Challenging the Aquaculture Industry on Sustainability

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Challenging the Aquaculture Industry on Sustainability

Introduction

01

image Bluefin tuna swim inside a transport cage.

Greenpeace is taking action on the threats to the sea and calling for a network of large-scale marine reserves to protect the health and productivity of the Mediterranean Sea.

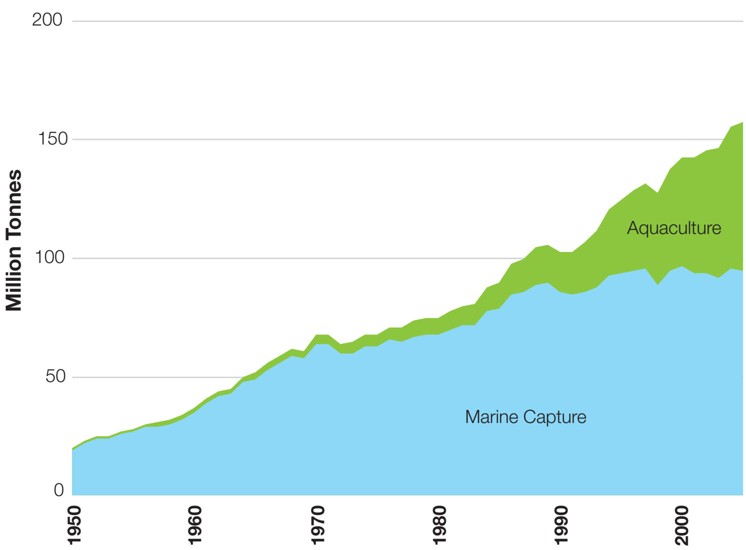
image Fish farm, Loch Harport, Scotland.

The farming of aquatic plants and animals is known as aquaculture and has been practised for around 4000 years in some regions of the world[1]. Since the mid-1980s, however, production of fish, crustaceans and shellfish by aquaculture has grown massively (Figure 1). Globally, aquacultural production has become the fastest growing food production sector involving animal species. About 430 (97%) of the aquatic species presently in culture have been domesticated since the start of the 20th century[2] and the number of aquatic species domesticated is still rising rapidly. It was recently estimated that aquaculture provides 43% of all the fish consumed by humans today[3].

The landings of fish from the world's oceans have gradually declined in recent years as stocks have been progressively overfished[4]. At the same time, demand for seafood has been steadily rising and, in parallel, aquaculture production has expanded significantly. This expansion is both a response to increasing demand for seafood and, especially in the case of luxury products such as salmon and shrimp, an underlying cause of that rising demand (see figure 1).

The animal species that tend to dominate world aquaculture are those at the lower end of the food chain – shellfish, herbivorous fish (plant-eating) and omnivorous fish (eating both plants and animals), (see figure 2). For example, carp and shellfish account for a significant share of species cultivated for human consumption in developing countries[5]. However, production of species higher in the food chain, such as shrimp, salmon, and marine finfish, is now growing, in response to a ready market for these species in developed countries[3,5].

Figure 1. Global Fish Harvest, Marine Capture Fisheries and Aquaculture, 1950-2005.



Source: FAO.

Table 1. World Aquaculture Production For The Years 2000 to 2005

World Production (Million tonnes)	2000	2001	2002	2003	2004	2005
Marine Aquaculture	14.3	15.4	16.5	17.3	18.3	18.9
Freshwater Aquaculture	21.2	22.5	23.9	25.4	27.2	28.9

Source: Adapted from FAO[3].

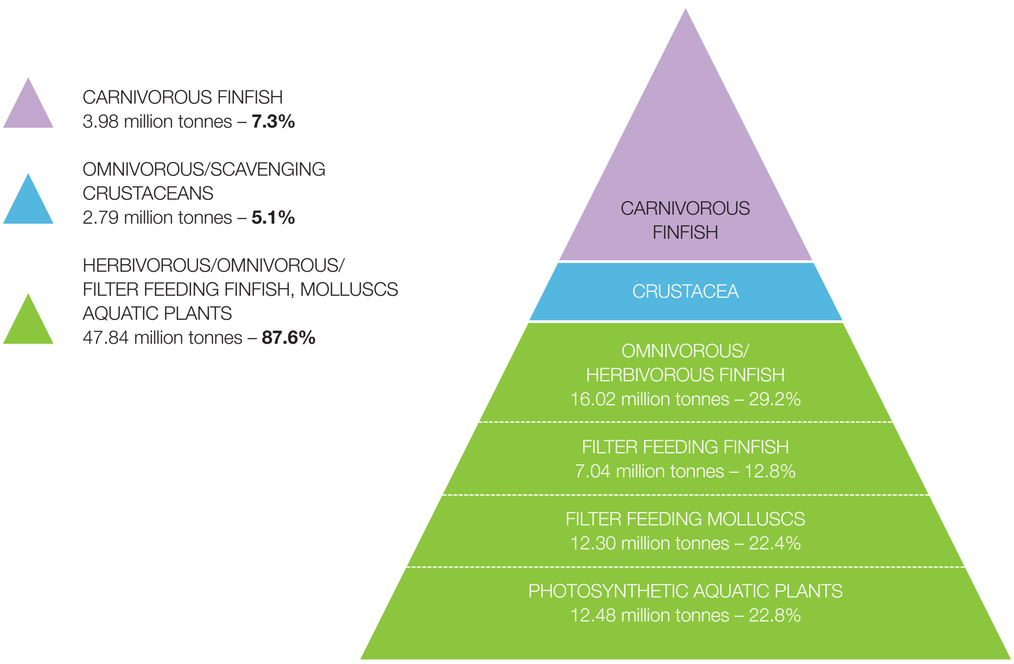
Introduction

Against a continuing background of diminishing and over–exploited marine resources, aquaculture has been widely held up as a panacea to the problem of providing a growing world population with ever-increasing amounts of fish for consumption. With the expansion of the industry, however, the tendency has been for methods of production to intensify, particularly in the production of carnivorous species. This has resulted in many serious impacts on the environment and human rights abuses.

This report examines some of the serious environmental and social impacts that have resulted from the development and practice of aquaculture and which are reflected across the global industry. It starts by looking at the production of salmon, tuna, other marine finfish, shrimp and tilapia. These case studies serve to illustrate a number of these environmental and social problems, which together undermine the sustainability of contemporary aquaculture (Section 2). Negative social impacts have been associated with both the production and processing industries in developing countries. Abuses stem from the desire of producers and processors to maximise profits within a highly competitive market, while meeting the low prices demanded by consumers (Section 2). The use of fishmeal and fish oil as feed in the production of some species is a key issue (Section 3). Other negative environmental impacts can be addressed in a variety of ways in order to place aquaculture on a more sustainable footing (Section 4 and 5). Section 6 briefly explores certification of aquaculture products. Ultimately, aquaculture must become sustainable. In order to achieve this, the aquaculture industry will need to adopt and adhere to rigorous standards (Section 7).

