquaculture (shrimp, crab, fish) as well as agriculture (rice, timber) contributing to secure livelihoods and diversified employment (Bosma et al. 2016). Regardless, having an integrated forestry-fisheries-aquaculture system (as proposed by Vaiphasa et al. 2007) implies super-intensive ponds of which technology and highly efficient mechanization are essential parts (Bush et al. 2010). Yet those are extremely expensive and thus cannot be borne by local farmers that are used to traditional extensive methods. This is why sustainable shrimp farming in South and Southeast Asia is challenging, as its access is difficult for the local communities, whose livelihoods depend on it.

Conclusion

Shrimp farming has been a huge boon for coastal communities since the end of the 20th century, especially in South and Southeast Asia. Its continuous growth (past and planned) proves that shrimp business is an economic opportunity for local and outsiders. For many years it has sustained livelihoods but similarly to many other business opportunities, the lack of legislative framework put in place in concerned areas has been greatly damageable for the most vulnerable communities. Indeed, the dominance of foreign investors on the market has strongly held back the trickle-down effect of shrimp farming on farmers, leaving them in precarious situations (Alauddin et al. 1999). In addition to leaving many farmers landless and jobless, it has greatly harmed their environment;

[66] The Grameen Bank, the motivation being "for their efforts to create economic and social development from below"

what could have been beneficial for South and Southeast Asian coastal areas is currently devastating in many ways. Moreover the negative effects are felt differently between countries. For instance China, which is the first shrimp exporter but for which shrimp represents only 0.07% of its global commodities exports, has room for manoeuvre and anticipation. Conversely, Bangladesh is only the 7th global shrimp exporter but this market represents almost 5% of its global commodities exports, pressuring the country to sustain the shrimp economy in spite of its negative effects (Index Mundi, computed in April 2018).

As a final word, I would like to stress the importance of the Western countries in the shrimp market that keeps pulling the prices down. As a matter of fact the USA and Europe, where shrimp consumption has been widely standardised, jointly account for 80% of the global shrimp market (Shamsuzzaman et al. 2017). Without better awareness from the final consumers as well as a better protection for local farmers implemented by regional and national government, shrimp farming activities will not only put mangrove and the environment in jeopardy, but also livelihoods, the living standards of citizens and the growth of countries in general.

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7. Certification and sustainable labelling

By Vincent Virat

Introduction

Seafood production has expanded greatly in the last 50 years, both in terms of total production and per-capita consumption, driven predominately by population growth and changes in dietary and lifestyle choices. (FAO, 2016). Aquaculture, the cultivation of freshwater and marine foods in a controlled environment, has been steadily increasing as capture fisheries has plateaued, with aquaculture now considered a major strategy for global food security (Godfray *et al.*, 2010). Representing more than half of global seafood supply for human consumption with a production amounting to 73.8 million MT in 2014, aquaculture has an estimated value of US$160.2 billion (FAO, 2016). Furthermore, with the expansion of the middle-class in developing regions such as Asia, demand for animal protein, including seafood, will increase, further exacerbating existing pressures on marine ecosystems and seafood production (Jonell *et al.*, 2013). The unprecedented growth in the development of aquaculture means that good management often gets left behind, which poses a major challenge to the sustainability of global seafood production (Monterey Bay Aquarium, 2011).

As reviewed by Jonell *et al.* (2013), the overall environmental impacts of aquaculture comprise the discharge of untreated effluents, the spread of diseases and invasive species, habitat degradation and subsequent loss of ecosystem services, as well as more global impacts such as greenhouse gas emissions. With the focus of this report being mangroves and shrimp production, major impacts of shrimp farming include:

> *"(…) The loss of important ecological and socio-economic functions of mangrove ecosystems, changes in hydrology, salinization, introduction of non-native species and diseases, pollution from effluents, chemicals and medicines, use of wild fish for feed, capture of wild shrimp seed and loss of livelihoods and social conflicts." (Ashton, 2008)*

Growing awareness of the impacts of aquaculture, and more precisely the impacts of shrimp farming on mangroves, has led to the demand for solutions that ensure the sustainability of seafood production systems, which can be understood through three essential elements: (i) the provision of a long-term, sustainable yield, (ii) ensuring inter-generational equity and (iii) maintaining social, biological and economic systems (Hilborn, 2005). Various tools to support these solutions exist, including government policy and regulation, which seek to address access to, utilization and production of seafood, but also market mechanisms like certification and ecolabels.

This chapter will focus on the latter – certification and ecolabels – as possible solutions to enhance the sustainability of aquaculture systems. The first section will look at the rationale surrounding certification and eco-labelling mechanisms for aquaculture production. The second section will highlight the main issues and possible opportunities surrounding existing aquaculture certification schemes. The third section will consist of a case-study on the application of an organic certification for integrated shrimp-mangrove systems in Vietnam, adapted from Ha *et al.*, (2012). The fourth section will then conclude by taking a reflective look on the future of eco-certifications in ensuring the sustainability of mangrove ecosystems.

Rationale behind certification and eco-labelling schemes

Eco-labels emerged in the 1970s as a way for industries to communicate specific qualities or characteristics of their products to consumers, such as fair-trade coffee or "dolphin-safe" tuna, in response to media attention and consumer awareness on a variety of issues. Eco-labels are a means of educating consumers on the advantages, whether they be health, environmental, social, of purchasing a particular product over other products and thereby encouraging its purchase (Cooper, Ludlow and Clift, 2012). The development of eco-labels, in particular defining their standards and processes, usually involves a large array of stakeholders: "*civil society and non-government organizations, governments, industry associations, retailers and supermarket chains and consumers concerned about food safety, and/or social and environmental impacts*" (Jonell *et al.*, 2013).

When international and national government institutions fail to deliver "sound fisheries management", eco-labels are a tool for private actors to influence international governance. As a "non-state, market-governance" scheme, eco-labels satisfy the demand of "science experts and environmental groups" (Hadjimichael and Hegland, 2016).

The first objective of eco-labels is thus to satisfy purchasers' (consumers and retailers) demands in terms of an acceptable "degree of comfort regarding the product", answering concerns enunciated above (Tlusty, 2012). Eco-labels for seafood production must take into account consumers' perspectives and willingness to pay for more sustainable products. Attention should be paid to consumers' awareness of action strategies, such as their recognition and understanding of existing labels, their subjective and objective knowledge of the impact of seafood production on various parameters, such as the environment, and the value they place on these parameters (Jonell *et al.*, 2016).

Improving the sustainability of seafood is secondary: in theory, certification will incentivize environmentally-sound practices (e.g. production, sourcing, purchasing) within the targeted sector (here, aquaculture and shrimp production with the aim of protecting mangroves). By setting a "sustainable production" threshold, the certification provides producers with an incentive to gain certification and thereby become sustainable, on the assumption that benefits, such as access to foreign markets and price premiums, will follow (Tlusty, 2012).

The Marine Stewardship Council (MSC) is the oldest and most cited seafood label in the literature, representing 12% of total marine catch in 2017 (Marine Stewardship Council, 2018). Despite its focus on wild marine food production, as opposed to aquaculture, it illustrates well the rationale behind eco-labels. Created in 1999 by Unilever and the World Wildlife Fund, MSC is now an independent eco-labelling organization that aims to halt the decline of global fish stocks by implementing a labelling process to encourage the dispersion of sustainable fishery practices (Cooper, Ludlow and Clift, 2012). To gain certification, a fishery must satisfy criteria to demonstrate (i) stock health, (ii) ecosystem health and (iii) adequate management that respects relevant laws and regulations (Selden *et al.*, 2016).

Despite its promising objectives, the MSC is often criticized for its lack of reliability and transformative power as a certification mechanism. For example, MSC can be quite tolerant of questionable fishing practices and their consequences, including non-target species bycatch and the use of destructive fishing gear. as it faces "pressure to certify" in the face of a growing demand (Christian *et al.*, 2013; Hadjimichael and Hegland, 2016; Selden *et al.*, 2016). A further criticism is the programme's inaccessibility to small-scale producers in developing countries, who are unable to afford the high cost of certification and yet have a large cumulative impact (Cooper, Ludlow and Clift, 2012; Pérez-Ramírez *et al.*, 2012; Jonell *et al.*, 2013). Such challenges from the marine seafood certification industry need to be considered when designing and implementing aquaculture certification schemes in the future.

With regards to aquaculture, as of 2012, there are 36 aquaculture certification programs in operation, certifying about 1.3 million MT of product or 2.58% of total aquaculture production (Boyd and McNevin, 2012). Only three of these schemes (Best Aquaculture Practices (BAP), Friends of the Sea and GlobalG.A.P.) represent more than 10,000 MT each (i.e. other certification schemes are minor in size). A more recent addition, the Aquaculture Stewardship Council (ASC), founded in 2010 as a brother to the MSC and also developed by WWF, is expected to attract considerable attention, as it was developed through "Aquaculture Dialogues" which gathered more than 2,000 stakeholders to produce standards of sustainable production (WWF, 2018). The standards set by the ASC could be achieved, according to WWF, by 10-20% of the aquaculture industry (Boyd and McNevin, 2012).

Overall, the existing certification programs for aquaculture cover similar criteria, including changes in land use, use of fish meal, water pollution, impacts on biodiversity, predator control, food safety, as well as social issues (Boyd and McNevin, 2012). The focal point they use, however, differs. For example, the older BAP certification program is geared towards minimising environmental impacts and ensuring food safety, while the recent ASC standards "*are heavily oriented toward environment and social issues*" (Boyd and McNevin, 2012). Moreover, standards often look solely at the direct impact of aquaculture as opposed to the indirect impacts, such as would be included in a Life Cycle Assessment (LCA). Ideally, LCA considerations should be included in certification schemes to address all of a product's environmental and social impacts (Cooper, Ludlow and Clift, 2012; Nhu *et al.*, 2016). The following section will explore this in relation to the eco-certification of aquaculture.

Main issues with eco-certification schemes for aquaculture production

The history of aquaculture certification is relatively short, having started in the early 2000s, makes it difficult to assess the transformative impact of aquaculture certification programs (Tlusty and Tausig, 2015). Yet, some data and early analysis can be found in the literature. The limitations and challenges faced by aquaculture certification programs so far can be broken down into five key elements, listed below (Jonell *et al.*, 2013).

→ Mismatch of targeted species and global environmental impacts

Eco-certification schemes only target species present in the markets of developed countries, thereby excluding a major share of the global market. The Asian market, for example, is expected to skyrocket in the coming years. More than half of the certified species constitute less than 1% of total global aquaculture production, while species like carp, which represent more than 40% of global aquaculture production, are entirely excluded from certification schemes.

→ Small certified volume

While the total volume of certified aquaculture production is currently small, it is likely to remain so in the near future (Jonell *et al.*, 2013), due to the current lack of demand for eco-certified seafood products from major markets, such as in Asia.

→ Exclusion of small-scale farmers

The exclusion of small-scale farmers is a major point of contention for eco-certification schemes, as illustrated earlier with the MSC framework. Including "*technically and financially weak producers*", who rely on family labour and extensive, yet input-limited practices, is difficult as cost barriers remain high (Jonell *et al.*, 2013). Small-scale farming systems present large, unquantified environmental risks, which threaten valuable ecosystems such as mangroves, which are often turned into aquaculture ponds, as explained in our introduction. 80% of global aquaculture production comes from developing countries, where small-scale farmers are common. Integrating such farmers into certification schemes is key to avoiding their otherwise substantial environmental impacts, such as mangrove depletion (Jonell *et al.*, 2013). This will be further explored and illustrated in Section 3.

→ Challenge of solely targeting best environmental performers

Certification or eco-labels set a desired "sustainability threshold", usually expressed as a criteria-based score, (i.e. passing a certain "sustainability threshold") which producers can claim . The theoretical assumption is that certifying "best performers" will incentivize others to make the necessary improvements. However, this poses several issues as explained by Tlusty's (2012) pull-threshold model. Improvement, or "pull for certification", will only come from producers slightly below the threshold. Producers who fall well below the threshold (i.e. the producers with the highest environmental impact) will not be incentivized to improve as the costs of reaching the threshold will be too high.. Furthermore, producers who are already certified, situated on or slightly above the threshold, will have no incentives to continuously improve and make their practices more sustainable. Solutions to this particular challenge will be discussed in the fourth section.

→ Lack of long-term biophysical sustainability perspective

The standards set by aquaculture certification generally lack a vision regarding "long-term biophysical sustainability" of aquaculture systems, including climate change impacts, energy consumption and use of biotic resources. While complex and difficult to implement for farmers, LCA analysis is a relevant tool for such considerations, as it allows consumers to see, for example, where fish-feed comes from, or the total energy consumption of the product they are purchasing, two challenges which are relevant to aquaculture production (Jonell *et al.*, 2013).

These challenges are common to most certification schemes and require further attention from the research and policy communities. Further assessment of the impact of certification schemes on production methods is crucial, especially for designing more effective mechanisms.

Case-study: certification of integrated shrimp-mangrove production systems in Vietnam

The following case-study, adapted from Ha *et al.* (2010, 2012), illustrates some of the practical social and economic challenges of implementing aquaculture certification schemes, including mangrove protection, in a developing country. This particular case, compared to previous examples, focuses on a national certification scheme, which are generally characterized by being more limited in breadth and scope compared to global standards (Tlusty, Thompson and Tausig, 2016).

Despite high economic and environmental risks, high-value tropical shrimp production in South Asia is a major source of income, driven mainly by exports to Western countries. Organic farming was promoted by the Vietnamese government to boost its international image and protect both small-holder farmers (i.e. a majority of shrimp producers in Vietnam) and crucial mangrove ecosystems. The government reached out to Naturland, a private certifying body. The Naturland certification had been successfully implemented in the Nam Cam district for more than 10 years, increasing from 143 certified households in 2002 to 784 in 2009 and representing nearly 700 MT of shrimp (see Table 2 in Ha *et al*. 2012).

Naturland embraces "non-state market governance". The program follows a logic similar to the one described in earlier sections of this paper. Production standards were defined by an "environmental regulatory network" which consisted of various actors, including "*state institutions, certification bodies, environmental groups, development agencies, international organizations, trade agreements, consumers, retailers, traders and farmers*". The governance power of the environmental regulatory network extended well beyond the State (Vandergeest, 2007; Ha and Bush, 2010; Ha *et al.*, 2012).

Vietnamese authorities later wished to expand the program throughout the wider Ca Mau region, which is the country's leading shrimp producer and accounts for 48% of total shrimp farming area. The aim was to create an "organic coast," which would reconcile conservation and shrimp cultivation through integrated shrimp-mangrove systems, a "traditional form of extensive aquaculture" characterized by low inputs, the inclusion of biodiversity and reduced probability of disease dispersion (for more details, see Ha *et al.* 2012).

The implementation of the Naturland standards in the Ca Mau region revealed the existence of "clusters of conflict," which impact the acceptability of the standards as well as the capacity of local farmers to follow them (Ha *et al.* 2012). These "clusters" must be governed with particular attention to (i) diverging epistemologies of what organic farming means, (ii) issues related to the link between producers and processors and (iii) the controversial role of third party auditors.

The early success of the certification process can be attributed to little epistemological conflict as Naturland standards matched well with existing smallholder production methods, which required little or no change. However, when the project was expanded, inconsistencies in the definition of forest cover protection standards were revealed. Farmers claimed that the requirement of a 50:50 ratio between forest cover and farmland could be met at the territorial level (i.e. an average across various farms), while Naturland standards required that this objective be met at the individual level, thereby excluding farmers with limited land.

The case-study provides a good illustration of the need for strong market incentives to join certification mechanisms, especially for small-holder farmers. In Vietnam, there was little difference in price between certified and non-certified shrimp, which discouraged farmers from continuing their engagement in the certification scheme (Ha *et al.* 2012). Furthermore, they have little bargaining power given their disadvantaged position at the bottom of the value chain.

Other challenges highlighted by the case-study includes the absence of a real price premium raises the question of the strength and attractiveness of the Vietnamese organic certification. Enforced internal auditing practices fail to control certain detrimental practices by shrimp collectors (e.g. the mixing of organic and non-organic shrimp to increase revenue). Increased intervention of local governments to support farmers both in the process of applying to the standards, oversight, as well as through the process of bargaining for prices, could address this issues (Ha *et al.* 2012).

