Chapter 12. Aquaculture

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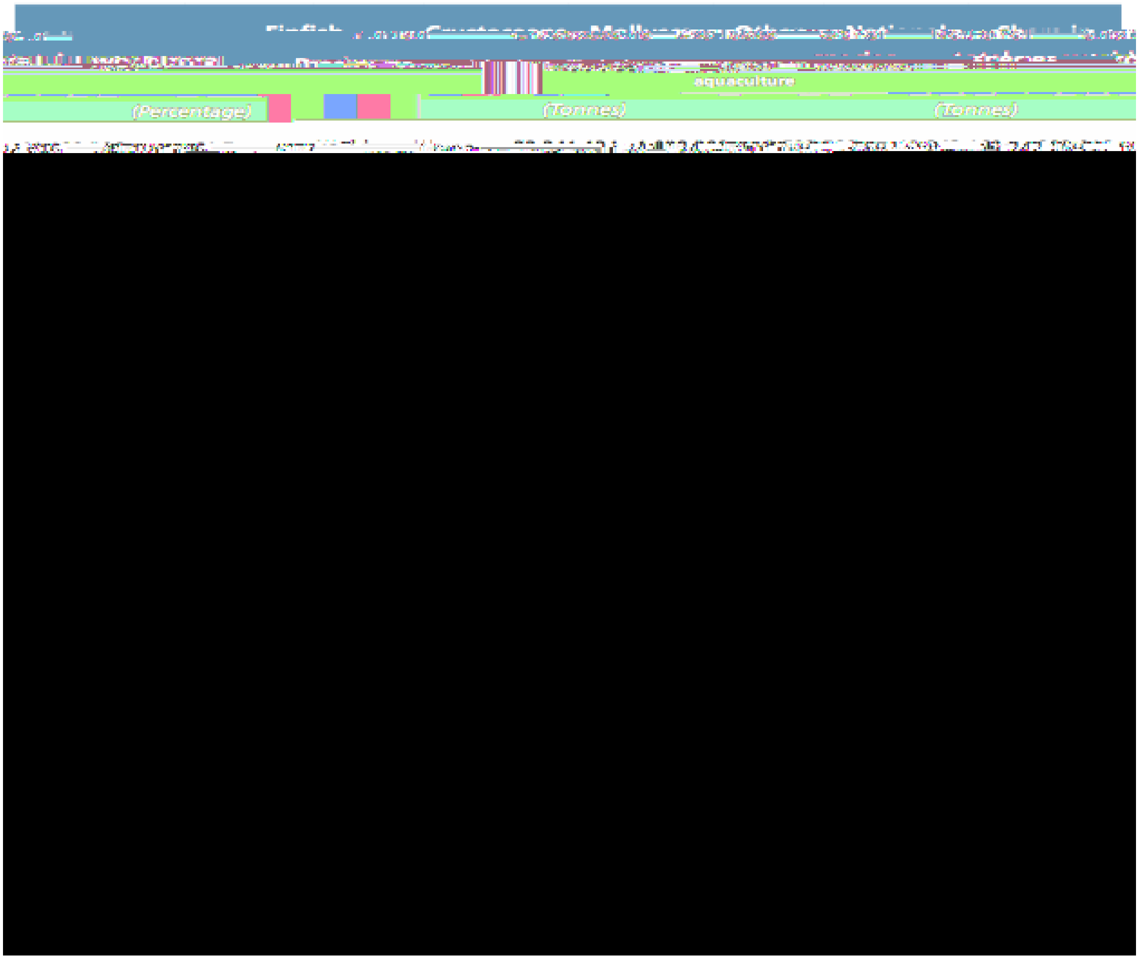
1. Scale and distribution of aquaculture

Aquaculture is providing an increasing contribution to world food security. At an average annual growth rate of 6.2 per cent between 2000 and 2012 (9.5 per cent between 1990 and 2000), aquaculture is the world's fastest growing animal food producing sector

4. Species cultivated

Table 1. Farmed food fish production by 15 top producers and main groups of farmed species in 2012 (FAO, 2014).