A more extensive and fully referenced version of this report can be downloaded at: www.greenpeace.org/aquaculture_report

Figure 2 Global aquaculture production pyramid by feeding habit and nutrient supply in 2003



Source: FAO[52]

Negative Impacts of Aquaculture on People and on the Environment

02

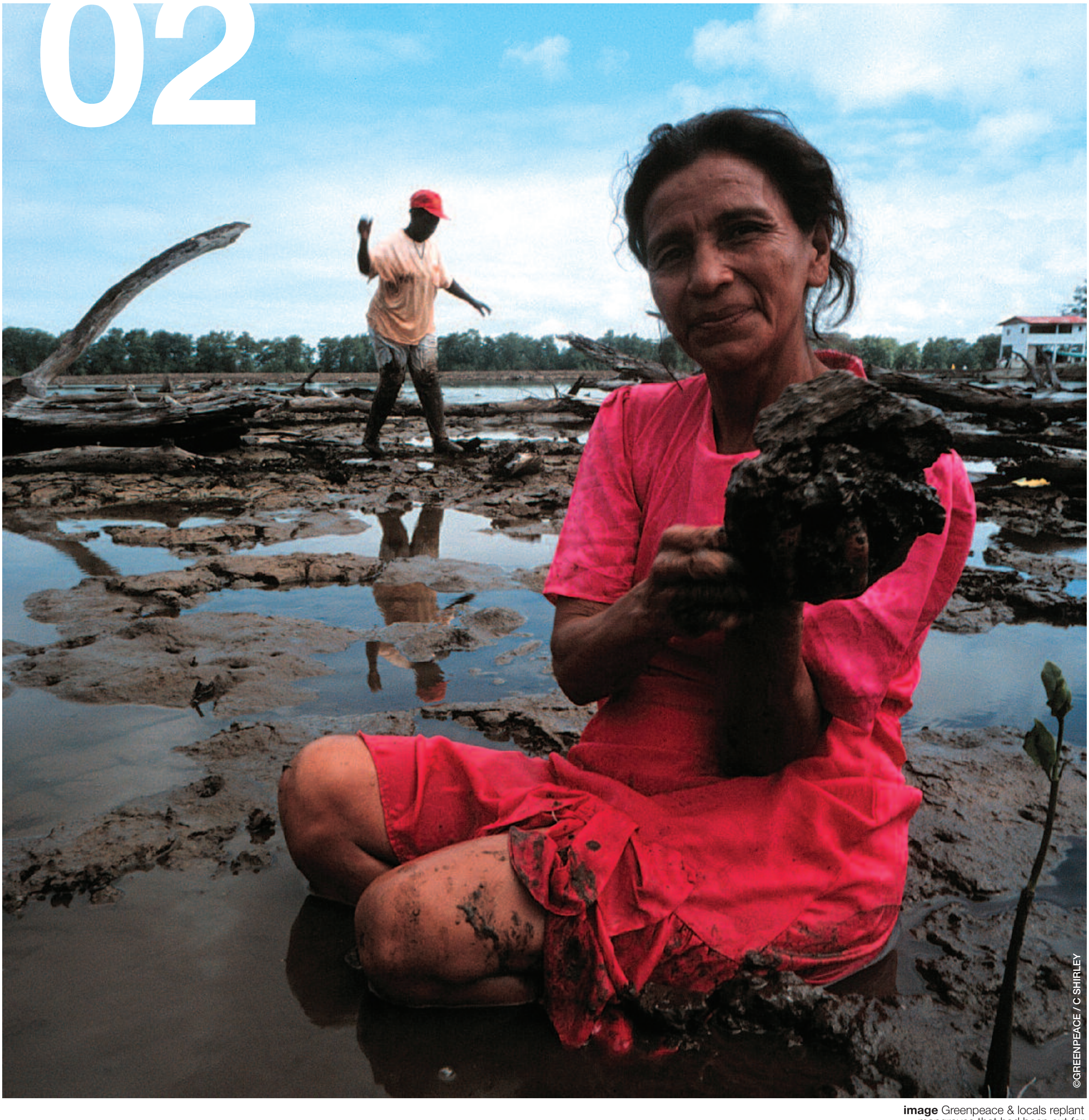


image Greenpeace & locals replant mangroves that had been cut for shrimp farming, Ecuador.

©GREENPEACE / C SHIRLEY

Negative Impacts of Aquaculture on People and on the Environment

The following case studies of negative impacts of aquaculture are far from exhaustive. Rather, they provide examples that illustrate the wide spectrum of problems associated with aquacultural activities, and cast serious doubts on industry claims of sustainability.

2.1 SHRIMP

Destruction of Habitat: The creation of ponds for marine shrimp aquaculture has led to the destruction of thousands of hectares of mangroves and coastal wetlands. Significant losses of mangroves have occurred in many countries including the Philippines[6], Vietnam[7], Thailand[8], Bangladesh[9] and Ecuador[10].

Mangroves are important because they support numerous marine as well as terrestrial species, protect coastlines from storms and are important in the subsistence of many coastal communities. Mangroves provide nursery grounds for various young aquatic animals including commercially important fish, and their destruction can lead to substantial losses for commercial fisheries[11,12].

Collection of Wild Juveniles as Stock

Aquaculture of some species relies on juvenile fish or shellfish being caught from the wild to stock culture ponds. For example, even though hatchery-raised shrimp constitute a major supply of shrimp juveniles (scientifically called “postlarvae”) to the aquaculture industry, shrimp farms in many parts of the world are still based on wild-caught juveniles. Some natural stocks of shrimp are now over-exploited as a result of juveniles collection from the wild[13,14]. Furthermore, the juvenile shrimp may only represent a small fraction of each catch, with a large incidental catch (by-catch) and mortality of other species taking place (see text box 1). This poses serious threats to regional biodiversity and reduces food available to other species such as aquatic birds and reptiles.

Box 1 Loss of other species during the collection of wild shrimp juveniles

- In Bangladesh, for each tiger shrimp juvenile collected there were 12–551 shrimp larvae of other species caught and killed, together with 5–152 finfish larvae and 26–1636 macrozooplanktonic animals.
- In Honduras, the reported annual collection of 3.3 billion shrimp juveniles resulted in the destruction of an estimated 15–20 billion fry of other species[13].
- In the Indian Sundarbans, tiger shrimp juveniles only account for 0.25–0.27% of the total catch. The rest of the catch contains huge numbers of juvenile finfish and shellfish which are left aside on the beach flats to die[15].

Chemicals used to Control Diseases

A wide variety of chemicals and drugs may be added to aquaculture cages and ponds in order to control viral, bacterial, fungal or other pathogens[16]. There is a risk that such agents may harm aquatic life nearby. The use of antibiotics also brings a potential risk to public health as over-use of these drugs can result in the development of antibiotic-resistance in bacteria that cause disease in humans. Studies on shrimp farms in Vietnam[17] and the Philippines[18] found bacteria had acquired resistance to the antibiotics used on the farms.

Depletion and Salinizsation of Potable Water and Salinisation of Agricultural Land

Intensive shrimp farming in ponds requires considerable amounts of fresh water to maintain pond water at the optimum salinity for shrimp growth. Typically this involves pumping water from nearby rivers or groundwater supplies, and this may deplete local freshwater resources. Furthermore, if aquifers are pumped excessively, salt water seeps in from the nearby sea causing salinisation and making the water unfit for human consumption[19,20]. For example, in Sri Lanka, 74% of coastal people in shrimp farming areas no longer have ready access to drinking water[21]. Shrimp farming can also cause increased soil salinity in adjacent agricultural areas, leading to declines in crops. For instance, there are numerous reports of crop losses in Bangladesh caused by the salinisation of land, associated with shrimp farming[22].

Human Rights Abuses

The positioning of shrimp farms has often blocked access to coastal areas that were once common land in use by many people. There is often a lack of formalised land rights and entitlements in such areas and this has led to large scale displacement of communities, often without financial compensation or alternative land made available on which to live (see text box 2).

Non-violent protests against the industry have frequently been countered with threats and intimidation. According to the Environmental Justice Foundation[21], violence has frequently been meted out by security personnel and “enforcers” associated with the shrimp industry, many protesters have been arrested on false charges and there are even reports from at least 11 countries of protesters being murdered (see figure 3). (In Bangladesh alone there have been an estimated 150 murders linked to aquaculture disputes.) Perpetrators of such violence are very rarely brought to justice.

image Crabs gathered from mangrove forest for sale at Gayaquil market, Ecuador. Mangrove ecology is endangered by cutting for shrimp farms.

