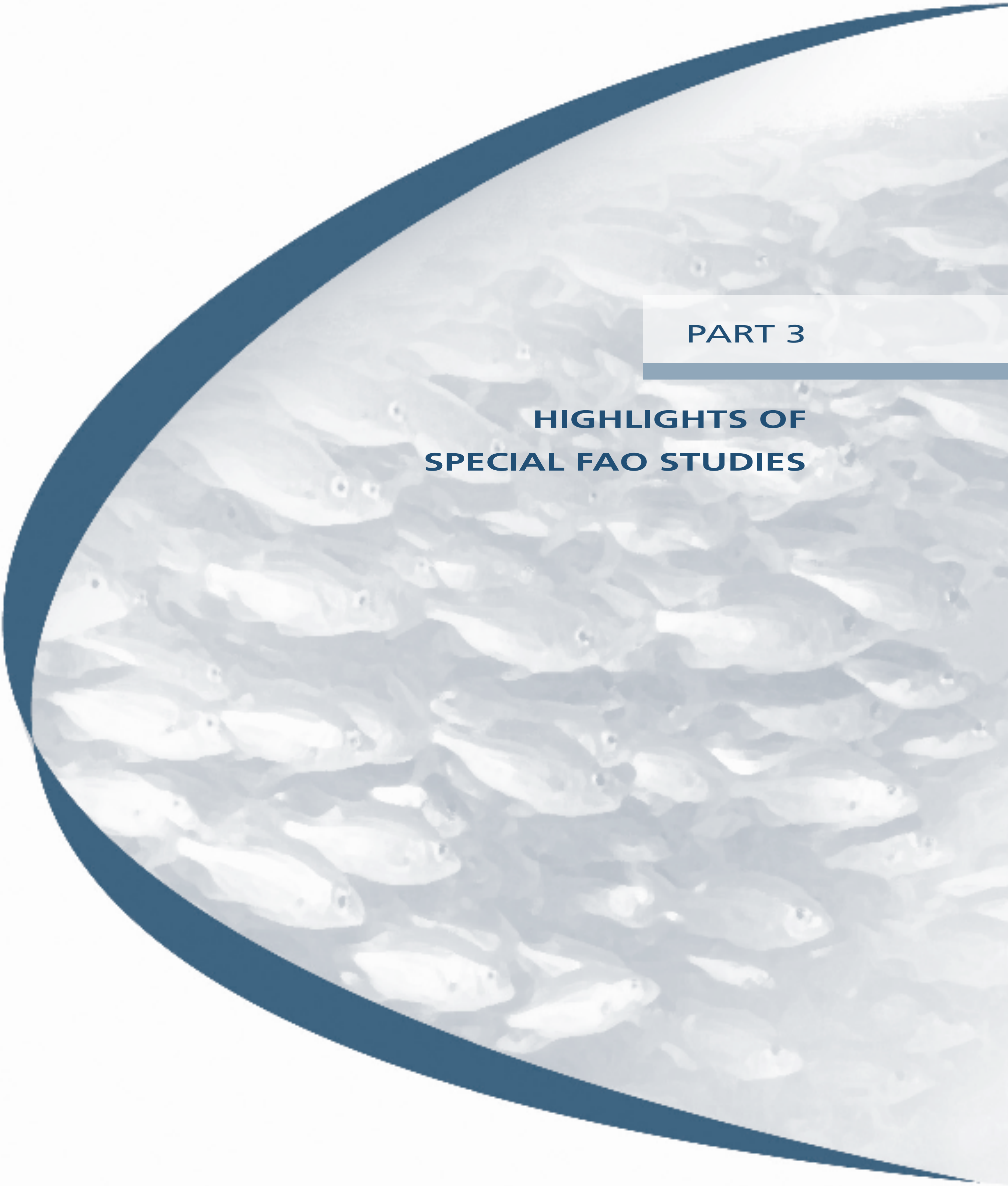


PART 3

HIGHLIGHTS OF SPECIAL FAO STUDIES

HIGHLIGHTS OF SPECIAL FAO STUDIES

Scope of the seaweed industry

INTRODUCTION

The seaweed industry provides a wide variety of products that have an estimated total annual production value of US$5.5–6 billion. Food products for human consumption contribute about US$5 billion to this figure. Substances that are extracted from seaweeds – hydrocolloids – account for a large part of the remaining billion dollars, while smaller, miscellaneous uses, such as fertilizers and animal feed additives, make up the rest. The industry uses 7.5–8 million tonnes of wet seaweed annually, harvested either from naturally growing (wild) seaweed or from cultivated (farmed) crops. The farming of seaweed has expanded rapidly as demand has outstripped the supply available from natural resources. Commercial harvesting occurs in about 35 countries, spread between the northern and southern hemispheres, in waters ranging from cold, through temperate, to tropical.