Overall, the case-study provides an insight into the practical challenges of certification mechanisms. Although not transformative, as the standards set allows farmers with existing organic farming and conservation methods to be certified, the Vietnamese scheme offers the possibility of preserving and valorising sustainable practices as well as a proportion of forest cover.

Conclusion

Given the pressure exerted on world seafood supply and the subsequent rise of aquaculture food production, methods are needed to encourage and promote the sustainable management of aquaculture systems. Ecolabels and certifications are only one of a set of tools that should be implemented to improve the sustainability of aquaculture practices, and more specifically, the preservation of mangrove ecosystems. Government intervention through legislation and regulation remains key, as it provides a framework for the correct and sustainable application of certification programs, as illustrated by the case-study. Indeed, there is always a risk that certification and eco-labels will be hijacked by the demands of purchasers, thereby undermining the benefits and threatening the producers, which can lead to serious cross-scale impacts. The livelihoods of smallholder food producers in developing countries, in particular, are at risk (Getz and Shreck, 2006; Hadjimichael and Hegland, 2016).

As a market mechanisms, ecolabels first seek to fulfil the demands of consumers and retailers for more sustainable products and in doing so, may create a "carrot-like" incentive for producers to improve their practices. However, given their current configuration, limited evidence exists for the transformative power of certification schemes, as evidenced by Tlusty's pull-threshold model (Tlusty and Tausig, 2015). The single threshold-setting mechanism of certification does not encourage continuous improvement for certified producers, and may not encourage improvement at all for high-impact producers. One proposed solution is the introduction of multiple thresholds within a certification program to "broaden the extent of the pull", with for instance "silver" and "gold" standards (Tlusty 2012). This approach frames sustainability as a trajectory with various stops and an ultimate "ideal end goal" rather than a single threshold to be met. The "vertical differentiation" of environmental standards rather than a "horizontal differentiation" required by such a mechanism allows for comparison between various certification schemes (Bush and Oosterveer, 2015). Setting lower and more achievable thresholds would facilitate the inclusion of small-scale farmers within developing countries (Pérez-Ramírez *et al.*, 2012). More comprehensive mechanisms should be developed, along with educational programmes like Aquaculture without Frontiers, to build capacities for smallholder farmers to adopt more environmentally-sound management methods and thereby further increase the "pull" factor of the certification standard (Tlusty, 2012).

8. Are Payments for Ecosystem Services efficient tools to prevent Mangrove depletion?

By Marie Thomas

Integrating ecosystems and biodiversity benefits into decision-making through incentives and price signals in order to protect those benefits can be achieved through a variety of economic mechanisms, which can be market-based or embedded in policy decisions like *Payments for Ecosystem Services* (PES).

Mangroves provide many provisioning, regulation, support and cultural ecosystem services. Beneficiaries of these ecosystem services are not limited to local communities but extend to national and international levels. There are therefore many opportunities for PES schemes to be implemented in order to protect those services.

Concerns about the disappearance of Mangroves have led to some innovations in Mangroves conservation and restoration efforts. PES enables to create incentives to conserve ecosystems through providing sources of incomes for the local population. Therefore, applying PES to Mangroves ecosystem services appear as an interesting opportunity.

The aim of this chapter will be to determine *whether Payments for Ecosystem Services are efficient tools to prevent Mangrove depletion*. In order to answer this question, we will first analyse existing economic tools to preserve ecosystem services, then if those economic tools would be efficient for Mangrove preservation, and finally which characteristics should be respected to implement efficient PES to protect Mangroves ecosystems.

Economic tools to preserve ecosystem services

Measuring ecosystem services values is a challenge

Ecosystem services are becoming better measured, but their economic value is still an extremely complicated issue, due to difficulties of measuring their interconnection, the impossibility of substitution and their changing states.

First, giving a value to nature is a very ***subjective process***. According to how people perceive their natural environment, at a certain point in time, because of a multi-dimensional and socio-cultural subjectivity, any exercise of valuation is only applicable to precise given context.

Second, ecosystem services values are generally ***incommensurable*** because they cannot be measured in the same units. Trying to provide common economic values to different ecosystems might leave out relevant aspects of these ecosystems. It is especially the case with giving monetary value ecosystem services and therefore essential to communicate monetary values with carefulness.

Third, there is an ***uncertainty issue***. Adding economic uncertainty to ecological uncertainty, could harm nature services in an irreversible way. We cannot wait for perfect information to act, but actions have to be taken limiting uncertainty risks at maximum, using science resources at disposition.

Lastly, **the "*financialisation*" of nature and its services**, which will lead to its commodification and marketization, could be dangerous. Nature could become merchandise like any other, subject to free trade. Placing a value on nature's ecosystem services should not be miscomprehended as only putting a price on nature.

Economic solutions

→ Payments for ecosystem services

One way of taking into account ecosystem services value in our economic system in order to protect them was the introduction of *Payments for Environmental Services* (PES), more recently called *Payment for the Preservation of Environmental Services* (PPES). They are defined as ***the contractual remuneration of actors, conditionally to maintenance or restoration of one or several previously identified ecosystem services***. The most widely known definition is Wunder's, that puts forward five characteristics of PES: *A PES is: (1) a voluntary transaction where*, *(2) a well-defined ES (or a land-use likely to secure that service)*, *(3) is being "bought" by a (minimum one) ES buy*, *(4) from a (minimum one) ES provide*, *(5) if and only if the ES provider secures ES provision (conditionality) (Wunder, 2008)*. However, Wunder acknowledges that these five characteristics rarely meet. Contrary to what the title *Payment for Ecosystem Services* may suggest, the transaction object is not the ecosystem service itself, derived from one or more non-appropriable ecological functions, but the adoption of specific uses of resources, or specific practices, that may maintain or restore one or more defined ecosystem services. In other words, it is man's action to facilitate ecosystem services preservation that is remunerated.

→ Market solutions

Market solutions rely on putting a monetary value on nature. Through exchanges on nature markets it would be possible to compare and substitutes different ecosystem services with the existence of many buyers and sellers and private claims to buy and sell. However, most ecosystem services are hardly substitutable and, once degraded, cannot be replaced. Ecosystem services such as biodiversity are categorized as public goods and services, and markets are known to be deficient for their management. Developing non-monetary methods for valuing human health and security, and cultural services, is then a favoured way developed by academic researchers.

Ecosystem services are then difficult to measure; however, it is still possible to internalise those services through different economic processes such as PES or the market logic.

Are PES relevant to prevent mangroves depletion?

Public PES implementation

→ Public payers are needed

Mangroves are located in coastal areas, mostly in developing countries, and involve many different actors. Economic development through the development of agriculture, infrastructure, industry and tourism in coastal areas causes significant loss of mangroves. Therefore, coordination between these many private actors, through multiple small-scale PES, would be difficult to implement and would not limit the development of economic activities and the depletion of mangroves.

The intervention of the public authorities for the smooth running of PES in this context seems necessary (*Slayde Hawkins, et al., 2010*). The purchaser of PES is often the one who benefits from the protection of the defined ecosystem service. In this case the public authorities would be the payers of PES from local populations, which would enable homogenization of the program and reduced leakage of harmful development to other non-regulated areas. For instance, public payments for the conservation or restoration of Mangroves could reduce the cost of repairing and maintaining dikes *a posteriori* while providing funds for the future conservation of Mangroves.

→ Sellers of ES

ES vendors are not the only, nor the only main beneficiaries of the protection of an ecosystem service. Therefore the measures taken by these actors, in order to protect these services, must be remunerated.

Local populations are eligible to sell this protection of Mangroves ecosystem services. They would receive PES that could take the shape of forestland allocation, forest contracts or co-management agreements (*Slayde Hawkins, et al., 2010*). Many of the world's poorest coastal communities are highly dependent on Mangroves services and their conservation. Therefore they are likely to be inclined to participate in conservation PES schemes.

Barriers to mangroves PES implementation[67]

→ Opportunity costs

Opportunity costs for Mangroves conservation in developing countries are very high. The important yields of aquaculture and especially shrimp farming create difficulties for PES to implement payments large enough to offset these opportunity costs. To counter these high opportunity costs, PES programs must take into account the market and non-market values of ecosystem services to qualitatively highlight their attractiveness. In addition, PES should be implemented with traditional regulatory practices to provide strong incentives for Mangrove conservation.

→ Management challenge

The need for consistent and clear management across all levels of intervention is primordial. A lack of long-term planning at each decision-making level leads to poor conservation policies for natural resources. Mangroves conservation and restoration efforts may fail due to imperfect control, poor coordination among the relevant authorities, and insufficient funding. PES cannot be implemented effectively with ambiguous or inconsistent regulation.

→ Regulations application

Compliance and enforcement of the law and regulations on Mangroves conservation is also a major obstacle in most developing countries. First and foremost, the lack of resources to enforce regulations may be a reason for the failure of PES. Short-term interests may outweigh long-term interests for economic actors and the local population. In developing countries, such as in Vietnam, the priority has always been the development of aquaculture and shrimp farming compared to Mangroves conservation, and it is still the government's policy, in view of generating high profits in the short term to the detriment of long-term ecosystem health.

Facing weak enforcement, strong economic incentives for shrimp production can easily outweigh conservation efforts and jeopardize payments for Mangroves ecosystem services. Ensuring that local people understand they could have alternative incomes opportunities to Mangroves exploitation will be a key element of a successful strategy to change practices on the ground.

Few PES in Mangroves are implemented to date, but more information on the effectiveness of PES will emerge as pilot projects are developed and new regulations are adopted.

[67] Adapted from (Slayde Hawkins, et al. 2010)

Small-scale projects with private actors

→ REDD+

REDD+ means *Reduction of emissions from deforestation and forest degradation*, and the addition of + corresponds to taking into account the increase in carbon stocks. REDD+ is coordinated by the UN within the UN-REDD Program. Its principle is to remunerate developing countries through contributions from developed countries, with REDD credits whether through a market or a fund. It aims to help developing countries in implementing policies to fight deforestation and to integrate environmental concerns into their development policies. This set of international policies includes compensation for landowners reducing carbon emissions from forests, capacity building, governance, engagement of indigenous peoples and providing technical needs (*Corbera, Schroeder, 2010*).

→ Implementation of REDD+ on voluntary carbon markets

The forest carbon market is divided into two systems:

Compliance systems: created and regulated by binding national and international agreements

Voluntary projects: in which businesses and individuals choose to invest in carbon offsets

The inability of the compliance market to take into account forest emissions has encouraged more than 90% of forest carbon projects to become certified under the voluntary market. The voluntary carbon market offers opportunities for the development of appropriate mangroves conservation programs mainly with private and often small-scale actors. In the voluntary carbon market, the private sector represents 70% of the market activity (*Locatelli et al., 2010*). However, motivations of companies purchasing forest credits still primarily reflects an interest in communicating social and environmental benefits generated by these projects.

→ Relevance for Mangroves

REDD+ could stimulate the sustainable management of current forests and enable rapid payments to local populations. Mangroves ecosystems are particularly well suited for carbon credit generation and application of the REDD+ system because of their resilience and potential as carbon sinks, 90% of the ecosystem carbon being stored in mangrove soils. Mangroves destruction can lead to the rapid release of large volumes of soil-stored carbon, while new plantations will assimilate carbon at much slower rates. In 2011, REDD+ projects accounted for 29% of the credits traded on the voluntary carbon market, whereas they represented 7% of the credits in the previous year (*Peters-Stanley et al., 2011*). Carbon markets can thus play an important role in the conservation of Mangroves, even if they are limited to voluntary systems.

Barriers to implementation

→ Exclusion of poor populations

Assigning economic value to resources, such as land and mangroves, leading to institutional transformations, can exclude and make access to local resources more difficult for local people. Land grabbing, in the name of biodiversity conservation and reforestation, including through REDD+, leads to drifts such as privatization of land inherently inequitable. Local participation in PES systems is increasingly seen as a way to address these exclusion issues and to lead to greater environmental justice (*Locatelli et al., 2010*).

→ The need to include local community knowledge

While REDD+ programs are currently developed and implemented in more than 40 countries (*World Bank Group, 2013*), they often relegate local communities to marginal roles. Imposed environmental discourses do not take into account local knowledge and may produce unfairness through land dispossession. It is thus important to achieve full and equitable participation in decision-making by affected parties and recognition of their diverse cultural values, knowledge and identities. Greater participation of local populations through consultation with the authorities managing the allocation of credits is desirable for a greater legitimacy of conservation projects, fair sharing of long-term revenues and respect for heterogeneity of local populations (*Locatelli et al., 2010*).

→ A spatiotemporal disconnection of the compensation

Carbon markets are one of the most efficient compensation mechanisms because benefits from carbon sequestration services are the same worldwide. However, often ecological functions of a degraded environment will not be compensated locally or typologically, consequently the actual impact of the compensation will be low or non-existent. Fair compensation, i.e. measures that compensate as much as possible ecosystem services, where they have been destroyed or degraded, is extremely difficult to implement. There is no equivalence between similar ecosystems located in different parts of the world; rendered services are, for the most part, intrinsically local. Moreover, actors with significant financial resources can afford to destroy more natural environments, as long as they are compensating more. Therefore, according to some authors, we are witnessing the birth of a right to destroy, often irreversibly, rare or vulnerable species or natural environments.

Lessons drawn on PES implementation for Mangroves conservation

Necessary conditions to a successful environment preservation

The importance of spatial and temporal variables

The scale importance is the first determining factor in preserving a defined ecosystem service. Physical, biological and geographical spatial characteristics must therefore be assessed.

→ Identification of the milieu and relevant actors in order to protect a given ecosystem service

The first challenge is to identify actors whose activity has a quantifiable impact on a geographically defined ecosystem that provides the targeted service. As mentioned above, the benefits derived from the carbon sequestration service, regarded as a pure public good, are the same worldwide, irrespective of their production location. In this case, the scale of action and the range of actors are global. Conversely, water services are generally much more localized. The perimeter of study can then be restricted at the level of a basin or watershed, which facilitates the identification of actors, whose practices can directly influence the quality of the ecosystem service.

→ Understanding effectiveness cycles of a defined ecosystem service

Living systems being constantly evolving and adapting, the objective of preserving ecosystem services necessarily involves a better understanding of natural systems cycles characterized by phases of growth and maturation, and how these cycles interact with one another. Action chronology must be guided by the identification of strategic moments according to these dynamics. It is, most of the time, useless to fight against a cycle dynamic, it is better to know at which cycle period the action should be the most efficient.

→ Necessity of performance evaluation, which remains difficult to implement (*Sukhdev et al., 2014*)

Measuring the performance of the protection of an ecosystem service is not easy. At this stage, due to the lack of robust long-term scientific data on PES, few evaluations of their impacts are available. Only a PES, which remunerates additional practices to those that would have been realised in absence of payments, can be considered as ***economically efficient*** and potentially ***environmentally effective***. However, this environmental effectiveness and economic efficiency remain difficult to measure. First, the assessment of environmental performance is subject to ***scientific uncertainties*** about connection between land use, ecological functions and ecosystem services. Second, ***budgetary constraints***, inherent in the implementation of projects, with the costs of collecting necessary information to evaluate the results, considerably limit the possibility of making reliable evaluation.

Key actors

It is possible to distinguish two major situations of PES involving different types of actors:

When beneficiaries are the direct users of services situation

In this case, beneficiaries are in a position to have the best information available on the program and can observe the actual maintenance of the ecosystem service. User-buyer situations are often found when benefits from ecosystem services have a degree of exclusivity on a limited scale, reducing both free-rider behaviour and transaction costs, thanks to the lower number of actors in negotiation. The situation, which is the most likely to lead to an efficient result, corresponds to a monopolistic exchange.

When beneficiaries are public organizations acting on behalf of users whose payments are not always voluntary

In this case, the non-exclusive nature of the ecosystem service, often global services, such as carbon segregation, strongly encourages free-rider behaviours and important transaction costs between agents, given the number and the geographical dispersion of beneficiaries. An intervention from a public hierarchical structure, representative of the general interest, is in this case indispensable.