Box 2 Case studies of land seizures for shrimp farm construction

- Some Indonesian shrimp farms have been constructed following forced land seizures in which companies, supported by police and government agencies, provided either inappropriate compensation or none at all. Such cases have been reported from Sumatra, Maluku, Papua and Sulawesi.
- In Ecuador, reports indicate that there have been thousands of forced land seizures, only 2% of which have been resolved on a legal basis. Tens of thousands of hectares of ancestral land have allegedly been seized. This has often involved use of physical force and the deployment of military personnel[21].
- Between 1992-1998 in the Gulf of Fonseca, Honduras, many coastal-dwelling people lost access to their traditional food sources and access to fishing sites because of encroachment on land by commercial shrimp-farming companies[23].

2.2 SALMON

Nutrient Pollution

Organic wastes from fish or crustacean farming include uneaten food, body wastes and dead fish[24]. In salmon farming, these wastes enter the aquatic environment in the vicinity of the cages. In extreme cases the large numbers of fish present in the cages can generate sufficient waste to cause oxygen levels in the water to fall, resulting in the suffocation of both wild and farmed fish. More usually, the impacts of intensive salmon culture are seen in a marked reduction in biodiversity around the cages[25]. For example, a study in Scotland found a reduction in biodiversity on the seabed up to 200 metres away from salmon cages[26]. In Chile, biodiversity close to eight salmon farms was reduced by at least 50%. Wastes can also act as plant nutrients and, in areas where water circulation is restricted, these may also lead to the rapid growth of certain species of phytoplankton (microscopic algae) and filamentous algae[27]. Some of the algal blooms which can result are very harmful: they can cause the death of a range of marine animals and also cause shellfish poisoning in humans.

Figure 3 Worldmap showing 11 countries where there has been murder associated with the shrimp industry

Countries include Mexico, Guatemala, Honduras, Ecuador, Brazil, India, Bangladesh, Thailand, Vietnam, Indonesia and the Philippines.
Source: Environmental Justice Foundation.

Negative Impacts of Aquaculture on People and on the Environment

Threat to Wild Fish from escaped Farmed Salmon

Farmed Atlantic salmon have a lower genetic variability than wild Atlantic salmon[28,29]. Hence, if they interbreed with wild salmon, the offspring may be less fit than wild salmon and genetic variability that is important for adaptability in the wild may be lost. It was originally thought that escaped salmon would be less able to cope with conditions encountered in the wild and would be unable to survive, thereby not posing a threat to the genetic diversity of wild populations. In reality, the sheer numbers that have escaped (an estimated 3 million per year)[30] mean that they are now breeding with wild salmon in Norway, Ireland, the United Kingdom and North America. Because they produce offspring less able to survive in the wild, this means that already vulnerable populations could be driven towards extinction. In Norway, farmed salmon have been estimated to comprise 11–35% of the population of spawning salmon; for some populations this may rise to more than 80%[28]. Continuing escapes may mean that the original genetic profile of the population will not re-assert itself[31].

In addition to threats to wild Atlantic salmon caused by escapees in their native regions, farmed Atlantic salmon that have been introduced to Pacific streams pose a threat to other native fish populations, such as steelhead in North America and galaxiid fishes in South America, because they compete for food and habitat[28].

Diseases and Parasites

Diseases and parasites can be particularly problematic in fish farming where stocking densities are high. Wild populations of fish passing near to farms may also be affected. One notable example is that of parasitic sea lice which feed on salmon skin, mucous and blood and which can even cause the death of the fish. There is evidence that wild salmon populations have been affected by lice spread from farms in British Columbia[32] and Norway[31]. Recent research in British Columbia suggests that sea lice infestation resulting from farms will cause the local pink salmon populations to fall by 99% within their next four generations[33]. If outbreaks continue unchecked, extinction is almost certain.

Human Rights Issues

In southern Chile the salmon farming industry has grown rapidly since the late 1980s to serve export markets in western nations[34,35]. In 2005, nearly 40% of the world's farmed salmon was supplied from Chilean producers and processors[36].

This burgeoning industry has an appalling safety record. Poor or non-existent safety conditions have been widely reported on Chilean farms and in processing plants[35,36]. Over the past three years there have been more than 50 accidental deaths, mostly of divers. By contrast, no deaths have been reported in the Norwegian salmon industry, the world's largest producer of salmon[37]. Reports from Chile also tell of low wages (around the national poverty line), long working hours, lack of respect for maternity rights and persistent sexual harassment of women[35,36].

2.3 OTHER MARINE FINFISH

Marine finfish aquaculture is an emerging industry. Improvements in the technology of salmon farming together with decreasing market prices for salmon have inspired the industry to start farming higher-value marine finfish species. Species which are now being farmed include (1) Atlantic cod in Norway, UK, Canada and Iceland; (2) haddock in Canada, Norway and northeastern United States; (3) Pacific threadfin in Hawaii; (4) black sablefish under development in British Columbia and Washington State; (5) mutton snapper; (6) Atlantic halibut; (7) turbot; (8) sea bass and (9) sea bream[5,28]. Most species are reared in net pens or cages like salmon, although Atlantic halibut and turbot are generally farmed in tanks on land.

It is likely that environmental problems similar to those encountered in salmon farming will also manifest themselves in the farming of these "new" marine species in cages. In some cases they could be worse. For example, cod produce considerably more waste than Atlantic salmon[28] leading to potential nutrient pollution. Even if the impacts of this can be reduced by siting cages some distance offshore where water movements are more vigorous, other impacts are still likely to result. As in the case of salmon aquaculture, these include a risk of disease spreading to wild populations and, if selectively bred, there is a risk of escapees competing with wild fish and interbreeding with them, causing a reduction in genetic variability.

2.4 TUNA RANCHING – WIPING OUT BLUEFIN TUNA IN THE MEDITERRANEAN SEA

The present level of fishing effort directed at northern bluefin tuna in the Mediterranean threatens the future of this species in the region and the future of hundreds of fishermen. There are serious concerns that commercial extinction of the species may be just around the corner[38].

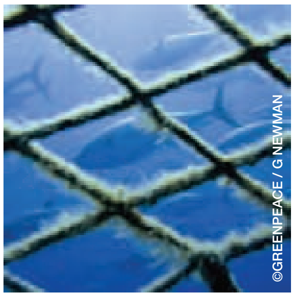


image Captive bluefin tuna inside a transport cage. The cage is being towed by a tug from fishing grounds in Libya to tuna farms in Sicily.

Greenpeace is calling on the countries of the Mediterranean to protect bluefin tuna with marine reserves in their breeding and feeding areas.

In May 1999, Greenpeace released a report describing the depletion of bluefin tuna in the Mediterranean[39]. This noted that the spawning stock biomass (total weight) of tuna was estimated to have decreased by 80% over the previous 20 years. In addition, huge amounts of juvenile tuna were being caught every season. Greenpeace reported that the main threat to the bluefin tuna at that time was Illegal, Unreported and Unregulated (IUU) fishing, also called "pirate fishing". IUU fishing operates outside of management and conservation rules and, in effect, steals fish from the oceans. It has become a serious and wide-ranging global problem, is a threat to marine biodiversity and a serious obstacle to achieving sustainable fisheries[40,41].

Seven years on in 2006, further analysis by Greenpeace showed that threats to the tuna had worsened[38]. Pirate fishing continued unabated, and was now fuelled by a new incentive of supplying tuna to an increasing number of tuna ranches in Mediterranean countries.