5. Aquaculture systems development

The cultivation of farmed food fish is the aquatic version of animal husbandry, where full control of the life cycle enables the domestication of wild species, their growth in large-scale farming systems and the application of well-known and well-established techniques of animal artificial selection of desirable traits, such as resistance to diseases, fast growth and size.

For most farmed aquatic species, hatchery and nursery technologies have been developed and well established, enabling the artificial control of the life cycle of the species. However wild seed is still used in many farming operations. For a few species, such as eels (*Anguilla* spp.), farming still relies entirely on wild seed (FAO, 2014).

Aquaculture can be based on traditional, low technology farming systems or on highly industrialized, capital-intensive processes. In between there is a whole range of aquaculture systems with different efficiencies that can be adapted to local socioeconomic contexts.

Physically, inland aquaculture and coastal shrimp mariculture uses fixed ponds and raceways on land that put a premium on the use of land. Finfish mariculture and some farming of molluscs such as oysters and mussels tend to use floating net pens, cages and other suspended systems in the water column of shallow coastal waters, enabling these systems to be fixed by being anchored to the bottom.

Direct land use needs for fish and shrimp ponds can be substantial. Current aquaculture production occupies a significant quantity of land, both in inland and coastal areas. Aquaculture land use efficiency, however, differs widely by production system. While fish ponds use relatively high amounts of land (Costa-Pierce et al., 2012, cited in WRI, 2014), flow-through systems (raceways) use less land, while cages and pens suspended in water bodies use very little (if any) land (WRI, 2014).

The handling of monocultures with high densities of individuals in confinement replicates the risks typical to monocultures in land-based animal husbandry, such as the spread and proliferation of parasites, and the contagion of bacterial and viral infections producing mass mortalities, and the accumulation of waste products. If on land these risks can be partially contained, in mariculture, the use of semi-enclosed systems open to the natural flow of seawater and sedimentation to the bottom, propagate these risks to the surrounding environment affecting the health of the ecosystems in which aquaculture operations are implanted.

The introduction of these risks to the coastal zones puts a premium in the application of good management practices and effective regulations for zoning, site selection and maximum loads per area.

In 1999 during the early development of shrimp culture, a White Spot Syndrome Virus (WSSV) epizootic quickly spread through nine Pacific coast countries in Latin America, costing billions of dollars (McClennen, 2004). Disease outbreaks in recent years have affected Chile's Atlantic salmon production with losses of almost 50 percent to the virus of "infectious salmon anaemia" (ISA). Oyster cultures in Europe were attacked by herpes virus Os HV-1 or OsHV-1 µvar, and marine shrimp farming in several countries in Asia, South America and Africa have experienced bacterial and viral infections, resulting in partial or sometimes total loss of production. In 2010, aquaculture in China suffered production losses of 1.7 million tons caused by natural disasters, diseases and pollution. Disease outbreaks virtually wiped out marine shrimp farming production in Mozambique in 2011 (FAO, 2010, 2012).

New diseases also appear. The early mortality syndrome (EMS) is an emerging disease of cultured shrimp caused by a strain of *Vibrio parahaemolyticus*, a marine micro-organism native in estuarine waters worldwide. Three species of cultured shrimp are affected (*Penaeus monodon*, *P. vannamei* and *P. chinensis*). In Viet Nam, about 39 000 hectares were affected in 2011. Malaysia estimated production losses of 0.1 billion dollars (2011). In Thailand, reports indicated annual output declines of 30–70 percent. The disease has been reported in China, Malaysia, Mexico, Thailand and Viet Nam (FAO, 2014).

It is apparent that intensive aquaculture systems are likely to create conditions that expose them to disease outbreaks. When semithe environment, where they can persist for long periods of time as a potential source of recurring outbreaks.