Beyond these two extremes, the mediation of an external organisation may be necessary

An intermediary organisation, in the case of a local-scale PES, may be useful to represent a relatively heterogeneous group of beneficiaries, and/or to create favourable conditions for a mutual trust between the exchange parties. In a context of imperfect information, lack of knowledge, and scientific uncertainty, beneficiaries and providers may not be aware of the dependencies of their activities on some ecosystem services. They may therefore need support from a third agent, to better structure and coordinate their actions.

Conclusion

PES is unlikely to be a miracle tool for Mangrove preservation but rather an additional instrument to combine with other regulations in order to counterbalance deforestation pressures on Mangroves. Many constraints must be met for a PES to be efficient, local knowledge, evaluation of results, payments high enough to offset the opportunity costs, and a clear definition of actors' role based on a contract. If all those requirements are met, it will be possible to reduce, halt or reverse Mangroves loss. In case of REDD+, a process of reducing initial emissions of companies might be wiser to introduce, than an often-ineffective compensation, while their initial pollution does not have to be reduced. In both cases, strong regulation is necessary to ensure the smooth conduct of these operations. In order to ensure efficient environment preservation and a sustainable way of using resources, a long-term perspective should be adopted. In theory, if we can help individuals and institutions to recognize nature's value, then this should significantly increase investments in conservation of ecosystem services. In practice, however, it is more difficult to develop the scientific basis, policy and finance mechanisms, for integrating natural capital into resources and land use decisions.

9. Drawbacks of conventional shrimp farming, and alternatives

By Chiara Bonino and Julia Serban-Penhoat

Introduction

Bui Thanh Cong is a retired habitant from the province of Tra Vinh, in the South of Vietnam. During his free time, Cong decided to put in place a shrimp farm, due to the fact that shrimp farming is becoming a lucrative activity in the region. Like many other farmers specialized in the shrimp industry, he firstly ran his farm using conventional, intensive, unsustainable practices, which involved a heavy use of chemical products. The result of these practices was the depletion of mangroves on his property (International Union for Conservation of Nature (IUCN), 2015). But this isn't an isolated case. The development and intensification of shrimp farming in Southeast Asia started almost fifty years ago, with as initial goal the protection of fish populations. Shrimp were supposed to reduce the existing pressure on fish stocks, a consequence of the population growth in the region (Ha, Van Dijk & Bush, 2012). But today, the increasing demand for shrimp products coming predominantly from developed countries, such as the United States or European States (World Wildlife Fund (WWF), 2017), is pushing farmers in developing countries to increase their productions to unreasonable amounts. Thus, in 2007, shrimp productions accounted for a total of 2.3 million tons, and an important majority came from Asian developing countries (Lima, Rivera & Focken, 2012). In order the increase productions to follow the increasing demand, farmers are usually more attracted to unsustainable farming practices, which require less effort to put in place. However, while helping farmers to become more productive, these practices have also very negative impacts on the environment.

For instance, large fractions of mangrove forests have been intensively and consistently degraded over the last twenty years. This is particularly the case in countries such as Bangladesh (Sohel & Ullah, 2012). Mangroves, as well as other animal and plant species living in maritime areas, are therefore threatened by these activities. This is due to the fact that the climatic and biological characteristics of coastal regions are the most suitable for the development of shrimp farms (Azad, Jensen & Lin, 2009). Consequently, it is becoming a necessity to transition to more sustainable farming methods, in order to protected the environment and enable farmers to remain profitable over the long term.

Because of these unsustainable methods threatening entire ecosystems, the international community started to be involved in the shrimp sector. Given environmental disruptive impacts, international institutions, aquaculture associations and non-governmental organizations have raised the issues arising from the unsustainability of the shrimp farming industry; thus, putting great emphasis on the need for a radical change of shrimp farming methods. Consumers themselves have also started to show some concerns, and are looking for more environmentally friendly alternatives (Lima et al., 2012). But shrimp farming generates yearly important incomes for several developing countries such as Bangladesh, but also Indonesia, Brazil, Vietnam, Thailand and others (WWF, 2017). Moreover, shrimp farming, as well as other activities related to aquaculture, employ usually important parts of the concerned countries' national populations.

For example, over 0.7 million Bangladeshis have an employment related to aquaculture (Azad et al., 2009). Moreover, in the shrimp sector specifically, a majority of the production comes from small-scale farms (WWF, 2017). Hence, the governments themselves are looking for alternatives to conventional, unsustainable shrimp farms.

Taking these several issues into consideration, this paper seeks to analyse to what extent the current predominantly farming methods impact the environment, and how this now worldwide concern could be tackled.

To answer this question, the following part will be focusing on the several issues arising from conventional farming, and the way in which they represent a danger to large ecosystems in Southeast Asia. In a second part, the existing and more sustainable alternatives will be elaborated, with a focus on their advantages and inconveniences. The third synthesizes the main challenges encountered in the implementation of these alternatives. It concludes that, to proceed to an effective transition from conventional to sustainable shrimp farming system, support mechanisms need to be set in place and/or reinforced at national and legal levels in order to ensure employment to the concerned farmers.

Environmental issues related to conventional shrimp farming

Conventional shrimp farming systems have been criticized by international institutions, as well as non-governmental organizations from different levels, for their negative impact on the environment. Shrimp farms in Asia are usually located in coastal areas that have a rich and unique biodiversity. These regions also rely on fragile ecosystems, and the conversion of these regions to shrimp farms highly disturbs the well-functioning and balance of these ecosystems. As such, these regions are threatened with environmental degradation, environmental changes, biodiversity losses and disease outbreaks.

Environmental degradation

The first issue related to conventional shrimp farming is its impact on the environment, and especially the degradation that is taking place. Environmental degradation refers to "the deterioration in environmental quality from ambient concentrations of pollutants and other activities and processes such as improper land use" (Organisation for Economic Co-operation and Development (OECD), 2001). Indeed, since the development and intensification of shrimp farming, in Southeast Asia especially, important environmental degradations have been observed The main environmental degradation is on mangroves. Mangroves refer to marine ecosystems. As such, mangrove forests represent a main characteristic of coastal areas, and are particularly developed in countries such as Indonesia, Malaysia, Philippines, Bangladesh, Vietnam or Thailand. These mangroves provide important ecosystem services, such as the mitigation of floods for example. This is very important for developing countries because they often have large part of their population located in coastal areas, which is due to coastal areas being the most suitable for the development of several agricultural activities, such as shrimp farming. But today, it is estimated that over half of the mangrove forests worldwide have been lost, and 52% of this loss is due to the development of shrimp productions (Ha et al., 2012). This destruction is growing at a very fast rate. Indeed, estimations show that in 2009, over a third of the mangrove regions had already been destroyed due to shrimp farming (Azad et al., 2009).

Thus, within only a few years, the destruction extended a lot. The destruction of mangrove forests by conventional shrimp farming can be explained by the fact that mangroves represent suitable environments for shrimp farms, and ponds are often created in mangroves areas in order to benefit from its composition. Hence, many mangrove forests are converted into marine shrimp ponds (Lima et al., 2012). It is estimated that in order to produce one kilogram of shrimp, and average of 13 m2 of mangroves is needed. But because of the intensification of shrimp farming practices, that usually involve the use of a lot of chemical products, the mangroves deteriorate very fast after being converted. Therefore, farmers have to often leave behind converted mangrove areas, ones they used all its capacities. This practice is referred to as the “rape and run” practice (Shang, Leung & Ling, 1998, p.197). This is an important issue because it is now estimated that shrimp farms in coastal areas don’t last more than three to nine years before being left behind. But these environments need between 35 and 40 years to regenerate themselves. Besides reducing the mangroves ability to provide ecosystem services and mitigate floods and other environmental catastrophes, there destruction also leads to the subsidence of the land, which represents a hazard for populations leaving in coastal areas.

But the mangroves aren’t the only type of environment that has been degraded due to conventional shrimp farming. For example, wetlands are also a type of environment that has been converted into shrimp farms, even though wetlands are providing important ecosystem services as well (Azad et al., 2009).

Environmental changes

The conversion of environmental areas into shrimp farms isn’t only degrading the environment, but it is also impacting its composition. This phenomenon is referred to as an environmental change. Several environmental changes are currently taking place around shrimp farms that use conventional methods.

First of all, shrimp farming is leading to an increase in the greenhouse gas (GHG) emissions of the concerned area. This is due to the degradation of different forests types. The degradation of forests reduces the capacity of the planet to act as a carbon sink, meaning absorbing carbon dioxide located in the atmosphere (United Nations Environment Program (UNEP), 2012). Moreover, it is estimated that the production of shrimp itself released gazes that participate in increasing GHG emissions. As such, it is estimated that in order to produce 100 grams of Asian pink shrimp, 198 kilograms of carbon dioxide will be released in the atmosphere. In some areas, such as the province of Ca Mau in Vietnam, studies go further. While analysing the performances of conventional and organic farming systems, experts found out that the deforestation of mangroves was responsible for 94% of the GHG emissions of the area (Jonell & Henriksson, 2014).

A second environmental change is a higher pollution in the surrounding water sources. This can be explained by the waste created by the ponds, which is later on released in water sources. Another factor of pollution is the produced sludge (Lima et al., 2009). The waste is nevertheless the main contributor to the pollution of coastal waters because it is, in conventional farms, composed of organic waste, as well as chemical products and antibiotics (WWF, 2017).

The release of polluted waters in other water sources and the neighbouring agricultural fields can have important impacts on the functioning of the marine ecosystems, as well as on the health of the fauna, the flora and the population living in the area.

Thirdly, conventional shrimp farming changes the salinity of the soil. This is explained by the pumping of important volumes of groundwater. This intensive pumping in order to fill the ponds lowers the level of the groundwater, empties the aquifers that retain it, which leads to the subsidence of the land. This land subsidence allows saline water to enter aquifers, which overall increases the salinization of the soil and the water (Lima et al., 2012). This can lead to the destruction of ecosystem that can’t survive with too high degrees of salinization, and also represent a risk for the access of freshwater sources. As such, in Bangladesh, some population living near shrimp farms ended up with saline water instead of potable freshwater in their households (Azad et al, 2009).

These are the main environmental changes, but many other changes have occurred since the intensification of conventional shrimp farming in coastal areas. Another change is for example the increase of the acidity of the soils. Indeed, experts showed that conventional farms released acidifying substances in the atmosphere (Jonell & Henriksson, 2014). Acidity increase can be very dangerous for the produced shrimp themselves, because it makes them more vulnerable to diseases and parasites. Many production losses in shrimp farming have therefore been attributed to the outbreak of diseases that followed and acidification of the soils. A last change observed is also the eutrophication of the coastal area. All of these changes have caused of the abandon of shrimp farms, which we mentioned earlier, in several countries of Southeast Asia, such as for example Indonesia or Thailand (Azad et al., 2009).

Reduction of biodiversity

Conventional shrimp farming methods also lead to the reduction of biodiversity. Biodiversity represents “the range of genetic differences, species differences and ecosystem differences in a given area” (OECD, 2001). Because biodiversity is unique and tied to its location, a loss of biodiversity can’t be replaced. Therefore, it is important to consider the threats conventional shrimp farming methods are putting on the environment’s biodiversity.

First of all, it is reducing biodiversity through the degradation of the environment, because some plant and animal species living in coastal areas can be very specific to one region, and the destruction of their natural habitats represents a hazard on the development of their populations. The environmental changes, which we also already mentioned, impact ecosystems and therefore the good functioning of an entire coastal region. But the loss of biodiversity can also be found within the shrimp populations themselves.

Indeed, mainly two species are currently being cultivated in Southeast Asia. These two specific species are the penaeus vannamei, commonly called the Pacific white shrimp, and the penaeus monodon, known as the giant tiger prawn. The World Wildlife Fund (2017) estimates that up to 80% of the shrimp produced in conventional shrimp farming are these two species only. These is very alarming because the other type of shrimp is now threatened to become endangered species, due to the fact that the focus today is mainly on two types of shrimp.

Moreover, another issue is that wild fish species are often captured in areas with intense shrimp farming, and used to feed the produced shrimp (Azad et al., 2009). This intense catching of wild species has two major consequences. Firstly, many of these species die before they can be fed to the shrimp, and are therefore thrown away because they were not stocked correctly. This means that important volumes of fish are captured and then wasted. Some wild young shrimps have also been captured in order to be placed in the conventional shrimp ponds (WWF, 2017). If the depletion of wild species in coastal areas continues this way, the concerned captured species could be threatened by extinction. Secondly, removing these species from their natural habitat means that their natural predators can’t feed themselves on them anymore. In other words, conventional shrimp farming that uses wild shrimp as feed or in their ponds highly impact the stability of ecosystems by intensively removing essential feed sources from the oceans. Hence, a change in the production systems and practices is needed in order to reduce the impact on the biodiversity of the concerned areas.

Disease outbreaks

Disease outbreaks mean that unwanted organisms are developing themselves in the shrimp ponds, affecting their health and development. Disease outbreaks are very frequent in conventional shrimp farming. Holmström et al. (2003) did a study in order to illustrate this phenomenon. They decided to interview seventy-six farmers working along the Thai Coast, a region with very intense shrimp farming. Within these farmers, 86% explained that they had to deal with disease outbreaks on their farms. These numbers can go even higher in some regions. This is a big issue because in order to fight against pest and disease outbreaks, the most used solution in conventional farming is the use of antibiotics. As such, out of the seventy-six interviewed farmers, 74% admitted that they had already use antibiotics, and 14% of them explained that they use antibiotics on a daily basis in their ponds. The issue with antibiotics is that they are made out of chemical products, which has already explained pollutes the environment, such as water sources and neighbouring soils. The fact that disease outbreaks are so frequent is due to the type of shrimp that are cultivated. Mainly two species are cultivated in Asia, the pacific white shrimp and the giant tiger prawn. But these types of species are very vulnerable to diseases. The other problem linked with diseases is that they are often deadly. Once the shrimp get affected, they usually start to go to the top of the pond more often, which makes them easier prays for birds such as seagulls. These seagulls, once they feed on the contaminated shrimp, get contaminated themselves and spread the disease to other ponds nearby when they defecate (WWF, 2017). Thus, the impact of the disease gets bigger and can destroy.

Therefore, disease outbreaks are considered as “the biggest obstacle to the development of shrimp aquaculture” in several countries, such as Bangladesh (Paul & Vogl, 2011, p.206). Besides the environmental damages they represent, disease outbreaks are also an important financial threat to shrimp farmers, because they can lead to important production losses. Some farms had to be shut down because of too intense disease outbreaks, which can increase the unemployment rate of a region. These outbreaks are also very costly. For example, in China, several billions of renminbi (RMB) have been lost due to disease outbreaks in the period from 1993 to 2000 (Biao & Kaijin, 2007).

These several impacts on the environment are making conventional farming systems unsustainable on the long term. Therefore, it is a necessity to develop sustainable alternative that would reduce, or completely stop, the pressure of shrimp farms on their surrounding environments. A few practices and farm systems have already been developed and put in place in several countries, and are going to be developed in the following part.

Alternative solutions to conventional shrimp farming methods

Conventional shrimp farming systems have proved unsustainable on the long-term. Given its socio-environmental disruptive impacts, some actors along the shrimp supply chain such as shrimp farmers are already implementing techniques to improve the sustainability performance of the shrimp aquaculture.

However, despite the potential solutions that innovative farming systems may offer, their socio-economic impacts have so far been quite limited. That is mainly due to the very limited adoption of such practices on large-scale farms, as well as the lack of governmental support, insufficient and inefficient transcalar governance, and smallholder farmers’ difficult access to financing.

Furthermore, there is still little research on the economic and financial long-term viability, notably with regards to more intensive shrimp farms that have recently been developed in major shrimp exporting countries such as Thailand and Viet Nam (Engle, et al., 2017).

In this context, it emerges that an analysis of the arising opportunities for sustainable shrimp farming is therefore critical to address the future development perspectives of the industry; while at the same time addressing concerns that may hinder its long-term sustainability potential.

Defining Sustainability

In 1987, the Bruntland report identified sustainability as a form of “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” Hempel, Winther, & Hambrey, 2003).