In tuna ranching, fish are caught alive and grown on in cages with artificial feeding. The fattened fish are then killed and exported, mainly to Japan. Tuna ranching began in the late 1990s and has boomed, spreading to 11 countries by 2006 (see figure 4). Today, due to poor management of tuna fisheries, nobody knows the exact numbers of tuna taken from the Mediterranean Sea each year. Nonetheless, it is clear that current catch levels are well above the legal quota. For example, it was estimated, based on 2005 figures, that over 44,000 tonnes of tuna may have been caught in the Mediterranean. This was 37.5% over the legally sanctioned catch limit and, disturbingly, almost 70% above the scientifically recommended maximum catch level. The total capacity of the tuna ranches exceeds the total allowable catch quotas which exist to supply them. This is a clear incentive for illegal fishing in the region. An examination of available trends in the industry clearly indicates that illegal fishing for tuna is supplying ranches[38].

2.5 TILAPIA

Introduction of Alien Species

When a species is released into an environment where is it not native, it may reproduce successfully but have negative consequences on native species[42]. Tilapia species provide a striking illustration of the problems that such releases can cause. Three species of tilapia are the most important in aquaculture: the Nile tilapia, the Mozambique tilapia and the blue tilapia[43]. These freshwater fish are native to Africa and the Middle East but over the past 30 years their use in aquaculture has expanded and they are now farmed in about 85 countries worldwide. Presently, tilapia are second only to carp as the quantitatively most important farmed fish in the world[44]. Tilapia have escaped from sites where they are cultured into the wider environment, have successfully invaded new habitats and consequently have become a widely distributed exotic species.

Once in a non-native environment, tilapia threaten native fish by feeding on their juveniles as well as on plants that are habitat refuges for juveniles. Negative impacts of tilapia invasions into non-native regions have been widely reported and include:

1 the decline of an endangered fish species in Nevada and Arizona,

2 the decline of a native fish in Madagascar,

3 the decline of native cichlid species in Nicaragua and in Kenya, and

4 the breeding of escaped tilapia in Lake Chichincanab, Mexico to become the dominant species[44] at the cost of the native fish populations.

Figure 4 Tuna farming proliferation

1985	1996	2000	2001	2002	2003	2004	2006
Spain	Spain	Spain	Spain	Spain	Spain	Spain	Spain
	Croatia	Croatia	Croatia	Croatia	Croatia	Croatia	Croatia
		Malta	Malta	Malta	Malta	Malta	Malta
			Italy	Italy	Italy	Italy	Italy
				Turkey	Turkey	Turkey	Turkey
					Cyprus	Cyprus	Cyprus
					Libya	Libya	Libya
						Greece	Greece
						Lebanon	Tunisia
							Morocco
							Portugal
							Lebanon

Source: Lovatelli, A. 2005. Summary Report on the status of BFT aquaculture in the Mediterranean. FAO Fisheries Report No 779 and ICCAT database on declared farming facilities, available online at www.iccat.es/ffb.asp

Use of Fishmeal/Fish Oil/Bycatch
in Aquaculture Feeds and their Associated Problems

03

image Salmon run at Annan Creek in the Tongass National Forest, Alaska.

image View from above of people sorting shrimps on long tables, Muisne, Ecuador

Fishmeal and fish oil used in aquaculture feeds are largely derived from small oily fish such as anchovies, herrings and sardines (larger sardines are also known as pilchards), taken in the so-called “industrial fisheries”. As aquaculture methods have intensified, there has been a growing dependence on fishmeal/oil as a feed source. The farming of carnivorous species in particular is highly dependent on the use of fishmeal and fish oil, in synthetic diets used to simulate natural prey taken as food in the wild.

Farming Carnivores – A Net Loss of Protein....

The aquaculture industry has consistently promoted the idea that its activities are key to assuring future sustainable world fish supplies and will relieve pressures on over-exploited marine resources. In fact, in the case of carnivorous fish and shrimp the input of wild caught fish exceeds the output of farmed fish by a considerable margin, since conversion efficiencies are not high. For example, each kilogram of salmon, other marine finfish or shrimp produced may use 2.5–5 kg of wild fish as feed[45]. For tuna ranching, the ratio of wild fish needed as feed to the amount of tuna fish produced is even higher – 20 kg fish-feed to 1 kg farmed fish[46]. Thus, farming of carnivorous species results in a net loss rather than a net gain of fish protein. Instead of alleviating pressure on wild fish stocks, therefore, aquaculture of carnivorous species increases pressure on wild stocks of fish, albeit of different species. With further intensification of aquaculture and expansion of marine finfish aquaculture, it is likely that demand for fishmeal and fish oil will even outstrip the current unsustainable supply.

Unsustainable Fisheries....

Many global marine fisheries are currently exploited in an unsustainable manner, and this includes industrial fisheries. Concerns extend to other marine species because fish taken by industrial fishers play a vital role in marine ecosystems. They are prey for many other fish species (including commercially important species), marine mammals and sea birds. Overfishing of industrially fished species has led to negative impacts on the breeding success of some seabirds (see text box 3).

Box 3 Negative impacts of industrial fisheries on seabirds

- In the late 1960s the Norwegian spring-spawning herring stock collapsed due to over fishing. Stocks continued to remain low between 1969 and 1987 and this severely impacted the breeding success of Atlantic puffins due to lack of food[50].
- Overfishing of North Sea sandeel stocks in recent years has had a negative impact on the breeding success of black-legged kittiwakes[51]. Closure of the fishery east of Scotland was recommended from 2000–2004 to safeguard these birds and the local population of puffins.

A specific assessment of several important industrially fished species concluded that, for the most part, the fisheries were entirely unsustainable[47]. Other research has shown that the fisheries must be regarded as fully exploited or over-exploited[48,49]. Consequently, there is a crucial need for aquaculture to reduce its dependence on fishmeal and fish oil.

Demands for Fishmeal and Fish Oil in Aquaculture.....

The quantity of fishmeal and fish oil used by the aquaculture industry has increased over the years as aquaculture has expanded and intensified. In 2003, the industry used 53% of the total world’s fishmeal production and 86% of the world’s fish oil production[5,52]. The increased demand for fishmeal and fish oil by aquaculture has been met by diverting these products away from their use as feed for agricultural animals, in itself a controversial issue. Currently, agricultural use of fishmeal and fish oil is increasingly restricted to starter and breeder diets for poultry and pigs. Fish oil previously used in the manufacture of hard margarines and bakery products has now been largely diverted to aquacultural use[53]. Figure 5 depicts the estimated global use of fishmeal within compound aquafeeds in 2003 by major species.

Although a trend has emerged in recent years of replacing fishmeal with plant-based proteins in aquaculture feeds, the fraction of fishmeal/oil used for diets of carnivorous species remains high. Moreover, this trend has not been fast enough to offset the growing use of fishmeal, caused simply by an increase in the overall number of farmed carnivorous fish produced. For example, the quantity of wild fish required as feed to produce one unit of farmed salmon reduced by 25% between 1997 and 2001, but the total production of farmed salmon grew by 60%[5], eclipsing much of the improvement in conversion efficiencies.

Figure 5 Estimated global use of fishmeal within compound aquafeeds in 2003.

- Marine Shrimp **22.8%**
- Marine Fish **20.1%**
- Trout **7.4%**
- Salmon **19.5%**
- Eel **5.8%**
- Milkfish **1.2%**
- Carp **14.9%**
- Tilapia **2.7%**
- Catfish **0.8%**
- Freshwater Crustaceans **4.7%**

Source: FAO[52]

Use of Fishmeal/Fish Oil/Bycatch in Aquaculture Feeds and Associated Problems

Food Security Issues….