Optimization of industrial systems selects for few or a single preferred species. This is the case in the oyster culture with the widespread culture of Crassostrea gigas and in the shrimp industry by the dominance of Penaeus vanamei, the white shrimp as the preferred species. This can be also an additional source of risk, if evolving pathogens develop resistance to antibiotics or other treatments used to control well-known diseases.

6. Fed and non-fed aquaculture

Animal aquaculture production can be divided among those species that feed from

In Europe, after much publicly and privately sponsored research, the technology to farm cod was fully developed and supported by large amounts of venture capital, and industrial production of cod started. In the early 2000s this industrial development suffered from the financial crisis of 2008, and further growth and development almost stopped. Although the participation of risk capital in the development of aquaculture might be an option in particular places and circumstances, it is far from being the preferred option. Development of aquaculture systems, supplying domestic and international markets, has a better chance to succeed if supported by a mix of long-term public support systems (credit, technical assistance) for small and rural producers coupled with entrepreneurial initiatives well implanted in the markets.

Marine finfish aquaculture is rapidly growing in the Asia-Pacific region, where high-value carnivorous fish species (e.g. groupers, barramundi, snappers and pompano) are typically raised in small cages in inshore environments. In China this development has led to experiments in offshore mariculture using larger and stronger cages. (FAO, 2014).

These examples show that at least to the present, decision-making for the development of mariculture, particularly finfish mariculture, tends to be dominated

In 2012 about 35 per cent of world fishmeal production was obtained from fisheries by-products (frames, off-

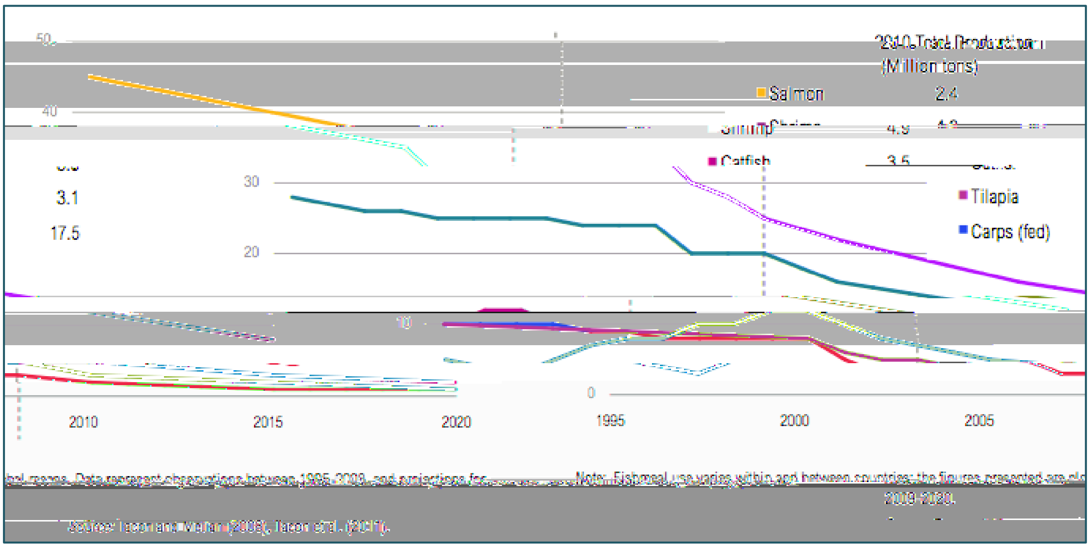


Figure 3. The aquaculture industry has reduced the share of fishmeal in farmed fish diets (percent) (FAO, 2014).