Thanks to its simplicity and comprehensiveness, the Bruntland report’s definition of sustainability is still nowadays the most commonly accepted in the international community. By stressing the importance of natural resources preservation to ensure the long-term productive capacity of the Earth, this definition of sustainability encompasses the three pillars of sustainable development: social, economic and environmental sustainability. Consequently, sustainable shrimp farming models shall account for improved impacts with regards to all the aspects of the tridimensional concept of sustainable development.

According to the Mangrove Action Project initiative (MAP), four main criteria can be identified to measure the sustainability performance of a shrimp farm:

- 1. The maintenance of affected ecosystems integrity
- 2. A fair balance between the exploitation of natural resources and its impacts on the affected local communities - the users that most heavily rely for their livelihoods on those natural resources that are being depleted by land conversion and conflicting land use due to shrimp farming.
- 3. A business structure oriented towards the promotion of socio-economic equity within and between nations
- 4. Economic and financial viability

(MAP, 2018)

According to the aforementioned indicators, several forms of sustainable shrimp culture systems are currently being implemented. The latter can be divided into extensive and intensive production systems; the first drawing from traditional, low-input aquaculture, and the second based on technical innovation and efficiency coupled with grater upfront investment, as well as higher capital and resources inputs.

Extensive shrimp farming alternatives

Originating from traditional aquaculture, extensive shrimp farming methods have been sustainably practiced for thousands of years in Southeast Asian countries. Usually practiced in small-scale farms, extensive shrimp production requires very little input and maintenance, as it relies "on diurnal tidal inundations to supply the larval shrimp and (…) their food nutrients to the ponds" (MAP, 2018). In addition to that, ponds are usually placed among mangroves, which, by allowing for the preservation of shrimp' natural habitat, serve not only as natural shrimp nurseries, but they also provide regular feeding as well as the optimal place for juvenile shrimp to mature before harvesting. Mangroves thus provide most of the required services for shrimp farming, without adding any extra cost for small farmers since ponds are excavated among mangroves, which in turn drastically reduces the necessary maintenance levels and associated costs. Low-inputs however correspond to low-yields, which explains why extensive farming systems target mainly local demand and harvested shrimp does not constitute a major ratio in the total export shrimp production (MAP, 2018).

In Southeast Asian countries and specifically in Viet Nam, shrimp farmers are implementing innovative production methods; which mainly consist of slight variations of the traditional extensive farming system. Notably two among these techniques have obtained better results in terms of environmental sustainability: the rice – shrimp farming model (I) and the poly-culture production system (II).

- (I) Rice – shrimp farming model

Based on the traditional Indonesian "tambak" system, this farming model combines rice paddy production with shrimp farming. Based on a yearly, rotating cycle of crops production, this system alternates shrimp crops (during the wet season, lasting from February to August) to rice crop (during the dry season). This farming system has revealed a model of environmentally sustainable and economically sound shrimp farming, specifically in the Tra Vinh province of Viet Nam, in the Mekong River Delta region, where rice-shrimp production has been practiced since 1999 (Hương, 2017). The main advantage of this dual production system is the reciprocal benefits it brings for both rice crops and shrimp farming. In fact, organic residues from shrimp crops enrich soil fertility by enhancing nutrition facts. At the same time, shrimp farming takes advantage of improved pond environment thanks to increased soil mineralization and a net reduction in toxic substances and germs (Hương, 2017).

As a result, when coupled with rice production, shrimp farming can be sustainable through the delivery of a "clean shrimp product", thanks to the limited use of chemical substances and pesticides, which would in turn reduce production costs, thus creating room for higher profit margins for farmers. (Hương, 2017).

→ (II) Poly-culture production system

As an alternative to intensive shrimp farming methods that are heavily reliant on chemical inputs, mainly to prevent diseases outbreak, small scale farmers in the Tra Vinh province of Viet Nam are experiencing new farming systems.

A pilot project, directed and funded by the organization Mangroves for the Future (MFF) through the Research Institution for Aquaculture 2 (RIA 2), is at present being implemented in the region, with the objective of promoting mangrove-based poly-culture to help farmers shift away from more intensive forms of aquaculture.

According to the International Union for the Conservation of Nature (IUCN) "polyculture is an agricultural technique where different crops occupy the same plot, imitating nature's diverse ecosystems" (IUCN, 2015). Allowing for the culture of various species within the same pond, this farming method is substantially different form intensive farms, where land is cleared to make room for single-crop cultures.

In Viet Nam, farmers are implementing poly-culture by combining shrimp with crab and mud clam crops. The latter serving as natural water filters, and mangroves providing the optimal feeding and breeding ground, shrimp in their natural habitat become more resistant to diseases (IUCN, 2015).

Consequently, thanks to lower inputs and higher profits, poly-culture can be another effective and economically viable model for sustainable shrimp farming (IUCN, 2015).

Extensive farming methods, coupled with innovative variations, can claim to be effective alternatives to more intensive farming techniques. However, despite offering solutions to decrease the use of chemicals and pesticides and limit mangroves forests' depletion due to land use conversion, extensive farming systems are often small-scale and do not have the production capacity to address the steadily increasing global demand for shrimp.

As a result, it is interesting to analyse whether large-scale shrimp farms have taken any sustainability measures; and to what extent the latter have proved effective in tackling the current unsustainable structure of the shrimp industry.

Intensive shrimp farming alternatives

In response to an increasing demand for aquaculture products, and specifically for shrimp, on the international markets, shrimp exporting countries such as China, Thailand, Vietnam, Bangladesh and Indonesia have developed intensive farming systems. Such methods require less space in terms of land occupation; but, given their high-density stocks, increased production costs are required, both in terms of feeding and technical equipment (water filtration and aeration systems) (Engle, et al., 2017).

Moreover, as diseases outbreaks are more common in high-stock density farms and given that they are one of the major threats to the sustainability of shrimp farms, intensive methods require an increased use of chemicals and pesticides for diseases prevention and regular water quality control.

Awareness-raising campaigns on the sustainability issues in the shrimp industry have led major exporting countries to develop innovative farming practices. Among them, two deserve a deeper analysis: sustainable, intensive farming systems in Thailand and Viet Nam (I) and the alternative, highly-intensive, US-designed farming method aimed at reducing export dependency in western shrimp importing countries (II).

→ (I) Intensive farming systems in Thailand and Viet Nam

To answer the increasing global demand for aquaculture products, several exporting countries have recently shifted their shrimp production towards more intensive systems. Exemplary is the case of Thailand and Vietnam, where some preliminary research has concluded that intensified aquaculture can be more sustainable and economically viable than extensive farming (Engle, et al., 2017).

Intensive production can outperform less intensively managed farms due to increased yields and higher volumes in shrimp production. The latter would in fact further spread annual fixed costs, which allows for a net reduction in the overall cost per metric ton of shrimp produced (Engle, et al., 2017)[68]. Thanks to a more efficient use of fixed input resources such as land and investment capital, intensified aquaculture proves to be an efficient technique to increase yields, and ultimately allow for increased profitability. Nonetheless, the ability for small scale farmers to change their techniques towards increased intensification is subject to a number of constraints.

The drivers that are most likely to hinder a successful transition for smallholder farmers are the lack of adequate access to capital, farms' location differences; as well as the lack of technical expertise and appropriate management skills (Engle, et al., 2017).

(II) "Closed production system": a highly-intensive, innovative farming technique. As an analysis from the Mangroves Action Project underlines, "open production systems", which are nowadays the most widely used shrimp farming techniques, "still pollute and degrade their surrounding environments, while at the same time depending on a healthy state of natural resources to maintain their own production" (MAP, 2018). As a result, this dependency comes at great environmental costs, which explains why "closed production systems", by eliminating at least some drawbacks of such "throughput systems", emerge as an alternative of extensive, open-production schemes (MAP, 2018).

Fully enclosed systems are currently being developed in various countries, from Thailand to the US (MAP, 2018). They implicate the construction of "fully contained facilities"; and require massive regular investment in technology and equipment to primarily ensure good aeration and water quality, thus enabling the prevention of diseases outbreak. As a closed system, this new technique could in the future be coupled with poly-culture, or become the ideal space and opportunity, thanks to ongoing monitoring of environmental conditions, for the development of fully organic shrimp production (MAP, 2018; Quarto, 1998).

Despite its conventional connotation of "unsustainable" farming system, intensive aquaculture may effectively complement traditional, extensive shrimp culture, as it would allow for increased production, a more efficient use of resources and increased profitability.

Furthermore, highly-intensive, enclosed systems could not only adapt their production capacities to meet demand flows; they could also provide a solution to reduce import countries' current heavy dependence on foreign shrimp supply (MAP, 2018; Quarto, 1998).

As previously stressed, a major disadvantage of intensified and highly-intensive production is the prohibitive upfront cost, permanent capital intensity and initial high financial risk (MAP, 2018).

In addition to that, low management skills and technical expertise can hinder the shift towards an intensification of culture practices for smaller farmers; whose extensive production systems, in 2015, still account for over 85% of total shrimp farming producers in Vietnam (Hai, Duc, Son, Minh, & Phuong, 2015).

[68] According to Engle et al (2017), "costs per metric ton of shrimp produced decreased from the lowest to the highest intensity level (from US$10,245 at lowest intensity to US$3484 at highest for P. monodon and from US$24,301 to US$5387 for L. vannamei in Vietnam and from US$8184 at the lowest intensity level to US$3817 at the highest intensity level per metric ton for L. vannamei in Thailand)"

Discussion

Innovative and environmentally-friendly techniques for sustainable shrimp farming are currently being developed and tested in most exporting countries. Sustainable systems range from the use of mixed crops on the same land plot, known as polyculture, to mangrove-integrated systems and rice-shrimp rotating farming techniques. In addition to those, aquaculture intensification and highly-intensive farms also emerge as potential solutions to increase yields and profitability of shrimp production, while reducing environmental impacts, as they allow the industry to meet the increasing global demand for shrimp.

Nonetheless, each innovation comes with associated challenges and drawbacks. Vietnamese smallholder farmers using modified extensive systems for instance, are still heavily dependent on foreign seed imports due to the lack of high-quality, domestic brood stock availability. Also, they permanently struggle against the spreading of diseases, and specifically the EMS: Early Mortality Syndrome. In the attempt to prevent diseases outbreaks, farmers make constant use of chemicals and pesticides; which, as for the reliance on foreign seed supply, is not sustainable on the long run (Rurangwa, Baumgartner, Nguyen, & Van de Vis, 2016).

Moreover, despite the fact that the shrimp farming industry in Vietnam is largely based on small farms, smallholders are often marginalized in the shrimp supply chain. Small farmers are in fact too often unaware of the opportunities for innovation, since improvement programs rather target large-scale farming companies. (Rurangwa, Baumgartner, Nguyen, & Van de Vis, 2016).

In this context, the intensification of aquaculture emerges therefore as a potential solution to these challenges as well as a future perspective for the sustainable development of an integrated and inclusive shrimp farming industry.

Further and more accurate research need to be conducted as to examine the economic viability and financial feasibility of intensified systems on the long-term. However, it seems that an improved horizontal (through cooperatives) and vertical (along the supply chain) integration is needed to ensure the long-term sustainability and effectiveness of the shrimp industry (Phung & Pham, 2017).

Conclusion

Sustainable shrimp farming seems a feasible alternative to conventional systems. Innovative measures and small-scale initiatives have already been developed and implemented to counteract the dangerous impacts of current unsustainable shrimp farming practices. However, it also emerges that more sustainable systems are still at their very early stage of development. Therefore, for them to become mainstream and be widely adopted, there will be the need for further support on the policy level. This may include improved access to funding for smallholder farmers, improved infra-governance coordination, increased smallholders' engagement and collaboration through the establishment of farmers' associations and cooperatives for sharing individual experiences and draw best practices.

Sustainability is a very recent development in the shrimp farming industry; as such, it provides a great opportunity for mobilization of capital and resources towards the sustainability objective. Shrimp farming has wide impacts on the socio-economic and environmental levels. To address the complexity of the multi-layered issues behind it, governments need to take proactive action. There is currently much need for change as well as room for improvement. The consequences of inaction, or of little action are already detrimental; governments and stakeholders along the shrimp supply chain shall therefore no longer wait, but start acting now.

10. Consumption Alternatives to Mangrove-Depleting Shrimp

By Charlotte Festa

Introduction

Imagine, twenty years from today, you are visiting your neighbourhood supermarket to buy some shrimp for the prawn salad you want to prepare for dinner. You walk up to the fish section and stop in front of the cooling shelf. You now have the option to choose out of three different products: the first is a package of conventional shrimp, imported from Thailand. It has a sign on it indicating that animals and the environment have been harmed in the process of producing it. This product is also particularly expensive due to an environmental tax that has been put on it. Next to it sits another package that says 'clean shrimp'. It contains exactly the same shrimp, with the same taste and the same quality, however it was produced in a lab. The third package you spot contains plant-based shrimp – a shrimp-resembling product that tastes suspiciously similar to conventional shrimp but that was made of algae.

Which one are you going to choose? In all likelihood, you are an average consumer with the following train of thought: Plant-based products might be healthier and eco-friendlier, however you don't want to make any concessions in terms of taste – in fact, you just prefer the real thing. You thus eliminate the third product. Considering the second package, you might be convinced by the animal and environment argument on the label, however you are most probably neither an animal advocate nor an environmentalist. Since product one and two are basically the same in terms of taste and quality, it is the lower price of the second, combined with its positive connotations, that finally convinces you to choose it.

Is this whole scenario merely a figment? Maybe, but not probably. Quite on the contrary, it is very likely that this scenario is going to come true – and it would be highly desirable if it did, keeping in mind the different aspects highlighted by previous sections. With the global population continuing to be on the rise it is hard to imagine how we are going to satisfy our growing hunger for shrimp in years to come without completely exploiting our environment.

The previous sections have however shown that not all shrimp are necessarily exploiting the environment. There are indeed sustainable shrimp producers. Furthermore, as touched upon in Section 5, there are imaginable solutions to environmental, economic and social impacts of shrimp farms. One approach that has been mentioned is the return to local, traditional agriculture, possibly focused on a larger variety of products depending on seasonal peculiarities. However, attaining similar scope and cost efficiency with such systems seems virtually impossible. At the same time, we cannot count upon a future decrease in demand for shrimp. In order to sustainably satisfy our world's appetite for shrimp, our system needs to become more efficient – in fact, it needs to become much more efficient.

Numerous scientists are currently working on attaining this very efficiency. This section seeks to explore potential consumption alternatives to mangrove-depleting shrimp. Thereby, in order to ensure the usefulness of this analysis, a particular focus shall be laid on existing alternatives which are – or could be – able to display comparable economies of scale as conventional, mangrove-depleting shrimp. Two consumption alternatives have been identified as meeting this criterion, whereby one represents an alternative product outside of the shrimp market and the other a product within the market. The former is represented by plant-based shrimp and the latter by clean shrimp, as portrayed in the introductory scenario. Numerous obstacles are however expected to impede the breakthrough of both products. Chapter two and three will respectively introduce the two products, illustrating not only the nature of the product and its advantages but also challenges linked to its market success. While plant-based shrimp clearly outdoes conventional shrimp in the environmental and health realm and while it convinces regarding taste and appearance, a complete substitution of conventional by plant-based seems improbable due to consumer preferences. Clean meat, on the contrary, seems to provide plausible answers to many of the most pressing issues introduced by mangrove-depleting shrimp. Objections however likewise remain for this product, particularly in terms of funding, consumer acceptance and political will.

Alternatives Outside of the Shrimp Market: Plant-Based Shrimp

The Product

“Seafood from Seaplants” is the slogan of New Wave Foods, a company founded in late 2015 by Dominique Barnes and Michelle Wolf who had formerly been working in marine conservation (New Wave Foods, n.d.-a). The female duo started to focus on developing plantbased seafood alternatives after they had been accepted by Indie Bio, the largest biotech accelerator worldwide (ibid.). Their vision: to provide healthy and sustainable seafood, to save the oceans and to tackle social rights issues within the billion-dollar shrimp industry (Pellman Rowland, 2017). The result: shrimp made from algae and soy-based plant proteins – “natural, Kosher, non-GMO, and vegan-friendly” (New Wave Foods, n.d.-b), free from setbacks in terms of health, allergens, chemicals, cholesterols, moral convictions and the environment.