The use of fishmeal and fish oil derived from marine species of fish for aquaculture also has implications for human food security. For example, in Southeast Asia and Africa, small pelagic (open water) fish such as those targeted by industrial fisheries are important in the human diet[54]. Demand for such fish is likely to grow as populations increase, bringing them under pressure both from aquaculture and direct consumption[55]. In addition, low value fish (inappropriately termed "trash fish") caught as by-catch and used for fishmeal production are actually an important food source for poorer people in developing countries[56]. Use of "trash fish" in aquaculture inflates prices such that the rural poor can no longer afford to buy it[52]. With these factors in mind, the UN Food and Agricultural Organization (FAO) has recommended that governments of major aquaculture-producing countries prohibit the use of "trash fish" as feed for the culture of high value fish.

©GREENPEACE / K DAVISON

image Catch landed on board EU bottom-trawler, the Ivan Nores, in the Hatton Bank area of the North Atlantic, 410 miles north-west of Ireland. Bottom-trawling boats, the majority from EU countries, drag fishing gear weighing several tonnes across the sea bed, destroying marine wildlife and devastating life on underwater mountains - or 'seamounts'.

Moving Towards More Sustainable Feeds

04

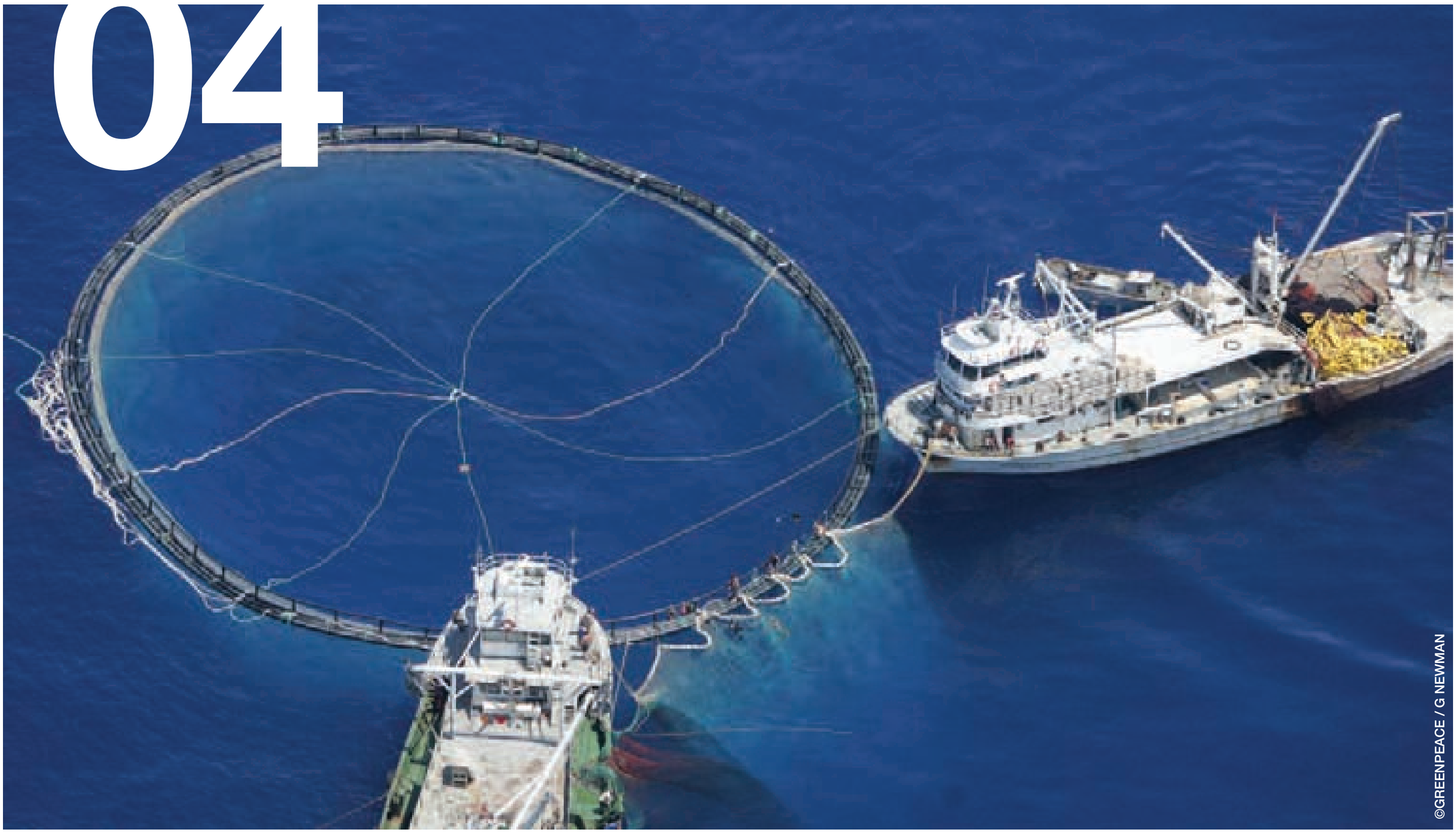


image Turkish tuna fleet Purse Seine fishing and transfering catch to transport cage.

The aquaculture industry is highly dependent upon wild caught fish to manufacture feed for cultured species. This is widely recognised as an intensive and generally unsustainable use of a finite resource. In turn, the industry has recognised the need to evaluate and use more plant-based feed materials and reduce dependence on fishmeal and fish oil.

Plants are already used in aquaculture feeds. Those that are used and/or show particular promise for the future include soybean, barley, canola, corn, cottonseed and pea/lupin[57]. It is important to note that if plant-based feeds are used in aquaculture, to be sustainable they must be sourced from agriculture that is sustainable. Sustainable agriculture by definition precludes the use of any genetically modified crops. These crops are associated with a number of potential environmental impacts, genetic contamination of non-GE crops and have also sparked a number of food-safety concerns which remain unresolved[58].

For some herbivorous and omnivorous fish, it has been possible to replace completely any fishmeal in the diet with plant-based feedstuffs without impacts on fish growth and yield[52]. Rearing such species in this way suggests a more sustainable future path for aquaculture provided that the feeds themselves are produced through sustainable agriculture.

Feeding of carnivorous species seems to be more problematic. Fishmeal and fish oil can be reduced by at least 50% in the diet, but complete substitution for plant ingredients has not yet been possible for commercial production. Problems include the presence of certain compounds in plants that are not favourable to fish, known as anti-nutritional factors, and the lack of certain essential (omega-3) fatty acids[29,52]. Oily fish is considered to be an important source of omega-3 fatty acids in human nutrition, but feeding fish with plant oil-based diets alone reduces the amount in their flesh. Recent research, however, has found that the fish oil input could be reduced by feeding fish with plant oils but switching to fish oils in the period just prior to slaughter[59]. Recent research on marine shrimp suggests that it may be possible to replace fishmeal in the diet largely with plant-based ingredients, although further study is needed[60,61].

Some aquaculture, particularly that classified as "organic", uses fish trimmings as feed – offcuts of fish from the filleting and processing of fish for human consumption. This is more sustainable than using normal fishmeal in that a waste product is being used. However, unless the fishery from which the fish trimmings come from is itself sustainable, the use of fish trimmings cannot be seen as sustainable because it perpetuates the cycle of over-exploitation of fisheries.

Moving Towards Sustainable Aquaculture Systems

05

©GREENPEACE / A SALAZAR

image Aerial views of shrimp farms along the coast of Tugaduaja, Chanduy near Guayaquil in Ecuador.

In order for aquaculture operations to move towards sustainable production, the industry needs to recognise and address the full spectrum of environmental and societal impacts caused by its operations. Essentially, this means that it will no longer be acceptable for the industry to place burdens of production, (such as the disposal of waste) onto the wider environment.

In turn, this implies moving towards closed production systems. For example, in order to prevent nutrient pollution, ways can be found to use nutrients present in waste products beneficially. Examples include integrated multi-trophic aquaculture (IMTA) (see text box 4), aquaponics and integrated rice-fish culture.