The use of fish oil by the aquaculture sector will probably increase in the long run albeit slowly. It is estimated that total usage will increase by more than 16 percent, from 782,000 tons (2.7 percent of total feeds by weight) in 2008 to the estimated 908.000 tons (1.3 percent of total feeds for that year) by 2020. It is forecast that increased usage will shift from salmonids, to marine finfishes and crustaceans because of the current absence of cost-effective alternative lipid sources that are rich in long-chain polyunsaturated fatty acids. (Tacon et al., 2011)

8. Economic and social significance

At the global level, the number of people engaged in fish farming has, since 1990, increased at higher annual rates than that of those engaged in capture fisheries. The most recent estimates (FAO 2014, Table 2) indicate that about 18.9 million people were engaged in fish farming, 96 per cent concentrated primarily in Asia, followed by Africa (1.57 percent), Latin America and the Caribbean (1.42 percent), Europe (0.54 per cent), North America (0.04 per cent) and Oceania (0.03 per cent). The 18,175 million fish farmers in 2012 represented 1.45 per cent percent of the 1.3 billion people economically active in the broad agriculture sector worldwide. (FAO, 2014).

Table 3. Per capita average outputs per fish farmer by region (in FAO, 2014).

Fish is among the most traded food commodities worldwide. Fish can be produced in one country, processed in a second and consumed in a third. There were 129 billion dollars of exports of fish and fishery products in 2012 (FAO, 2014)

In the last two decades, in line with the impressive growth in aquaculture production, there has been a substantial increase in trade of many aquaculture products based on both low- and high-valu occupied approximately 4.4 million ha—for a combined area of roughly 18 million hectares, overwhelmingly in Asia. Many of these ponds were converted from rice paddies and other existing cropland rather than newly converted natural lands—

Mariculture industry has undertaken a significant effort to produce and use variants of cultivated species that are infertile, diminishing the risk of gene-flow from cultivated/domesticated species to their wild counterparts when escapes occur.

9.5 Non-native species.

Aquaculture has been a significant source of intentional and unintentional introductions of non-native species into local ecosystems worldwide. The harm caused by invasive species is well documented.

Intensive fish culture, particularly of non-native species, can be and has been involved in the introduction and/or amplification of pathogens and disease in wild populations (Blazer and LaPatra, 2002, cited in WHOI, 2007).

Non-native oysters have been introduced in many regions to improve failing harvests of native varieties due to diseases or overexploitation. The eastern oyster, *Crassostrea virginica*, was introduced to th11(o)2]1austd to t C[5([5(.7 0 Td[(e)-1(9I.le(e)-i)10(v)3(e)-1(s)

(2,3,3,6-tetrachloro-4-methylsulfonyl pyridine), zinc pyrithione and Zineb. (Guardiola et al., 2012). The use of biocides is not as well-regulated as drug use in aquaculture because the information available on their effects on ecosystems is still limited.

9.8 Use of antibiotics

Antibiotic drugs used in aquaculture may have substantial environmental effects. The use of antibiotics in aquaculture can be categorized as therapeutic, prophylactic or metaphylactic. Therapeutic use is the treatment of established infections. Metaphylaxis are group-medication procedures, aimed at treating sick animals while also medicating others in the group to prevent disease. Prophylaxis means the precautionary use of antimicrobials in either individuals or groups to prevent the development of infections (Romero et al., 2012).

In aquaculture, antibiotics at therapeutic levels are frequently administered for short periods of time via the oral route to groups of fish that share tanks or cages. Fish do not effectively metabolize antibiotics and will pass them largely unused back into the environment in feces. 70 to 80 per cent of the antibiotics administered to fish as medicated pelleted feed are released into the ceqf.001 lre1.00ebed s. 7qf.00x(te)3(r)4(e)(4(w)6((re3

Aquaculture Service, recently released data reporting unprecedentedly high amounts of antibiotics used by the salmon industry.[6] Inefficiencies in the antibiotic treatment of fish illnesses now may lead to significant economic losses in the future (Romero et al., 2012).

Antimicrobial-resistant bacteria in aquaculture also present a risk to public health. The appearance of acquired resistance in fish pathogens and other aquatic bacteria means that such resistant bacteria can act as a reservoir of resistance genes from which genes can be further disseminated and may ultimately end up in human pathogens. Plasmid-borne resistance genes have been transferred by conjugation from the fish pathogen A. salmonicida to -0 T-

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FAO/The University of Alaska, 10–

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