Using algae as basic component, the company additionally manages to fight a major inefficiency ingrained in animal-based products: instead of directly consuming nutrients provided by plants, we often choose to process these nutrients through animals in order to subsequently consume animal flesh. The caloric loss that come along with multi-level food chains is substantial across the range of animal-based products. According to New Wave Food’s co-founder Barnes, “algae is part of the foundation on which the ocean is built on” (Barnes cit. in Webb, 2018). Fish, she continues, is being glorified for its high omega 3 content, however the fish actually derives its omega 3 from algae itself (Barnes cit. in Scher, 2017). New Wave Foods’ shrimp is however not only promising concerning its externalities but also with regards to the consumption experience. Thanks to meticulous texture development and a red algae extract which actually likewise provides the colour for conventional shrimp, New Wave Foods has been able to create a product that is “uncompromising in taste” (New Wave Foods cit. in Van Hare, 2017).

What started out as a promising idea has in the meanwhile become reality: New Wave Foods’ first product, plant-based shrimp, is being sold publicly since early 2018, primarily to foodservice operators such as schools and companies. One of the first customers of New Wave Foods’ shrimp was Google, aiming at cutting conventional shrimp consumption in the company’s cafeterias (Van Hare, 2017). New Wave Foods seeks to soon cater local retail stores on the large scale, with 2018 marking a year of important advancements, and to expand its product variety to additional seafood products such as crab, lobster and tuna (Webb, 2018).

Objections

Despite these positive aspects, some experts seem to abstain from eager optimism regarding plant-based shrimp as an alternative to conventional shrimp. While it is important to focus on expanding the plant protein sector considering current trends, some voices deem it unlikely for plant-based products to be able to ascend beyond a niche market for environmentalists and vegans/vegetarians (e.g. Precht, 2016; Shapiro, 2018). They claim that, during the past years and decades, human nature has taught us the unlikelihood of voluntary dietary changes, even if consumers are aware of health-related, environmental or social impacts of their habits (Shapiro, 2018, p. 220f.). This argument is illustrated by the share of vegetarians and vegans in high- GDP countries which has been increasing only very slowly in most regions, e.g. from 3% in 1989 to 5.7% in 2014 in the UK (British Council, n.d.) and from 8%–9% in 2001 to 10% in 2016 (Vegetarierbund Deutschland, n.d.).

Three factors mainly influence consumer food choices: price, taste and convenience (Shapiro, 2018, p. 230). In addition, social and cultural norms might account for certain preferences so that, even if plant-based products might persuade in terms of price and taste, and even if they are easily available, some people just prefer to eat 'real meat' (ibid.).

Furthermore, the possibility to consume meat is often regarded as a means to assess socioeconomic statuses – not only scientifically but also by indigenous people themselves who frequently refer to their welfare in terms of meat abundance (Shapiro, 2018, p. 37). Not least in combination with future world population prospects which postulate an increase from currently around 7.6 billion to 11.2 billion people by 2100 (UN DESA Population Division, 2017, p. 2) as well as the expected rise in affluence and growing middle classes in developing economies (e.g. Pezzini, 2012), these factors hint at future increasing demand for meat.

Taking into account the insights on customer behaviour provided above, plant-based shrimp might be one possible alternative to the consumption of conventional shrimp as soon as it is produced and sold at a large scale, particularly as it seems to be able to cater the three main food consumption choice factors price, taste and convenience. However, some people might still be deterred by the fact that, even if it looks and tasted exactly like conventional shrimp, plant-based shrimp is actually just that: plant-based. It is thus likely that plant-based shrimp alone will not be enough of an alternative to conventional shrimp if change ought to truly take place.

Alternatives Within the Shrimp Market: Clean Shrimp

The Product

The founding stone of the solution to virtually all remaining problems might have been laid in August 2013 when Dutch professor Mark Post gave substance to a scientific hope named clean meat[69] (Shapiro, 2018a, p. 56ff.). Together with his team, he had extracted stem cells from cow muscle tissue, subsequently growing them in a bovine serum solution. With the help of additional nutrients, the cells had soon multiplied inside the cultivator, "behaving as they do in the body" (Shapiro, 2018a), resulting in the first proof of concept – a burger paddy entirely made of clean meat. The stiff price of $330,000 for this first paddy could be lowered soon after, with current estimated price levels of $11 per

[69] 'Clean meat' – also known as cultured meat, lab-grown meat or in vitro meat – is meat produced through cellular agriculture, whereas cellular agriculture refers to the science or practice of farming animals from animal cells rather than entire animals. The term was first coined by the Good Food Institute, as a pointer to clean energy and clean meat's food safety benefits (Shapiro, 2018a).

burger by 2020 (Shapiro, 2018b, p. 84). Research has subsequently also expanded to several other animal-based products, among others seafood.

Put simply, clean meat is exactly the same as conventional meat, with the small but important difference that no animal had to be bred and killed in the process. Post and his team applied to food what has largely been used for medical purposes such as the production of real human tissues for transplantation to food products (Shapiro, 2018b, p. 10). Even though a lot still has to happen for clean meat to become a viable solution – including the necessity of attaining consumer acceptance – the majority of the scientific community is currently in agreement that raising animals for consumption shall soon become obsolete. Bill Gates, Richard Branson and Peter Thiel are among the people who have recently been investing in clean meat (Shapiro, 2018b; Singh, 2017) Even agribusinesses such as Tyson and Cargill have joined the ranks of cellular agriculture pioneers (Kowitt, 2018; Singh, 2017).

What these investors now believe in actually started out with a NASA research project in the years 1999–2002 when scientists worked on developing lab-grown meat to be used by astronauts in space (Shapiro, 2018b, p. 30ff.). The first meat product that was rendered was seafood – a goldfish. It was a student from Johns Hopkins University, Jason Matheny, who was the first to wonder why nobody strived at cultivating meat on earth and who subsequently left no stone unturned, finally resulting, among other undertakings, in Post's mandate (ibid.).

Fasting forward to 2018, scientists estimate that clean meat could be commercialized by 2021 (Shapiro, 2018b, p. 85). They thereby talk about several animal-based products ranging from cow, pig and chicken flesh to foie gras, milk, eggs, leather, fish – and shrimp. It will probably even be possible to breed hybrids such as lamb-shrimp steaks (Shapiro, 2018b, p. 74). Along the way, animal farmers will probably turn into microbiologists and slaughterhouses are likely going to be replaced by meat breweries (Shapiro, 2018b, p. 82). The fact that clean meat is produced in a cultivator has significant consequences: huge areas of land and ocean that have formerly been used as farms and fields could return back to their natural habitats (Shapiro, 2018b, p. 9). This would allow shrimp farms in mangroves to be replaced by local shrimp breweries in the village and subsequently permit mangroves to revitalise.

Even though the disruption of the whole industry might result in serious job losses, it likewise represents a promising possibility for indigenous people and smallholder farmers to reclaim power and independence from big agribusinesses, including reduced vulnerability in terms of price and climate events, as small-scale production in local village meat breweries could even be the optimal scenario. The transition to clean shrimp could result in the restoration of local businesses which, as discussed in Section 5, would be highly desirable from both the economic and the social perspective.

Clean meat seems to undoubtedly outdo its conventional equivalent as it promises to solve several pressing issues of our time including biodiversity loss, climate change, GMO utilisation, antibiotics resistance, water pollution and animal welfare (Shapiro, 2018b). Compared to conventional breeding techniques, cellular agriculture is much more efficient as it requires both less resources as well as significantly shorter timespans to attain an equal amount of meat. To provide an idea of the scope, one stem cell sample derived from a cow could produce up to 20'000kg of beef (Shapiro, 2018b, p. 64). Clean meat is also much safer in terms of hygiene, food-borne illnesses and diseases. In fact, "greater risk of contamination [comes] from your own hands than the meat itself" (Shapiro, 2018b, p. 49).

These prospects, although promising, might sound utterly implausible – however, prospects are rarely uncontested when disruption is in sight. The way the food industry would be altered might seem too incisive to be true but several past technological breakthroughs have likewise confounded our systems as well as the society's dependency on marine animals in similar ways, such as the discovery of kerosene in 1854 (Shapiro, 2018b, p. 27). Until then, homes had been lighted with the help of whale oil. The US whaling fleet alone had slaughtered over 8'000 whales annually in 1854, whereas only three decades later, the industry was already decimated by 95% (Shapiro, 2018b, p. 28).

Objections

Nevertheless, several challenges ought to be tackled until shrimp production could actually move from mangroves to the lab. While technology does still need a few years in order to render scale effects, science will only be able to advance with the necessary funding. According to experts, the possibly biggest barrier is that investment into tissue engineering is often directed towards medicine instead of food development (Shapiro, 2018b, p. 51).

Another substantial challenge lies within consumer acceptance. Even though not necessarily rational, some consumers claim that they would not be willing to switch to clean meat since they deem it unnatural (Shapiro, 2018b, p. 43). However, if we look at how animal products such as shrimp are cultivated today, there is likewise nothing much natural embedded within these processes. Additionally, a large variety of foods we regularly consume today are being produced in laboratories. It is likely that, if consumers are educated about the process and the benefits of clean shrimp mentioned above, and if price, taste and convenience are ensured, they will happily settle for clean shrimp if they find themselves in front of their local supermarkets' cooling shelves. Potentially, clean meat and shrimp will find acceptance and popularity without much ado. After all, our ancestors in 1854 would have probably asked for more efficient whale oil usage technologies rather than for kerosene.

The two most important remaining concerns relate to culture and capabilities. Will it be possible for producers to familiarize themselves with moving away from traditional shrimp farming? Are they even going to be able to attain the necessary skills to engage in cellular agriculture? Altogether, provided technological feasibility, consumer acceptance and the necessary policy actions to initiate funding, education and competence building, clean shrimp seems to represent an immensely promising alternative to conventional shrimp consumption.

Conclusion

This section has focused on alternatives to the consumption of conventional, i.e. mangrove depleting shrimp. Previous remarks in this paper series have provided insights into different shrimp farm designs. Among others, the preceding sections put sustainable and certified shrimp farm models in the spotlight, highlighting their compatibility with environmental concerns.

However, the shrimp market is characterized by high degrees of competition, forcing producers to attain high output levels at low prices. Furthermore, demographic and social developments give reason to expect even higher demand for shrimp in future years. It is thus deemed unlikely that sustainable, certified shrimp is going to take over from conventional shrimp as a valid and feasible consumer good.

The easiest alternative to the consumption of mangrove-depleting shrimp would be for everyone to simply stop consuming shrimp. However, as elaborated on in Chapter two of this section, relying upon voluntary changes in human behaviour seems unreasonable since only few consumers include environmental externalities in individual utility calculations.

Two conceivable products have been introduced in the course of this paper, both of which could represent serious and feasible alternatives to mangrove-depleting shrimp. First, plant-based shrimp was portrayed – a product developed by the company New Wave Foods. It has the potential to serve as an alternative to conventional shrimp, particularly since it is claimed to provide a strikingly similar consumption experience in terms of appearance and taste. However, coming back to the role human nature is able to play in decisions concerning behaviour and consumption, it might be slightly too gullible to trust that meat eaters will soon praise plant based shrimp just like vegetarians and vegans do.

On the contrary, clean shrimp seems to hold the ability to yield a serious answer to shrimp alternatives for all kinds of consumers. It represents precisely the same product as conventional shrimp – with the small but mighty difference that it entails no environmental or social concessions. Quite the opposite, it could even empower local communities and smallholder farmers by resulting in the restoration of local businesses.

Perhaps the best answer to fight mangrove-depleting shrimp consumption and production lies within a combination of several possible options; in setting all available levers in motion. It might be reasonable to foster the further development of clean shrimp while simultaneously promoting the substitution of conventional shrimp by plant-based shrimp. Thereby, governments and the international community need to pave the way – possibly supported by civil society and the private sector – by further facilitating research and development for clean shrimp; by educating the public about the effects of conventional shrimp consumption; by, in the long run, directing subsidies towards plant-based and clean shrimp; and by using political means to shape societal acceptance of consumption alternatives.

Forging the bridge back to the introductory remarks of this paper, chances are that our children's children will experience consternation in front of their local supermarket shelfs when being confronted with the option of buying either mangrove-depleting, plant-based or clean shrimp.

However, when they gape in disbelief it might not be due to the availability of the third but due to the unfamiliarity of the first option.

11. References

Section 1 (Mangroves depletion: what is the problem?)

Alongi, Daniel M. 2002. 'Present State and Future of the World's Mangrove Forests'. *Environmental Conservation* 29 (03). https://doi.org/10.1017/S0376892902000231.

Boone Kauffman, J, Virni B Arifanti, Humberto Hernández Trejo, Maria del Carmen Jesús García, Jennifer Norfolk, Miguel Cifuentes, Deddy Hadriyanto, and Daniel Murdiyarso. 2017. 'The Jumbo Carbon Footprint of a Shrimp: Carbon Losses from Mangrove Deforestation'. *Frontiers in Ecology and the Environment* 15 (4): 183–88. https://doi.org/10.1002/fee.1482.

Cooper, E., L. Burke, and N. Bood. 2008. 'Coastal Capital: Economic Contribution of Coral Reefs and Mangroves to Belize'. Washington DC: World Resources Institute.

Cuff, David J., and Andrew Goudie. 2009. *The Oxford Companion to Global Change*. New York: Oxford University Press.

Dear, Ian, and Peter Kemp Kemp. 2005. *The Oxford Companion to Ships and the Sea*. Oxford: Oxford University Press. http://0-www.oxfordreference.com.library.metmuseum.org/view/10.1093/acref/9780199205684.001.0001/acref-9780199205684.

Donato, Daniel C., J. Boone Kauffman, Daniel Murdiyarso, Sofyan Kurnianto, Melanie Stidham, and Markku Kanninen. 2011. 'Mangroves among the Most Carbon-Rich Forests in the Tropics'. *Nature Geoscience* 4 (5): 293–97. https://doi.org/10.1038/ngeo1123.

Ellison, Aaron M. 2004. 'Wetlands of Central America'. *Wetlands Ecology and Management* 12 (1): 3–55. https://doi.org/10.1023/B:WETL.0000016809.95746.b1.

FAO. 2005. 'Global Forest Resources Assessment 2005: Progress towards Sustainable Forest Management'. FAO Forestry Paper 147. Rome: FAO.

Giri, C., E. Ochieng, L. L. Tieszen, Z. Zhu, A. Singh, T. Loveland, J. Masek, and N. Duke. 2011. 'Status and Distribution of Mangrove Forests of the World Using Earth Observation Satellite Data: Status and Distributions of Global Mangroves'. *Global Ecology and Biogeography* 20 (1): 154–59. https://doi.org/10.1111/j.1466-8238.2010.00584.x.

Hamilton, Stuart E., and Daniel Casey. 2016. 'Creation of a High Spatio-Temporal Resolution Global Database of Continuous Mangrove Forest Cover for the 21st Century (CGMFC-21): CGMFC-21'. *Global Ecology and Biogeography* 25 (6): 729–38. https://doi.org/10.1111/geb.12449.

Hashim, Ahmad Mustafa, and Sim Mong Pheng Catherine. 2013. 'A Laboratory Study on Wave Reduction by Mangrove Forests'. *APCBEE Procedia* 5: 27–32. https://doi.org/10.1016/j.apcbee.2013.05.006.

IUCN. 2017. 'The IUCN Red List of Threatened Species'. 2017. http://www.iucnredlist.org/.

Kathiresan, Kandasamy, and Narayanasamy Rajendran. 2005. 'Coastal Mangrove Forests Mitigated Tsunami'. *Estuarine, Coastal and Shelf Science* 65 (3): 601–6. https://doi.org/10.1016/j.ecss.2005.06.022.

Kodikara, Kodikara Arachchilage Sunanda, Nibedita Mukherjee, Loku Pullukuttige Jayatissa, Farid Dahdouh-Guebas, and Nico Koedam. 2017. 'Have Mangrove Restoration Projects Worked? An in-Depth Study in Sri Lanka: Evaluation of Mangrove Restoration in Sri Lanka'. *Restoration Ecology* 25 (5): 705–16. https://doi.org/10.1111/rec.12492.