Box 4 Integrated multi-trophic aquaculture systems (IMTA)

In IMTA systems, organic waste products from the fed species (finfish or shrimp) are used as food by other cultivated species such as seaweed and shellfish. For example, at a commercial IMTA farm in Israel, marine fish (gilthead seabream) are farmed and their nutrient-rich waste is used to grow seaweed. In turn, the seaweed is used to feed Japanese abalone which can be sold commercially[62]. In other systems being developed, the seaweed itself may be commercially viable[63,64].

In aquaponics systems, effluents from fish farming are used as a nutrient source for growing vegetables, herbs and/or flowers. One existing commercially viable aquaponics system involves the cultivation of tilapia in land-based tanks from which the waste water is used to grow vegetables (without soil) in greenhouses[65]. A company in the Netherlands called 'Happy Shrimp' partially use waste from their farms to grow vegetables. The shrimp are fed on algae and bacteria as well as on aquaculture feed containing a high proportion of plant protein. The shrimp are cultivated in greenhouses and no shrimp juveniles are extracted from the wild[66].

In integrated rice–fish culture, fish are cultivated alongside rice, which optimises use of both land and water. The nitrogen-rich fish excretory products fertilise the rice, and the fish also control weeds and pests by consuming them as food. Much of the fish nutrition is derived naturally in this way. Major constraints to widespread use of such methods include the fact that many farmers are not educated in the required skills[67]. This could be overcome if policy makers gave active support to this practice. Integrated rice–fish culture is crucial for local food security rather than for supplying export markets.

Aquaculture Certification

06

image Shrimps.

The growth of aquaculture has led to a multiplicity of concerns attached to environmental impacts, social impacts, food safety, animal health and welfare and economic/financial issues. All of these factors influence the sustainability of a given aquaculture system. Presently, there are a growing number of certification schemes which seek to reassure buyers, retailers and consumers about various of these concerns. Currently existing certification schemes, however, do not cover all of these issues and can sometimes present a confusing and conflicting picture to retailers and consumers. A recent analysis of 18 aquaculture certification schemes by the World Wildlife Fund (WWF) showed that they generally had major shortcomings in terms of the way in which they considered environmental standards and social issues[68].

The WWF report sets out benchmark criteria on environmental, social and animal welfare issues in aquaculture. The FAO has also recently published a document which covers many of the relevant issues and could be used as a guide by certification bodies[69]. Any certification process, as an absolute minimum, needs to conform to these FAO guidelines. Nonetheless, certification criteria alone will not ensure the sustainability of the aquaculture industry worldwide. In order to do so, a more fundamental rethink and restructuring of the industry is essential.

Recommendations

image Aerial view of damned ponds with intact mangroves visible on lower left, bay of Guayaquil, Ecuador.

image Mock up picture of salmon, which will be 37 times bigger than normal, when genetically engineered.

Any aquaculture that takes place needs to be sustainable and fair. For aquaculture systems to be sustainable, they must not lead to natural systems being subject to degradation caused by:

1 an increase in concentrations of naturally occurring substances,

2 an increase in concentrations of substances, produced by society, such as persistent chemicals and carbon dioxide and

3 physical disturbance.

In addition people should not be subject to conditions that systematically undermine their capacity to meet their basic needs for food, water and shelter.

In practical terms, these four conditions can be translated into the following recommendations:

Use of Fishmeal, Fish oil and "Trash Fish": To reduce the pressure on stocks caught for fishmeal and fish oil, there needs to be a continued move towards sustainably produced plant-based feeds. Cultivating fish that are lower down the food chain (herbivores and omnivores rather than top predators) that can be fed on plant-based diets is key to achieving sustainable aquaculture practices. Industry must expand its research and development on herbivorous and omnivorous fish which have strong market potential and suitability for farming.

In more general terms, there is an urgent need for fisheries management to shift towards an ecosystem-based approach wherein a global network of fully protected marine reserves covering 40% of the oceans is established together with sustainable fisheries management outside of the reserves[70]. This is key to achieving sustainable fisheries.

Greenpeace considers the culture of species that require fishmeal or fish oil-based feeds derived from unsustainable fisheries and/or which yield conversion ratios of greater than one (i.e. represent a net loss in fish protein yield) as unsustainable. Plant-based feeds should originate from sustainable agriculture, and sources of omega 3 should be algal derivatives, grape seed oils, etc.

Nutrient Pollution and Chemical Pollution: To reduce nutrient wastes, there is great potential for the development of integrated multi-trophic aquaculture (IMTA) systems, aquaponics and integrated rice-fish culture.

Greenpeace considers aquaculture that results in negative environmental impacts in terms of discharges/effluents to the surrounding environment as unsustainable.

Escapes of Farmed Fish to the Wild: To overcome these problems it has been suggested that enclosed bag nets/closed wall sea pens should be used to prevent fish from escaping, or that land-based tanks should be used[5]. Ultimately, land-based tanks are the only option if the goal is to eliminate any risk of escapes which might otherwise occur as a result of hurricanes or other extreme weather events at sea. It is crucial to use native rather than exotic species[42].

Greenpeace recommends that only species which are native should be cultivated in open water systems, and then only in bag nets, closed wall sea pens or equivalent closed systems. Cultivation of non-native species should be restricted to land-based tanks.

Protection of Local Habitat: Some aquaculture practices have had serious negative impacts on local habitat. Aquaculture practices must be set up in a way that provides for the protection of coastal ecosystems and local habitats. In addition, no new aquaculture practices should be permitted in areas that are to be designated as marine reserves and any existing aquaculture operations within such areas should be phased out.

Greenpeace considers aquaculture which causes negative effects to local wildlife (plants as well as animals) or represents a risk to local wild populations as unsustainable.

Use of Wild Juveniles: The use of wild-caught juveniles to supply aquaculture practices, particularly some shrimp aquaculture, is destructive to marine ecosystems.

Greenpeace considers aquaculture which relies on wild-caught juveniles as unsustainable.

Transgenic Fish: The physical containment of genetically engineered fish cannot be guaranteed under commercial conditions and any escapes into the environment could have devastating effects on wild fish populations and biodiversity[71].

Greenpeace demands that genetic engineering of fish for commercial purposes should be prohibited.

Diseases: Greenpeace recommends cultivation at stocking densities that minimise the risk of disease outbreaks and transmission and, therefore, minimise requirements for therapeutic treatments.

Resources: *Greenpeace considers aquaculture that depletes local resources, for example, drinking water supplies and mangrove forests, as unsustainable.*

Human Health: *Greenpeace considers aquaculture that threatens human health as unfair and unsustainable.*

Human Rights: *Greenpeace considers aquaculture that does not support the long-term economic and social well-being of local communities as unfair and unsustainable.*

Footnotes

1 Iwama, G.K. (1991). Interactions between aquaculture and the environment. *Critical Reviews in Environmental Control* 21 (2): 177–216.

2 Duarte, C.M., Marbá, N. And Holmer, M. (2007). Rapid domestication of marine species. Science 316. (5823): 382-383

3 FAO (2007). The state of world fisheries and aquaculture 2006. FAO Fisheries and Aquaculture Department. Food and Agricultural Organization of the United Nations, Rome, Italy. 162 pp.

4 Pauly, D., Christensen, V., Guénette, S., Pitcher, U., Sumaila, R., Walters, C.J., Watson, R. and Zeller, D. (2002). Towards sustainability in world fisheries. Nature 418: 689–695.

5 Naylor, R. and Burke, M. (2005). Aquaculture and ocean resources: raising tigers of the sea. *Annu. Rev. Environ. Resour.* 30: 185–218.

6 Beveridge, M.C.M., Ross, L.G. and Stewart, J.A. (1997). The development of mariculture and its implications for biodiversity. In: *Marine Biodiversity: Patterns and Processes* (eds. R.F.G. Ormond, J.D. Gage and M.V. Angel), Ch. 16, pp. 105–128. Cambridge University Press, Cambridge, United Kingdom.