Lavieren, H. van, M. D. Spalding, D. Alongi, Mami Kainuma, M. Clüsener-Godt, and Z. Adeel. 2012. 'Securing the Future of Mangroves. A Policy Brief'. UNU-INWEH, UNESCOMAB with ISME, ITTO, FAO, UNEP-WCMC and TNC. http://inweh.unu.edu/wp-content/uploads/2015/05/Securing-the-Future-of-Mangroves1.pdf.

Luther, David A., and Russell Greenberg. 2009. 'Mangroves: A Global Perspective on the Evolution and Conservation of Their Terrestrial Vertebrates'. *BioScience* 59 (7): 602–12. https://doi.org/10.1525/bio.2009.59.7.11.

Mazda, Yoshihiro, Michimasa Magi, Yoshichika Ikeda, Tadayuki Kurokawa, and Tetsumi Asano. 2006. 'Wave Reduction in a Mangrove Forest Dominated by Sonneratia Sp.' *Wetlands Ecology and Management* 14 (4): 365–78. https://doi.org/10.1007/s11273-005-5388-0.

McIvor, A. L., T. Spencer, I. Möller, and M. D. Spalding. 2012. 'Storm Surge Reduction by Mangroves'. Cambridge Coastal

Research Unit Working Paper 41 2. Natural Coastal Protection Series. The Nature Conservancy and Wetlands International. http://www.innovators2015.com/Resources/storm-surge-reduction-by-mangroves-report.pdf.

Osland, Michael J., Nicholas Enwright, Richard H. Day, and Thomas W. Doyle. 2013. 'Winter Climate Change and Coastal Wetland Foundation Species: Salt Marshes vs. Mangrove Forests in the Southeastern United States'. *Global Change Biology* 19 (5): 1482–94. https://doi.org/10.1111/gcb.12126.

Osland, Michael J., Nicholas Enwright, and Camille L. Stagg. 2014. 'Freshwater Availability and Coastal Wetland Foundation Species: Ecological Transitions along a Rainfall Gradient'. *Ecology* 95 (10): 2789–2802. https://doi.org/10.1890/13-1269.1.

Polidoro, Beth A., Kent E. Carpenter, Lorna Collins, Norman C. Duke, Aaron M. Ellison, Joanna C. Ellison, Elizabeth J. Farnsworth, et al. 2010. 'The Loss of Species: Mangrove Extinction Risk and Geographic Areas of Global Concern'. Edited by Dennis Marinus Hansen. *PLoS ONE* 5 (4): e10095. https://doi.org/10.1371/journal.pone.0010095.

Richards, Daniel R., and Daniel A. Friess. 2016. 'Rates and Drivers of Mangrove Deforestation in Southeast Asia, 2000–2012'. *Proceedings of the National Academy of Sciences* 113 (2): 344–49. https://doi.org/10.1073/pnas.1510272113.

Saintilan, Neil, Nicholas C. Wilson, Kerrylee Rogers, Anusha Rajkaran, and Ken W. Krauss. 2014. 'Mangrove Expansion and Salt Marsh Decline at Mangrove Poleward Limits'. *Global Change Biology* 20 (1): 147–57. https://doi.org/10.1111/gcb.12341.

Spalding, M. D., R. D. Brumbaugh, and E. Landis. 2016. 'Atlas of Ocean Wealth'. Arlington: The Nature Conservancy.

Spalding, Mark, François Blasco, Colin Field, International Society for Mangrove Ecosystems, World Conservation Monitoring Centre, and International Tropical Timber Organization, eds. 1997. *World Mangrove Atlas*. Okinawa: The International Society for Mangrove Ecosystems.

Spalding, Mark, Mami Kainuma, and Lorna Collins. 2010. *World Atlas of Mangroves*. Earthscan.

Stong, A., and S. Minnemeyer. 2015. 'Satellite Data Reveals State of the World's Mangrove Forests'. World Resources Institute. 20 February 2015. http://www.wri.org/blog/2015/02/satellite-data-reveals-state-world%E2%80%99s-mangrove-forests.

Tanaka, Norio, Yasushi Sasaki, M. I. M. Mowjood, K. B. S. N. Jinadasa, and Samang Homchuen. 2007. 'Coastal Vegetation Structures and Their Functions in Tsunami Protection: Experience of the Recent Indian Ocean Tsunami'. *Landscape and Ecological Engineering* 3 (1): 33–45. https://doi.org/10.1007/s11355-006-0013-9.

Thomas, Nathan, Richard Lucas, Peter Bunting, Andrew Hardy, Ake Rosenqvist, and Marc Simard. 2017. 'Distribution and Drivers of Global Mangrove Forest Change, 1996–2010'. Edited by Shijo Joseph. *PLOS ONE* 12 (6): e0179302. https://doi.org/10.1371/journal.pone.0179302.

Tilman, David, Robert M. May, Clarence L. Lehman, and Martin A. Nowak. 1994. 'Habitat Destruction and the Extinction Debt'. *Nature* 371 (6492): 65–66. https://doi.org/10.1038/371065a0.

UNEP. 2014. *The importance of mangroves to people: a call to action*. Edited by Jan-Willem van van Bochove, Emma Sullivan, and Takehiro Nakamura. Cambridge: United Nations Environment Programme World Conservation Monitoring Centre. http://apps.unep.org/publications/index.php?option=com_pmtdata&task=download&file=-The%20importance%20of%20mangroves%20to%20people_%20a%20call%20to%20action-2014Mangrove.pdf.

UNESCO. 2017. 'Mangroves'. UNESCO. Ecological Sciences for Sustainable Development. 2017. http://www.unesco.org/new/en/natural-sciences/environment/ecological-sciences/specific-ecosystems/mangroves/.

———. 2018. 'UNESCO - MAB Biosphere Reserves Directory'. 2018. http://www.unesco.org/mabdb/br/brdir/directory/resecosy.asp.

Yates, K. K., C. S. Rogers, J. J. Herlan, G. R. Brooks, N. A. Smiley, and R. A. Larson. 2014. 'Diverse Coral Communities in Mangrove Habitats Suggest a Novel Refuge from Climate Change'. *Biogeosciences* 11 (16): 4321–37. https://doi.org/10.5194/bg-11-4321-2014.

Zhang, Keqi, Huiqing Liu, Yuepeng Li, Hongzhou Xu, Jian Shen, Jamie Rhome, and Thomas J. Smith. 2012. 'The Role of Mangroves in Attenuating Storm Surges'. *Estuarine, Coastal and Shelf Science* 102–103 (May): 11–23. https://doi.org/10.1016/j.ecss.2012.02.021.

Section 2 (Ecosystem services provided by healthy mangroves)

Alongi, D. M. (2002). Present state and future of the world's mangrove forests. Environmental Conservation.

Ariel E. Lugo, A. E. (1951). Ecology pf Mangroves. Miami Herald.

Bao, T. Q. (2011). Effect of mangrove forest structures on wave attenuation in coastal Vietnam. OCEANOLOGIA.

Bradley B. Walters, e. a. (2008). Ethnobiology, socio-economics and management of mangrove forests: A review. Aquatic Botany.

Clare Duncan, J. H. (2016). Rehabilitating mangrove ecosystemservices: A case study on the relative benefits of abandoned pond reversion from Panay Island, Philippines. Marine Pollution Bulletin.

EDWARD B. BARBIER, I. S. (1998). Valuing Mangrove Fishery. Environmental and Resource Economics.

F. Dahdouh-Guebas, e. a. (n.d.). How effective were mangroves as a defence against the recent tsunami? Current Biology Vol 15 No 12.

FAO Forest Department . (1994). Mangrove Forest Management guidelines . FAO.

Friess, D. A. (2016). Ecosystem Services and Disservices of Mangrove Forests: Insights from Historical Colonial Observations. Forests.

Luciana de Souza Queiroz, e. a. (2017). Neglected ecosystem services: Highlighting the socio-cultural perception of mangroves in decision-making processes. Ecosystem Services.

Luke M.Brander, A. J. (2012). Ecosystem service values for mangroves in Southeast Asia: A meta-analysis and value transfer application. Ecosystem services .

ONG, K. E. (1998). Different kinds of mangrove forests provide different goods and services. Biogeography letters.

Shay Simpson, G. B. (2016). Stakeholder perspectives for coastal ecosystem services and influences on value integration in policy. Science.

Syed Ainul Hussain, E. R. (2008). Valuing mangrove ecosystem services: linking nutrient retention function of mangrove forests to enhanced agroecosystem production. Science+Business Media.

UNEP. (1996). Tourism and Coastal Degradation in the Wider Caribbean. Island Resources Foundation .

UNEP. (2006). Marine and Coastal Ecosystems and Human Well-being . UNEP

Section 3 (Drivers of mangroves depletion)

ACKEFORS, Hans (World Aquaculture Society, 2009): The evolution of a worldwide shrimp industry. World Aquaculture Journal, p. 56. Retrieved 6 May 2018: https://www.was.org/magazine/ArticleContent.aspx?Id=592

AMERICAN MUSEUM OF NATURAL HISTORY (n.d.): Mangrove Threats and Solutions. Online resource. Retrieved 6 may 2018 from: https://www.amnh.org/explore/science-bulletins/bio/documentaries/mangroves-the-roots-of-the-sea/mangrove-threats-and-solutions

AMERICAN MUSEUM OF NATURAL HISTORY (n.d.): What's a Mangrove? And How Does It Work? Online journal, retrieved 6 may 2018 from: https://www.amnh.org/explore/science-bulletins/bio/documentaries/mangroves-the-roots-of-the-sea/what-s-a-mangrove-and-how-does-it-work/

C-CONDEM (2008): '¡10 años junt@s! 1998 – 2008'. Online magazine, anniversary edition. Retrieved 5 May 2018, from: http://www.ccondem.org.ec/imagesFTP/5036.10anos_2008.pdf

CHEANG, Michael (2010): Eco-friendly shrimp farming. Online article. Retrieved 6 May 2018 from: https://www.thestar.com.my/lifestyle/features/2010/03/29/ecofriendly-shrimp-farming/

DUKE, N. C. *et al*. (2007): A world without mangroves? Science Journal. Article. Vol. 317, pp. 41–42.

ENVIRONMENTAL JUSTICE ATLAS (n.a.): Shrimp Farming in Muisne, Ecuador. Online resource. Retrieved 6 may 2018 from: https://ejatlas.org/conflict/shrimp-farming-in-muisne-ecuador

FAO (1994): Mangrove Forest Management Guidelines. FAO Forestry Paper, n. 117, p. 1.

FAO (1998): Towards Sustainable Shrimp Culture Development: Implementing the FAO Code of Conduct for Responsible Fisheries (CCRF). Fisheries Department. Rome.

FAO (2003): Status and Trends in Mangrove Area Extent Worldwide. By Wilkie, Mette Løyche and Fortuna, Serena. Forest Resources Development Service, FAO Forestry Department. Resources Assessment Working Paper No. 63. Retrieved 6 May 2018 from: http://www.fao.org/docrep/007/J1533E/J1533E02.htm

FAO (2005-2018): Cultured Aquatic Species Information Programme. Hypophthalmichthys molitrix. Cultured Aquatic Species Information Programme. Text by Yang, N. In: *FAO Fisheries and Aquaculture Department* [online]. Rome. Retrieved 5 may 2018 from: http://www.fao.org/fishery/culturedspecies/Hypophthalmichthys_molitrix/en

FAO (2006): International Principles for Responsible Shrimp Farming. FAO, NACA, UNEP, WB, WWF.

FAO (2016): The State of World Fisheries and Aquaculture: Contributing to Food Security and Nutrition for All. Rome. Part 1: World Review, p. 76.

FUJINAGA, Motosaku Hudinaga (n.d.): Kuruma Shrimp (Penaeus japonicus) Cultivation in Japan. FAO E/44. Retrieved 8 May 2018: http://www.fao.org/docrep/005/ac741t/AC741T15.htm

GROUP ON EARTH OBSERVATIONS (2017): Earth Observations 2030 Agenda for Sustainable Development. Global Mangrove Watch – Mapping Extent and Annual Changes in the Global Mangrove Cover. p. 13. Retrieved 6 May 2018 from: https://www.earthobservations.org/documents/publications/201703_geo_eo_for_2030_agenda.pdf

GUNTHER, Marc (2012): Shrimp Farms' Tainted Legacy Is Target of Certification Drive. Yale School of Forestry & Environmental Studies. Online resource. Retrieved 6 may 2018 from: https://e360.yale.edu/features/shrimp_farms_tainted_legacy_is_target_of_certification_drive

LEWIS, R.R. III, PHILLIPS, M.J., CLOUGH, B. and MACINTOSH, D.J. (2003): Thematic Review on Coastal Wetland Habitats and Shrimp Aquaculture. Report prepared under the World Bank, NACA, WWF and FAO Consortium Program on Shrimp Farming and the Environment. Published by the Consortium. p. 11.

MANGROVE ACTION PROJECT (n.d.): Mangrove Issues: Deforestation. Online resource. Retrieved 6 may 2018 from: https://mangroveactionproject.org/mangrove-issues/

RICHARDS, D. R. and Friess, D. A. (2016): Rates and Drivers of Mangrove Deforestation in Southeast Asia, 2000–2012. PNAS, vol. 113, no. 2, pp. 344-349. Retrieved 6 May 2018: https://dx.doi.org/10.1073/pnas.1510272113

SPALDING, M.D, BLASCO, E. and FIELD, CD. (Eds., 1997): World Mangrove Atlas. The International Society for Mangrove Ecosystems, Okinawa, Japan. 178 pp.

STEVENS, William K. (1994): *Everglades: Paradise Not Quite Lost. New York Times: Article. Retrieved 6 may 2018 from: https://www.nytimes.com/1994/03/22/science/everglades-paradise-not-quite-lost.html*

TIME MAGAZINE (2008): Heroes of the environment 2008: Jurgenne Primavera. Online Article. Retrieved 6 May 2018 from: http://content.time.com/time/specials/packages/article/0,28804,1841778_1841782_1841792,00.html

UNESCO (2015): PROCLAMATION OF THE INTERNATIONAL DAY FOR THE CONSERVATION OF THE MANGROVE ECOSYSTEM. 38th Session of the General Conference, 38 C/66. Item 4.19 of the provisional agenda. Retrieved 5 May 2018 from: http://unesdoc.unesco.org/images/0023/002353/235350e.pdf

UNESCO (2016): International Day for the Conservation of the Mangrove Ecosystem. Online resource at the *Did you know* section. Retrieved 5 may 2018 from: http://www.unesco.org/new/en/unesco/events/prizes-and-celebrations/celebrations/international-days/int-day-for-the-conservation-of-the-mangrove-ecosystem/mangrove-ecosystem-2016/

VALIELA, I., BOWEN, J. L. & YORK, J. K. (2001): Mangrove Forests: One of the World's Threatened Major Tropical Environments. Bioscience Journal, vol. 51, n. 10, p. 812, reproducing data from Linden and Jernelov (1980), Saenger *et al.* (1983), Ong (1995), Fortes (1988), Jory (1997), and Stonich *et al.* (1999).

WARNE, Kennedy (2011): Let Them Eat Shrimp: The Tragic Disappearance of the Rainforests of the Sea. Island Press / Shearwater Books: Washington, Covelo, London.

Section 4. (Case studies)

Afroz, T., & Alam, S. (2013, January). Sustainable shrimp farming in Bangladesh: A quest for an Integrated Coastal Zone Management. *Ocean and Coastal Management, 71*, 275-283.

Ali, A. (2006). Rice to shrimp: land use/land cover changes and soil degradation in Southwestern Bangladesh. *Land Use Pol*(23), 421-435.

Anderson, C. (2014). *Mangrove and Forest Loss near Three Coastal Protected Areas in Ecuador: Integrating Global Tree Cover and National Census Data.* BSES Senior Dept. of Geography.

Bonilla, M. (2017, July 10). Afros conservan su tradición pesquera en el manglar urbano. *El Comercio*, pp. http://www.elcomercio.com/tendencias/afros-tradicion-pesca-manglar-esmeraldas.html.

Bravo, E. (2003). LA INDUSTRIA CAMARONERA EN ECUADOR. *Globalización y Agricultura. Jornadas para la Soberanía Alimentaria.* Barcelona.