7 Singkran, N. and Sudara, S. (2005). Effects of changing environments of mangrove creeks on fish communitites at Trat Bay, Thailand. *Environmental Management* 35 (1): 45–55.

8 Flaherty, M. and Karnjanakesorn, C. (1995). Marine shrimp aquaculture and natural resource degradation in Thailand. *Environmental Management* 19 (1): 27–37.

9 Das, B., Khan, Y.S.A. and Das, P. (2004). Environmental impact of aquaculture-sedimentation and nutrient loadings from shrimp culture of the southeast coastal region of the Bay of Bengal. *Journal of Environmental Sciences* 16 (3): 466–470.

10 Boyd, C.E. (2002). Mangroves and coastal aquaculture. In: *Responsible Marine Aquaculture* (eds. R.R.Stickney and J.P McVey). Ch. 9, pp. 145–158. CABI Publishing, New York NY, USA.

11 Rönnbäck, P. (1999). The ecological basis for economic value of seafood production supported by mangrove ecosystems. *Ecological Economics* 29: 235–252.

12 Kathiresan, K. and Rajendran, N. (2002). Fishery resources and economic gain in three mangrove areas on the south-east coast of India. *Fisheries Management and Ecology* 9: 277–283.

13 Islam, M.S., Wahad, M.A and Tanaka, M. (2004). Seed supply for coastal brackish water shrimp farming: environmental impacts and sustainability. *Marine Pollution Bulletin* 48: 7–11.

14 Islam, M.S. and Haque, M. (2004). The mangrove-based coastal and nearshore fisheries of Bangladesh: ecology, exploitation and management. *Reviews in Fish Biology and Fisheries* 14: 153–180.

15 Sarkar, S.K. and Bhattacharya, A.K. (2003). Conservation of biodiversity of coastal resources of Sundarbans, Northeast India: an integrated approach through environmental education. *Marine Pollution Bulletin* 47: 260–264.

16 Gräslund, S. and Bengtsson, B-E (2001). Chemicals and biological products used in south-east Asian shrimp farming, and their potential impact on the environment – a review. *The Science of the Total Environment* 280: 93–131.

17 Le, T.X., Munekage, Y. and Shin-ichiro, K. (2005). Antibiotic resistance in bacteria from shrimp farming in mangrove areas. *The Science of the Total Environment* 349: 95–105.

18 Holmström, K., Gräslund, S., Wahlström, A., Poungshompoo, S., Bengtsson, B-E. and Kautsky, N. (2003). Antibiotic use in shrimp farming and implications for environmental impacts and human health. *International Journal of Food Science and Technology* 38: 255–266.

19 Public Citizen (2004). Shell game. The environmental and social impacts of shrimp aquaculture. Public Citizen, Washington DC, US. 20 pp.

20 Barraclough, S. and Finger-Stich, A. (1996). Some ecological and social implications of commercial shrimp farming in Asia. United Nations Research Institute for Social Development Geneva, Switzerland.

21 Environmental Justice Foundation (2003). Smash & Grab: Conflict, Corruption and Human Rights Abuses in the Shrimp Farming Industry. Environmental Justice Foundation, London, UK

22 EJF (2004). Farming The Sea, Costing The Earth: Why We Must Green The Blue Revolution. Environmental Justice Foundation, London, UK. 77 pp.

23 Marquez, J.V. (2008). The human rights consequences of inequitable trade and development expansion: abuse of law and community rights in the Gulf of Fonseca, Honduras. Accessed Jan 2008 at: http://www.mangroveactionproject.org/issues/shrimp-farming/shrimp-farming

24 Goldberg, R. and Naylor, R. (2005). Future seascapes, fishing, and fish farming. *Frontiers in Ecology and the Environment* 3 (1): 21–28.

25 Mente, E., Pierce, G.J., Santos, M.B. and Neofitou, C. (2006). Effect of feed and feeding in the culture of salmonids on the marine aquatic environment: a synthesis for European aquaculture. *Aquaculture International* 14: 499–522.

26 Fisheries and Oceans Canada (2003). A scientific review of the potential environmental effects of aquaculture in aquatic ecosystems. Volume 1. Far-field environmental effects of marine finfish aquaculture. (B.T. Hargrave) *Canadian Technical Report of Fisheries and Aquatic Sciences* 2450: ix + 131 pp.

27 Buschmann, A.H., Riquelme, V.A., Hernández-Gonález, D., Varela, D., Jiménez, J.E., Henríquez, L.A., Vergara, P.A., Guíñez, R. and Filún, L. (2006). A review of the impacts of salmonid farming on marine coastal ecosystems in the southeast Pacific. *ICES Journal of Marine Science* 63: 1338–1345.

28 Naylor, R., Hindar, K., Fleming, I.A., Goldburg, R., Williams, S., Volpe, J., Whoriskey, F., Eagle, J., Kelso, D. and Mangel, M. (2005). Fugitive salmon: assessing the risks of escaped fish from net-pen aquaculture. *BioScience* 55 (5): 427–437.

29 Scottish Executive Central Research Unit (2002). *Review and synthesis of the environmental impacts of aquaculture.* The Scottish Association for Marine Science and Napier University. Scottish Executive Central Research Unit. The Stationery Office, Edinburgh, UK. 71 pp

30 Pure Salmon Campaign (2008). Environmental damage from escaped farmed salmon. Accessed Jan 2008 at: http://www.puresalmon.org/pdfs/escapes.pdf

31 Goldberg, R.J., Elliot, M.S. and Naylor, R.L. (2001). *Marine aquaculture in the United States. Environmental impacts and policy options.* Pew Oceans Commission, Philadelphia, PA, USA. 44 pp.

32 Naylor, R.L., Eagle, J., Smith, W.L. (2003). Salmon aquaculture in the Pacific Northwest. A global industry. *Environment* 45 (8): 18–39.

33 Krkošek, M., Ford, J.S., Morton, A., Lele, S., Myers, R.A. and Lewis, M.A. (2007). Declining wild salmon populations in relation to parasites from farm salmon. *Science* 318 (5857): 1772–1775.

34 Phyne, J. and Mansilla, J. (2003). Forging linkages in the commodity chain: the case of the Chilean salmon farming industry. *Sociologica Ruralis* 43 (2): 108–127.

35 Barrett, G., Caniggia, M.I. and Read L. (2002). "There are more vets than doctors in Chiloé": social and community impact of the globalization of aquaculture in Chile. *World Development* 30 (11): 1951–1965.

36 Pizarro, R. (2006). APP No. 37: The ethics of world food production: the case of salmon-farming in Chile. *Paper presented at the Conference 'Ethics of Globalization' Cornell, 29–30 September 2006.* Publicaciones Fundacion Terram, Santiago, Chile.

37 Santiago Times (2007). Unions scrutinize labor problems in Chile's salmon industry. 5th December 2007.

38 Greenpeace (2006). Where have all the tuna gone? *How tuna ranching and pirate fishing are wiping out bluefin tuna in the Mediterranean Sea.* Greenpeace International, Amsterdam, The Netherlands. pp 40.

39 Gual, A. (1999). *The bluefin tuna in the Eastern Atlantic and Mediterranean: chronicle of a death foretold.* Greenpeace International, Amsterdam, The Netherlands.

40 Greenpeace (2006). *Witnessing the plunder 2006. How illegal fish from West African waters finds its way to the EU ports and markets.* Greenpeace International, Amsterdam, The Netherlands. 52 pp

41 High Seas Task Force (2006). *Closing the net: stopping illegal fishing on the high seas.* Governments of Australia, Canada, Chile, Namibia, New Zealand, and the United Kingdom, WWF, IUCN and the Earth Institute at Columbia University. 116 pp.