C-CONDEM. (2013). *C-CONDEM denuncia la existencia de cercas con alambres de púas electrificadas en diversas camaroneras del país y exige revertir la concesión a los implicados.* Retrieved May 6, 2018, from ccondem.org.ec: http://ccondem.org.ec/boletin.php?c=1075

Chaboud, C., Courtois, S., & Feltz, G. (2002). *La ruée vers l'or rose : regards croisés sur la pêche crevettière traditionnelle à Madagascar.* IRD Éditions.

CNA. (2018). *SUSTAINABLE SHRIMP PARTNERSHIP (SSP) IMPULSA EL DESARROLLO SOSTENIBLE Y RESPONSABLE DE LA INDUSTRIA CAMARONERA MUNDIAL.* Retrieved May 5, 2018, from CÁMARA NACIONAL DE ACUACULTURA : https://www.cna-ecuador.com/sustainable-shrimp-partnership-ssp-impulsa-el-desarrollo-sostenible-y-responsable-de-la-industria-camaronera-mundial/

CNA. (2018). *Acuicultores insisten en ser atendidos directamente por el Ministro del Interior.* Retrieved May 5, 2018, from Cámara Nacional de Acuacultura: https://www.cna-ecuador.com/delincuencia-cobro-la-vida-de-una-persona-y-activa-las-alertas-en-el-sector-camaronero/

CNA. (2018). *Ecuador Lidera Sustainable Shrimp Partnership SSP.* Retrieved May 5, 2018, from Cámara Nacional de Acuacultura: https://www.cna-ecuador.com/ecuador-lidera-sustainable-shrimp-partnership-ssp/

CNA. (2018). *Más de 900 millones de camarón ecuatoriano se exportaron en el 2017.* Retrieved May 5, 2018, from Cámara Nacional de Acuacultura: https://www.cna-ecuador.com/mas-de-900-millones-de-libras-de-camaron-ecuatoriano-se-exportaron-en-el-2017/

El Comercio. (2017, Abril 10). Gobierno y productores impulsan desarrollo de la marca 'Camarón Ecuatoriano'. *El Comercio*, pp. http://www.elcomercio.com/actualidad/gobierno-productores-impulsan-desarrollo-camaron.html.

FAO. (2006?). *National Aquaculture Sector Overview.* Retrieved May 6, 2018, from Fisheries and Aquaculture Department: http://www.fao.org/fishery/countrysector/naso_ecuador/en

FAO. (2017, December 4). *Low farmed shrimp output for 2017.* Retrieved May 1st, 2018, from FAO: http://www.fao.org/in-action/globefish/market-reports/resource-detail/en/c/1070811/

Gaibor, M. d. (2014). Socio Manglar, una esperanza para un ecosistema en peligro. *GESTIÓN*(245), 62-63.

GAPCM. (2018). *Groupement des Aquaculteurs et Pêcheurs de Crevettes à Madagascar*. Retrieved May 5, 2018, from http://www.gapcm.org/aquaculture/

García, F. (2015). *PROGRAMA NACIONAL DE INCENTIVOS "SOCIO BOSQUE" CAPITULO: SOCIO MANGLAR.* Quito: Ministerio del Ambiente del Ecuador.

Giri, C., & Muhlhausen, J. (2008). Mangrove Forest Distributions and Dynamics in Madagascar (1975–2005). *Sensors (Basel), 8*(4), 2104–2117.

Harper, J. C. (2002). *Endangered Species: Health, Illness and Death among Madagascar's People of the Forest.* Durham: Academic Press.

Hossain, M. S., & Uddin, M. J. (2013, September). Impacts of shrimp farming on the coastal environment of Bangladesh and approach for management. *Environmental Science and Biotechnology, 12*(3), 313-332.

Islam, S. (2008). From pond to plate: Towards a twin-driven commodity chain in Bangladesh shrimp aquaculture. *Food Policy*(33), 209–223.

IUCN. (2010, Abril 10). *Mangrove forests in worldwide decline.* Retrieved May 5, 2018, from IUCN: https://www.iucn.org/content/mangrove-forests-worldwide-decline

Machado, D. (2013, September 25). *La historia oculta del camarón.* Retrieved March 25, 2018, from Pan V: http://www.planv.com.ec/investigacion/investigacion/la-historia-oculta-del-camaron

MAE. (2017). *MAE conmemora el Día Internacional de Defensa del Manglar.* Retrieved March 25, 2018, from ambiente.gob.ec: http://www.ambiente.gob.ec/mae-conmemora-el-dia-internacional-de-defensa-del-manglar/

MAE, & FAO. (2014). *Árboles y Arbustos de los Manglares del Ecuador.* Quito.

MAEP UPDR Ocean Consultant. (2004). *Filière Crevette d'Aquaculture.* Madagascar: Ministère de l'Agriculture, de l'Elevage et de la Pêche.

Mendoza, M. (2018, February 18). El camarón rompió 40 años de liderazgo del banano. *El Comercio*, pp. http://www.elcomercio.com/actualidad/camaron-rompe-liderazgo-banano-exportacion.html.

OEC. (2018). *Observatory of Economic Complexity*. Retrieved May 5, 2018, from https://atlas.media.mit.edu/en/

Paspuel, W. (2014, November 10). Medianos y pequeños camaroneros empujan el crecimiento del sector. *El Comercio*, pp. http://www.elcomercio.com/actualidad/camaron-empresas-crecimiento-economia-precios.html.

Paul, B. G., & Vogl, C. R. (2011, March). Impacts of shrimp farming in Bangladesh: Challenges and alternatives. *Ocean & Coastal Management, 54*, 201-211.

Salgado, N. R. (2014, March). Neoliberalismo e industria camaronera en Ecuador. (L. Verdes, Ed.) *Revista Latinoamericana de Estudios Socioambientales*(15), 55-78.

Sorgato, V. (2016, August 16). Ocho cosas que quizás no sabía sobre los manglares de Ecuador . *El Comercio*, pp. http://www.elcomercio.com/tendencias/curiosidades-manglares-ecuador-proteccion-ecosistemas.html.

World Bank. (2017, March 21). *Madagascar: Some Solutions to Reduce Poverty.* Retrieved May 4, 2018, from World Bank: http://www.worldbank.org/en/news/press-release/2017/03/21/poverty-in-madagascar-recent-findings

→ Documentaries

Swedish Society for Nature Conservation (2011). The devastating truth behind shrimp farming. Prod: Eco Storm. Link: https://www.youtube.com/watch?v=hPJpPEH3l7o

Swedish Society for Nature Conservation (2011). The truth behind "organic" shrimp farming in Ecuador. Prod: Eco Storm. Link: https://www.youtube.com/watch?v=NNpkEgtCEB8

Section 5. (Markets of "mangrove-depleting shrimp")

Anderson, J. L., Valderrama, D., & Jory, D. E. (2017, October 16). GOAL 2017: Global shrimp production review and forecast: Shrimp producer surveys generate forecast of 4.82 MMT by 2019. Retrieved 5 May 2018, from https://www.aquaculturealliance.org/advocate/goal-2017-shrimp-production-survey/

Ashton, E. (2008). The impact of shrimp farming on mangrove ecosystems. *CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources*, *3*(003). https://doi.org/10.1079/PAVSNNR20083003

Bales, K. (2016, January 15). How Hunger for Shrimp and Slavery Destroy Mangroves [Excerpt]. Shrimp demand satisfied with slave labor is also driving an environmental disaster in Southeast Asia. Retrieved 5 May 2018, from https://www.scientificamerican.com/article/how-hunger-for-shrimp-and-slavery-destroy-mangroves-excerpt/

Dear, I., & Kemp, P. (Eds.). (2006). *The Oxford companion to ships and the sea* (2nd ed). Oxford ; New York: Oxford University Press.

Food and Agriculture Organization of the United Nations. (2018). Cultured Aquatic Species Information Programme. Retrieved 5 May 2018, from http://www.fao.org/fishery/culturedspecies/Penaeus_vannamei/en

Leechman, A. (1918). The Genus Rhizophora in British Guiana. *Bulletin of Miscellaneous Information (Royal Gardens, Kew)*, *1918*(1), 4. https://doi.org/10.2307/4118290

Leung, P., & Engle, C. R. (2008). *Shrimp Culture Economics, Market, and Trade*. New York, NY: John Wiley & Sons. Retrieved from http://nbn-resolving.de/urn:nbn:de:101:1-2015012910159

Liu, D. (2016). *Molecular detection of animal viral pathogens*. Retrieved from http://www.crcnetbase.com/isbn/9781498700368

Macnae, W. (1969). A General Account of the Fauna and Flora of Mangrove Swamps and Forests in the Indo-West-Pacific Region. In *Advances in Marine Biology* (Vol. 6, pp. 73–270). Elsevier. https://doi.org/10.1016/S0065-2881(08)60438-1

NASA. (2000). Global Mangrove Forests Distribution, v1 (2000). Retrieved 5 May 2018, from http://sedac.ciesin.columbia.edu/data/set/lulc-global-mangrove-forests-distribution-2000/maps

Polidoro, B. A., Carpenter, K. E., Collins, L., Duke, N. C., Ellison, A. M., Ellison, J. C., … Yong, J. W. H. (2010). The Loss of Species: Mangrove Extinction Risk and Geographic Areas of Global Concern. *PLoS ONE*, *5*(4), e10095. https://doi.org/10.1371/journal.pone.0010095

Primavera, J. H. (1998). Mangroves as Nurseries: Shrimp Populations in Mangrove and Non-mangrove Habitats. *Estuarine, Coastal and Shelf Science*, *46*(3), 457–464. https://doi.org/10.1006/ecss.1997.0275

Saenger, P. (2002). Introduction: The Mangrove Environment. In P. Saenger, *Mangrove Ecology, Silviculture and Conservation* (pp. 1–10). Dordrecht: Springer Netherlands. https://doi.org/10.1007/978-94-015-9962-7_1

Sathirathai, S., & Barbier, E. (2001). VALUING MANGROVE CONSERVATION IN SOUTHERN THAILAND. *Contemporary Economic Policy*, *19*(2), 109–122. https://doi.org/10.1111/j.1465-7287.2001.tb00054.x

Shrimp News International. (2018). Barry Bowen and Belize Aquaculture Limited Recollections of Robins McIntosh, Who Ran BAL for Five Years. Retrieved 5 May 2018, from http://www.shrimpnews.com/FreeReportsFolder/FarmReportsFolder/RobinsMcIntoshWAS2011.html

Spalding, M., Kainuma, M., & Collins, L. (2010). *World atlas of mangroves*. London; Washington, DC: Earthscan. Retrieved from http://public.eblib.com/choice/publicfullrecord.aspx?p=585447

World Wildlife Fund. (2018). FARMED SHRIMP. Retrieved 5 May 2018, from https://www.worldwildlife.org/industries/farmed-shrimp

Section 6 (The economy of mangrove depleting shrimp: a focus on South and Southeast Asian coastal areas)

Ahmed, Nesar, Edward H. Allison, et James F. Muir. « Using the Sustainable Livelihoods Framework to Identify Constraints and Opportunities to the Development of Freshwater Prawn Farming in Southwest Bangladesh ». *Journal of the World Aquaculture Society* 39, nº 5 (October 2008): 598-611. https://doi.org/10.1111/j.1749-7345.2008.00198.x.

Ahmed, Nesar, et Max Troell. « Fishing for Prawn Larvae in Bangladesh: An Important Coastal Livelihood Causing Negative Effects on the Environment ». *AMBIO* 39, nº 1 (February 24, 2010): 20-29. https://doi.org/10.1007/s13280-009-0002-y.

Akhter, Sanzida. « Shrimp farming, mangrove depletion and environmental governance: A case study on the coastal region of Bangladesh ». Proc. of International Conference on Environmental Aspects of Bangladesh. Japan, September 2010.

Alauddin, Mohammad, et M Akhter Hamid. « Shrimp Culture in Bangladesh with Emphasis on Social and Economic Aspects ». *Towards Sustainable Shrimp Culture in Thailand and the Region: Proceedings of a Workshop Held at Hat Yai, Songkhla, Thailand, 28 October-1 November 1996*, Ed. Paul T. Smith. Canberra: Australian Centre for International Agriculture Research, 1999, 53-62.

Baumgartner, Urs, Shelagh Kell, et Tuan Hoang Nguyen. « Arbitrary mangrove-to-water ratios imposed on shrimp farmers in Vietnam contradict with the aims of sustainable forest management ». *SpringerPlus* 5 (2016): 438. https://doi.org/10.1186/s40064-016-2070-3.

Bosma, Roel H., Tin H. Nguyen, Audrie J. Siahainenia, Ha T. P. Tran, et Hai N. Tran. « Shrimp-based livelihoods in mangrove silvo-aquaculture farming systems ». *Reviews in Aquaculture* 8, nº 1 (March 1, 2016): 43-60. https://doi.org/10.1111/raq.12072.

Bush, Simon R., Paul AM Van Zwieten, Leontine Visser, Han van Dijk, Roel Bosma, Willem F. de Boer, et Marc Verdegem. « Scenarios for resilient shrimp aquaculture in tropical coastal areas ». *Ecology and society* 15, nº 2 (2010).

Doyle, Alister. « Mangroves under threat from shrimp farms: U.N. » Reuters, November 14, 2012. https://www.reuters.com/article/us-mangroves/mangroves-under-threat-from-shrimp-farms-u-n-idUSBRE8AD1EG20121114.

Ha, Tran Thi Thu, Han van Dijk, et Simon R. Bush. « Mangrove conservation or shrimp farmer's livelihood? The devolution of forest management and benefit sharing in the Mekong Delta, Vietnam ». *Ocean & Coastal Management* 69 (December 1, 2012): 185-93. https://doi.org/10.1016/j.ocecoaman.2012.07.034.

Holmyard, Nicki. « Strong growth seen in global shrimp market ». Seafood Source, August 22, 2017. https://www.seafoodsource.com/features/strong-growth-seen-in-global-shrimp-market.

Miao, Keith, Fiona Kinniburgh, Anirudh Kumar, et Tal Lee Anderman. « Shrimp Farming in Bangladesh ». *Columbia University, Undergraduate Program in Sustainable Development*, May 2012, 30.

Primavera, J H. « Socio-economic impacts of shrimp culture ». *Aquaculture Research* 28, nº 10 (October 1, 1997): 815-27. https://doi.org/10.1046/j.1365-2109.1997.00946.x.

Sathirathai, Suthawan, et Edward B. Barbier. « Valuing Mangrove Conservation in Southern Thailand ». *Contemporary Economic Policy*, 1995, 14.

Shamsuzzaman, Md. Mostafa, Mohammad Mahmudul Islam, Nusrat Jahan Tania, Md. Abdullah Al-Mamun, Partho Protim Barman, et Xiangmin Xu. « Fisheries resources of Bangladesh: Present status and future direction ». *Aquaculture and Fisheries* 2, nº 4 (July 1, 2017): 145-56. https://doi.org/10.1016/j.aaf.2017.03.006.

Shang, Yung C., Pingsun Leung, et Bith-Hong Ling. « Comparative Economics of Shrimp Farming in Asia ». *Aquaculture* 164, nº 1-4 (May 1998): 183-200. https://doi.org/10.1016/S0044-8486(98)00186-0.

« Status and trends in mangrove area extent worldwide ». Food and Agriculture Organization of the United Nations, 2003. http://www.fao.org/docrep/007/j1533e/J1533E02.htm.

World Wildlife Fund. « A Business Case for Improved Environmental Performance in Southeast Asian Shrimp Aquaculture », June 22, 2017. https://c402277.ssl.cf1.rackcdn.com/publications/1073/files/original/Vietnam_Shrimp_Business_Case_v5.pdf?1497988115.

———. « Farmed Shrimp | Industries ». Word Wild Life. Consulted on February 11, 2018. https://www.worldwildlife.org/industries/farmed-shrimp.

———. « Making shrimp sustainable in Thailand | Stories ». Word Wild Life. Consulted on February 12, 2018. https://www.worldwildlife.org/stories/making-shrimp-sustainable-in-thailand.