42 Pérez, J.E., Alfonsi, C., Nirchio, M., Muñon, C. and Gómez, J.A. (2003). The introduction of exotic species in aquaculture: a solution or part of the problem? *Interciencia* 28 (4): 234–238.

43 Watanabe, W.O., Lorsordo, T.M., Fitzsimmons, K. and Hanley, F. (2002). Tilapia production systems in the Americas: technological advances, trends, and challenges. *Reviews in Fisheries Science* 10 (3–4): 465–498.

44 Monterey Bay Aquarium (2006). *Seafood Watch, Seafood Report: Farmed Tilapia.* Final Report (eds. I. Tetreault). Monterey Bay Aquarium, Monterey, CA, USA. 38 pp.

45 Naylor, R.L., Goldberg, R.J., Primavera, J.H., Kautsky, N., Beveridge, M.C.M., Clay, J., Folke, C., Lubcheno, J., Mooney, H. and Troell, M. (2000). Effect of aquaculture on world fish supplies. *Nature* 405: 1017–1023.

46 Volpe, J.P. (2005). Dollars without sense: the bait for big-money tuna ranching around the world. *BioScience* 55 (4): 301–302.

47 Huntington, T.C. (2004). *Feeding the fish: sustainable fish feed and Scottish aquaculture.* Report to the Joint Marine Programme (Scottish Wildlife Trust and WWF Scotland) and RSPB Scotland. Poseidon Aquatic Resource Management Ltd, Hampshire, UK. 49 pp.

48 Deutsch, L., Gräslund, S., Folke, C., Troell, M., Huitric, M., Kautsky, N. and Lebel, L. (2007). Feeding aquaculture growth through globalization: exploitation of marine ecosystems for fishmeal. *Global Environmental Change* 17: 238–249.

49 Tacon, A.G.J (2005). *State of information on salmon aquaculture feed and the environment.* Report prepared for the WWF US initiated salmon aquaculture dialogue. 80 pp.

50 Anker-Nilssen, T., Barrett, R.T. and Krasnov, J.K. (1997). Long- and short-term responses of seabirds in the Norwegian and Barents Seas to changes in stocks of prey fish. Forage Fishes in Marine Ecosystems. *Proceedings of the International Symposium on the Role of Forage Fishes in Marine Ecosystems.* University of Alaska Fairbanks, Fairbanks, AK, USA, pp. 683–698.

51 Frederiksen, M., Wanless, S., Harris, M.P., Rothery, P. and Wilson, L.J. (2004). The role of industrial fisheries and oceanographic change in the decline of the North Sea black-legged kittiwakes. *Journal of Applied Ecology* 41: 1129–1139.

52 Tacon, A.G.J., Hasan, M.R. and Subasinghe, R.P. (2006). Use of fishery resources as feed inputs for aquaculture development: trends and policy implications. *FAO Fisheries Circular.* No. 1018, Food and Agricultural Organization of the United Nations, Rome, Italy. 99 pp.

Footnotes

53 Shepherd, C.J., Pike, I.H. and Barlow, S.M. (2005). Sustainable feed resources of marine origin. Presented at Aquaculture Europe 2005. *European Aquaculture Society Special Publication* No. 35. June 2005, pp 59–66.

54 Sugiyama, S., Staples, D. and Funge-Smith, S.J.. (2004). *Status and potential of fisheries and aquaculture in Asia and the Pacific.* RAP Publication 2004/25. FAO Regional Office for Asia and the Pacific, Bangkok, Thailand. 53 pp.

55 Naylor, R.L., Goldburg, R.J., Primavera, J.H., Kautsky N., Beveridge, M.C.M., Clay, J., Folkes, C., Lubchenco, J., Mooney, H. and Troell, M. (2000). Effect of aquaculture on world fish supplies. *Nature* 405: 1017–1023.

56 FAO (2007). *The state of world fisheries and aquaculture 2006.* FAO Fisheries and Aquaculture Department. Food and Agricultural Organization of the United Nations, Rome, Italy. 162 pp.

57 Gatlin, D.M., Barrows, F.T., Brown, P., Dabrowski, K., Gaylord, T.G., Hardy, R.W., Herman, E., Hu G., Krogdahl, A., Nelson, R., Overturf, K., Rust, M., Sealey, W., Skonberg, D., Souza, E.J., Stone, D., Wilson, R. and Wurtele, E. (2007). Expanding the utilization of sustainable plant products in aquafeeds: a review. *Aquaculture Research* 38: 551–579.

58 Greenpeace and Gene Watch UK (2007). GM contamination Register. Accessed Jan 2008 at: www.gmcontaminationregister.org

59 Pickova, J. and Mørkøre, T. (2007). Alternate oils in fish feeds. *Eur. J. Lipid Sci. Technol.* 109: 256–263.

60 Amaya, E., Davis, D.A., Rouse, D.B. (2007). Alternative diets for the Pacific white shrimp *Litopenaeus vannamei.* Aquaculture 262: 419–425.

61 Browdy, C., Seaborn, G., Atwood, H., Davis, D.A., Bullis, R.A., Samocha, T.M., Wirth, E. and Leffler, J.W. (2006). Comparison of pond production efficiency, fatty acid profiles, and contaminants in *Litopenaeus vannamei* fed organic plant-based and fish-meal-based diets. *Journal of the Aquaculture Society* 37 (4): 437–451.

62 Neori, A., Chopin, T., Troell, M., Buschmann, A.H., Kraemer, G.P., Halling, C., Shpigel, M. and Yarish, C. (2004). Integrated aquaculture: rationale, evolution and state of the art emphasizing seaweed biofiltration in modern mariculture. *Aquaculture* 231: 361–391.

63 Chopin, T., Robinson, S., Page, F., Ridler, N., Sawhney, M., Szemerda, M., Sewuster, J. and Boyne-Travis, S. (2007). Integrated multi-trophic aquaculture making headway in Canada. *The Canadian Aquaculture Research and Development Review,* January 2007, p. 28.

64 Zhou, Y., Yang, H., Hu, H., Liu, Y., Mao, Y., Zhou, H., Xu, X. And Zhang, F. (2006). Bioremediation potential of the macroalga *Gracilaria lemaneiformis* (Rhodophyta) integrated into fed fish culture in coastal waters of north China. Aquaculture 252: 264–276.

65 Diver, S. (2006). *Aquaponics – integration of hydroponics with aquaculture.* ATTRA – National Sustainable Agriculture Information Service, Fayetteville, AR, USA. 28 pp.

66 Happy Shrimp (2007). http://www.happyshrimp.nl/, and personal communication from Curtessi, G. (2007) employee of Happy Shrimp Farm B.V.

67 Frei, M. and Becker, K. (2005). Integrated rice-fish culture: coupled production saves resources. *Natural Resources Forum* 29: 135–143.

68 WWF (2007). Benchmarking study on International Aquaculture Certification Programmes. World Wildlife Fund (WWF), Zurich, Switzerland, and Oslo, Norway. 96 pp.

69 FAO (2007). FAO guidelines for aquaculture certification. Preliminary Draft Only. Accessed Jan 2008 at: http://www.enaca.org/modules/tinyd10/index.php?id=1

70 Roberts, C.M., Mason, L., Hawkins, J.P., Masden, E., Rowlands, G., Storey, J. and Swift, A. (2006). *Roadmap to recovery: a global network of marine reserves.* Greenpeace International, Amsterdam, The Netherlands. 56 pp.

71 Anderson, L. (2004). *Genetically engineered fish – new threats to the environment.* Greenpeace International, Amsterdam, The Netherlands. 20 pp

image Salmon farm near Puerto Chacabuco.

Any aquaculture that takes place needs to be sustainable and fair

GREENPEACE

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