———. « WWF Research Finds Improved Environmental Performance is Good for Shrimp Aquaculture Business | Press Releases ». Word Wild Life, June 22, 2017. https://www.worldwildlife.org/press-releases/wwf-research-finds-improved-environmental-performance-is-good-for-shrimp-aquaculture-business.

Section 7 (certification and labelling)

Ashton, E. (2008) 'The impact of shrimp farming on mangrove ecosystems.', CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources, 3(003).

Boyd, C. E. and McNevin, A. A. (2012) 'An Early Assessment of the Effectiveness of Aquaculture Certification and Standards', in Steering Committee of the State-of-Knowledge Assessment of standards and Certification (ed) Toward Sustainability: The Roles and Limitations of Certification. Washington DC, USA, p. A35–A69.

Bush, S. R. and Oosterveer, P. (2015) 'Vertically differentiating environmental standards: The case of the marine stewardship council', Sustainability (Switzerland), 7(2), pp. 1861–1883.

Christian, C. et al. (2013) 'A review of formal objections to Marine Stewardship Council fisheries certifications', Biological Conservation, 161, pp. 10–17.

Cooper, T., Ludlow, M. and Clift, T. (2012) 'Examining the role of eco-labels in changing the approach to sustainability in the commercial fisheries', Greener Management International, 57(Change and Sustainability), pp. 27–42. Available at: http://www.jstor.org/stable/greemanainte.57.27.

FAO (2016) The State of World Fisheries and Aquaculture 2016. Contributing to food security and nutrition for all. Rome.

Getz, C. and Shreck, A. (2006) 'What organic and fair trades lebals do not tell us: Towards a place based-understanding of certification.', 30(5)(September), pp. 490–501.

Godfray, H. C. J. et al. (2010) 'Food security: the challenge of feeding 9 billion people.', Science (New York, N.Y.), 327(5967), pp. 812–8.

Ha, T. T. T. et al. (2012) 'Organic coasts? Regulatory challenges of certifying integrated shrimp-mangrove production systems in Vietnam', Journal of Rural Studies, 28(4), pp. 631–639.

Ha, T. T. T. and Bush, S. R. (2010) 'Transformations of Vietnamese shrimp aquaculture policy: Empirical evidence from the Mekong Delta', Environment and Planning C: Government and Policy, 28(6), pp. 1101–1119.

Hadjimichael, M. and Hegland, T. J. (2016) 'Really sustainable? Inherent risks of eco-labeling in fisheries', Fisheries Research, 174, pp. 129–135.

Hilborn, R. (2005) 'Are sustainable fisheries achievable?', in Marine Conservation Biology: The Science of Maintaining the Sea's Biodiversity. Island Press.

Jonell, M. et al. (2013) 'Eco-certification of farmed seafood: Will it make a difference?', Ambio, 42(6), pp. 659–674.

Jonell, M. et al. (2016) 'Eco-labeled seafood: Determinants for (blue) green consumption', Sustainability (Switzerland), 8(9).

Marine Stewardship Council (2018) 'Global Impacts Report 2017', Global Impacts Report, p. 56. Available at: https://www.msc.org/documents/environmental-benefits/global-impacts/msc-global-impacts-report-2014.

Monterey Bay Aquarium (2011) 'Turning the Tide: The State of Seafood, Second Edition', pp. 1–60.

Nhu, T. T. et al. (2016) 'Environmental impact of non-certified versus certified (ASC) intensive Pangasius aquaculture in Vietnam, a comparison based on a statistically supported LCA', Environmental Pollution, 219, pp. 156–165.

Pérez-Ramírez, M. et al. (2012) 'Perspectives for implementing fisheries certification in developing countries', Marine Policy, 36(1), pp. 297–302.

Selden, R. L. et al. (2016) 'Evaluating seafood eco-labeling as a mechanism to reduce collateral impacts of fisheries in an ecosystem-based fisheries management context', Marine Policy, 64, pp. 102–115.

Tlusty, M. F. (2012) 'Environmental improvement of seafood through certification and ecolabelling: Theory and analysis', Fish and Fisheries, 13(1), pp. 1–13.

Tlusty, M. F. and Tausig, H. (2015) 'Reviewing GAA-BAP shrimp farm data to determine whether certification lessens environmental impacts', Reviews in Aquaculture, 7(2), pp. 107–116.

Tlusty, M. F., Thompson, M. and Tausig, H. (2016) 'Statistical tools to assess the breadth and depth of shrimp aquaculture certification schemes', Fisheries Research, 182, pp. 172–176.

Vandergeest, P. (2007) 'Certification and Communities: Alternatives for Regulating the Environmental and Social Impacts of Shrimp Farming', World Development, 35(7), pp. 1152–1171.

WWF (2018) Aquaculture Dialogues Webpage.

Section 8. (Are Payments for Ecosystemic Services efficient tools to prevent Mangrove depletion?)

Stefanie Engel, Stefano Pagiola, Sven Wunder, ***Designing payments for environmental services in theory and practice: An overview of the issues***, Ecological Economics, Volume 65, 2008, 663-674pp

Sandrine FEYDEL, Christophe BONNEUIL, ***Prédation, Nature le nouvel el dorado de la finance***, Edition La Découverte, 2015

François GEMENNE (dir.), ***L'enjeu mondial : L'environnement***, Les Presses de Sciences Po, 2015

Pavan Sukhdev, Heidi Wittmer and Dustin Miller, ***The economics of ecosystems and biodiversity in Nature in the balance: The economics of biodiversity***, Oxford University Press, 2014

R. COSTANZA, ***The value of the world's ecosystem services and natural capital***, Nature 387 (6630), p. 253–260, 1997

Bernard Chevassus et al., ***L'approche économique de la biodiversité et des services liés aux écosystèmes, rapports et documents***, Rapport du CAS, avril 2009

GC Daily et al., ***Ecosystem services in decision making : time to deliver***, Frontiers in Ecology and the Environment, Volume 7, 2009, 21-28pp

Kent H. Redford, William M. Adams, ***Payment for Ecosystem Services and the Challenge of Saving Nature,*** Conservation and biology, Volume 23, 2009, 785-787pp

Philippe Méral, ***Le concept de service écosystémique en économie : origine et tendances récentes***, Nature Sciences Sociétés, Volume 20, 2012, 3-15pp

Corbera, E., Schroeder, H., ***Governing and implementing REDD+, Environ***, Sci. Policy (2010)

Tommaso Locatelli, Thomas Binet, James Gitundu Kairo, Lesley King, Sarah Madden, Genevieve Patenaude, Caroline Upton, Mark Huxham, ***Turning the Tide: How Blue Carbon and Payments for Ecosystem Services (PES) Might Help Save Mangrove Forests***, Ambio, 2014

Albert, J.A, Warren-Rhodes, K, Schwarz, A.J and Duke, ***Mangrove Ecosystem Services & Payments for Blue Carbon in Solomon Islands***, The WorldFish Center, Solomon Islands, 2012

Daniel M. Alongi, ***Carbon payments for mangrove conservation: ecosystem constraints and uncertainties of sequestration potential***, Environmental Science & Policy, Volume 14, Issue 4, 2011, 462-470pp

World Bank Group: https://www.forestcarbonpartnership.org

Section 9 (impacts of conventional shrimp farming methods and available alternatives)

Ashton, E. C. (2008). The impact of shrimp farming on mangroves ecosystems. *CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources* , Vol. 3, No. 003; pp. 1-12.

Australian Institute for Marine Science; Research Institute for Aquaculture No. 2; Network of Aquaculture Centres in Asia-Pacific. (1999). *Mixed Shrimp Farming-Mangrove Forestry Models in the Mekong Delta.* Termination report. Part A: Main Report and Executive Summary.

Azad, A. K., Jensen, K. R., & Lin, C. K. (2009). Coastal aquaculture development in Bangladesh: Unsustainable and sustainable experiences. *Environmental Management, 44* (4), 800-809. doi:10.1007/s00267-009-9356-y

Biao, X., & Kaijin, Y. (2007). Shrimp farming in China: Operating characteristics, environmental impact and perspectives. *Ocean and Coastal Management, 50* (7), 538-550. doi:10.1016/j.ocecoaman.2007.02.006

Engle, C. R., McNevin, A., Racine, P., E., B. C., Paungkaew, D., Viriyatum, R., . . . Minh, H. N. (2017). Economics of Sustainable Intensification of Aquaculture: Evidence from Shrimp Farms in Vietnam and

Thailand. *Journal of the World Aquaculture Society* , Vol. 48, No. 2, pp. 227-239.

Ha, T. T. T., Van Dijk, H., & Bush, S. R. (2012). Mangrove conservation or shrimp farmer's livelihood? The devolution of forest management and benefit sharing in the Mekong delta, Vietnam. *Ocean and Coastal Management, 69* , 185. doi:10.1016/j.ocecoaman.2012.07.034

Hai, T. N., Duc, P. M., Son, V. N., Minh, T. H., & Phuong, N. T. (2015). Innovation of Marine Shrimp Seed Production and Farming in Vietnam. (V. College of Aquaculture and Fisheries - Can Tho University, A cura di) *World Aquaculture* .

Hempel, E., Winther, U., & Hambrey, J. (2003). *Shrimp Farming and the Environment: Can Shrimp Farming be Undertaken Sustainably?* NACA - Network of Aquaculture Centres in Asia-Pacific.

Holmström, K., Gräslund, S., Wahlström, A., Poungshompoo, S., Bengtsson, B., & Kautsky, N. (2003). Antibiotic use in shrimp farming and implications for environmental impacts and human health. *International Journal of Food Science & Technology, 38* (3), 255-266. doi:10.1046/j.1365-2621.2003.00671.x

Hương, G. (2017, 03 23). *Towards the sustainable development of rice – shrimp farming model in Tra Vinh province.* Tratto da Ministry of Agriculture and Rural Development-Directorate of Fisheries: https://tongcucthuysan.gov.vn/en-us/aquaculture/doc-tin/007387/2017-04-03/towards-the-sustainable-development-of-rice--shrimp-farming-model-in-tra-vinh-province

International Union for Conservation of Nature (IUCN). (2015, September 22 nd). *A model shrimp farm in the Mekong Delta* . Retrieved from https://www.iucn.org/content/model-shrimp-farm-mekong-delta Jonell, M. & Henriksson, P. J. G. (2014). Mangrove-shrimp farms in Vietnam - Comparing organic and conventional systems using life cycle assessment. *Aquaculture, 447* , 66-75.doi:10.1016/j.aquaculture.2014.11.001

MAP - Mangrove Action Project. (2018). *Sustainable Alternatives of Shrimp Aquaculture.* Retrieved from www.cbd.int: https://www.cbd.int/doc/case-studies/tttc/tttc-00155-en.pdf

Miao, K., Kinniburgh, F., Kumar, A., & Anderman, T. L. (2012). *Shrimp Farming in Bangladesh.* New York City: Columbia University.

Lima, J. S. G., Rivera, E. C., & Focken, U. (2012). Emergy evaluation of organic and conventional marine shrimp farms in Guaraíra lagoon, Brazil. *Journal of Cleaner Production, 35* , 194-202. doi:10.1016/j.jclepro.2012.05.009

Organisation for Economic Co-operation and Development (OECD). (2001). *Glossary of Statistical Terms* . Retrieved from http://stats.oecd.org/glossary/index.htm Paul, B. G., & Vogl, C. R. (2011). Impacts of shrimp farming in bangladesh: Challenges and alternatives. *Ocean and Coastal Management, 54* (3), 201-211. doi:10.1016/j.ocecoaman.2010.12.001

Phung, H. G., & Pham, D. B. (2017). Effects of Integrated Shrimp Farming in Vietnam. *Sustainable Shrimp Aquaculture Alternative: New Disruptive Technology* .

Quarto, A. (1998). Sustainable Shrimp Aquaculture Alternative: New Disruptive Technology. *SWARA - East Africa Wildlife Society's magazine* , pp. 16-21.

Rurangwa, E., Baumgartner, U., Nguyen, H., & Van de Vis, J. W. (2016). *Aquaculture Innovation in Vietnam.* Yerseke: Wageningen Marine Research at the request of and with funding from the Ministry of Economic Affairs.

Shang, Y. C., Leung, P., & Ling, B. (1998). Comparative economics of shrimp farming in Asia. *Aquaculture, 164* (1), 183-200. doi:10.1016/S0044-8486(98)00186-0

Sohel, M. S. I., & Ullah, M. H. (2012). Ecohydrology: A framework for overcoming the environmental impacts of shrimp aquaculture on the coastal zone of Bangladesh. *Ocean and Coastal Management, 63* ,67. doi:10.1016/j.ocecoaman.2012.03.014

United Nations Environment Program (UNEP). (October 2012). *Growing Greenhouse Gas Emissions Due to Meat Production* . Retrieved from https://na.unep.net/geas/getuneppagewitharticleidscript.php?article_id=92

World Wildlife Fund (WWF). (2017, June 22 nd). *Farmed Shrimp - Overview* . Retrieved from https://www.worldwildlife.org/industries/farmed-shrimp

Section 10. Consumption alternatives to shrimp

British Council (n.d.). Vegetarian UK. Retrieved from http://learnenglishteens.britishcouncil.org/uknow/read-uk/vegetarian-uk

Kowitt, B. (2018, January 29). Tyson Foods Has Invested in a Startup That Aims to Eradicate Meat from Live Animals. Retrieved from http://fortune.com/2018/01/29/tyson-memphis-meatsinvestment/

New Wave Foods (n.d.-a). About Us. Retrieved from https://www.newwavefoods.com/team New Wave Foods (n.d.-b). FAQ. Retrieved from https://www.newwavefoods.com/faq

Pellman Rowland, M. (2017, March 20). Meet The Women Leading The Future Of Food. Retrieved from https://www.forbes.com/sites/michaelpellmanrowland/2017/03/20/female-leaders-food/3/#c3795b326a2b

Precht, R. D. (2016). Tiere Denken. Vom Recht der Tiere und den Grenzen des Menschen. Munich: Goldmann.

Scher, R. (2017, October 18). Why Plant-Based Shrimp Is the Next Veggie Burger. Retrieved from https://www.alternet.org/food/why-fake-shrimp-next-veggie-burger-better-planet

Schwartz, A. (2016, February 5). I tried 'shrimp' made in a lab — and now I'd consider ditching the real thing. Retrieved from http://www.businessinsider.com/new-wave-foods-lab-made-shrimp-2016-2

Shapiro, P. (2018a). Commentary: Science fiction no more, can lab-grown meat feed – and save – the world? Retrieved from https://www.reuters.com/article/us-shapiro-meatcommentary/commentary-science-fiction-no-more-can-lab-grown-meat-feed-and-save-the-world-idUSKCN1GA25H

Shapiro, P. (2018b). Clean Meat. How Growing Meat Without Animals Will Revolutionize Dinner and the World. New York: Gallery Books.

Singh, S. (2017, August 23). Bill Gates and Richard Branson Back Startup That Grows 'Clean Meat'. Retrieved from https://www.bloomberg.com/news/articles/2017-08-23/cargill-bill-gates-beton-startup-making-meat-without-slaughter

UN DESA Population Division (2017). World Population Prospects: The 2017 Revision, Key Findings and Advance Tables. Working Paper No. ESA/P/WP/248. Retrieved from https://esa.un.org/unpd/wpp/Publications/Files/WPP2017_KeyFindings.pdf

Van Hare, H. (2017, October 23). Plant-based shrimp is a thing now, and it's still technically seafood. Retrieved from http://www.latimes.com/food/sns-dailymeal-1855055-healthy-eating-plantbased-shrimp-thing-now-and-it-s-still-technically-seafood-102317-20171023-story.html

Vegetarierbund Deutschland (n.d.). Anzahl der Veganer und Vegetarier in Deutschland. Retrieved from https://vebu.de/veggie-fakten/entwicklung-in-zahlen/anzahl-veganer-und-vegetarier-in-deutschland/

Webb, K. (2018, February 22). New Wave Foods' Dominique Barnes Talks New Plant-Based Shrimp Product. Retrieved from https://www.delimarketnews.com/specialty-foods/new-wave-foodsdominique-barnes-talks-new-plant-based-shrimp-product/kayla-webb/thu-02222018-1119/557

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