CLASSIFICATION OF SEAWEEDS

Seaweeds can be classified into three broad groups based on pigmentation: brown, red and green. Botanists refer to these broad groups as Phaeophyceae, Rhodophyceae and Chlorophyceae, respectively. Brown seaweeds are usually large, ranging from the giant kelp that can often be as long as 20 m, to thick, leather-like seaweeds from 2 to 4 m long, to smaller species 30–60 cm long. Red seaweeds are usually smaller, generally ranging from a few centimetres to about a metre in length. Red seaweeds are not always red in colour; they are sometimes purple, even brownish-red, but they are still classified by botanists as Rhodophyceae because of other characteristics. Green seaweeds are also small, with a similar size range to that of the red seaweeds. Seaweeds are also called macro-algae. This distinguishes them from micro-algae (Cyanophyceae), which are microscopic in size, often unicellular, and are best known by the blue–green algae that sometimes bloom and contaminate rivers and streams. Naturally growing seaweeds are often referred to as wild seaweeds, in contrast with seaweeds that are cultivated or farmed.

SOURCES AND USES OF COMMERCIAL SEAWEEDS

Seaweed as food

The use of seaweed as food has been traced back to the fourth century in Japan and the sixth century in China. Today, those two countries and the Republic of Korea are the largest consumers of seaweed as food. However, as nationals from these countries have migrated to other parts of the world, the demand for seaweed for food has followed them, as, for example, in some parts of the United States and in South America. Increasing demand over the last 50 years has outstripped the ability to supply requirements from natural (wild) stocks. Research into the life cycles of these seaweeds has led to the development of cultivation industries that now supply more than 90 percent of the market's demand. In Iceland, Ireland and Nova Scotia (Canada), a different type of seaweed has traditionally been eaten, and this market is being developed further. Some government and commercial organizations in France have been promoting seaweeds for restaurant and domestic use, with some success. An informal market exists among coastal dwellers in some developing countries where there has been a tradition of using fresh seaweeds as vegetables and in salads.

Kombu from Laminaria *species*

China is the largest producer of edible seaweeds, harvesting about 5 million wet tonnes annually. The greater part of this is for kombu, produced from hundreds of hectares of the brown seaweed *Laminaria japonica*. *Laminaria* was originally native to Japan and the Republic of Korea, and was introduced accidentally to China, in 1927, at the northern city of Dalian (formerly Dairen), probably by shipping. Prior to that, China had imported its needs from the naturally growing resources in Japan and the Republic of Korea. In the 1950s, China developed a method for cultivating *Laminaria*; sporelings ("seedlings") are grown in cooled water in greenhouses and later planted out in long ropes suspended in the ocean. This activity became a widespread source of income for large numbers of coastal families. By 1981, 1 200 000 wet tonnes of seaweed were being produced annually. In the late 1980s, production fell as some farmers switched to the more lucrative but risky farming of shrimp. By the mid-1990s, production had started to rise again and the reported annual harvest in 1999 was 4 500 000 wet tonnes. China is now self-sufficient in *Laminaria* and has a strong export market.

In the past, *Laminaria* was in plentiful supply in Japan, mainly from the northern island of Hokkaido, where several naturally growing species were available. However, demand grew as Japan became more prosperous after the Second World War, and by the 1970s cultivation became necessary. Today, the supply comes from a combination of natural and cultivated harvests. In the Republic of Korea, the demand for *Laminaria* is much lower and most is now provided from cultivation.

Wakame from Undaria pinnatifida

The Republic of Korea grows about 800 000 wet tonnes annually of three different species of edible seaweed, of which about 50 percent is for wakame, produced from the brown seaweed *Undaria pinnatifida*, which is cultivated in a similar fashion to *Laminaria* in China. Some of this is exported to Japan, where production is only about 80 000 wet tonnes per year. *Undaria* is less popular than *Laminaria* in China; by the mid-1990s China was harvesting about 100 000 wet tonnes per year of *Undaria* from cultivation, compared with 3 million wet tonnes per year of *Laminaria* at that time.

Hizikia from Hizikia fusiforme

Hizikia is popular as food in Japan and the Republic of Korea. Up to 20 000 wet tonnes were harvested from natural beds in the Republic of Korea in 1984, when cultivation began. Since then, cultivation has steadily increased, on the southwest coast, such that in 1994 about 32 000 wet tonnes were farmed and only 6 000 wet tonnes were harvested from the wild. A large proportion of the production is exported to Japan, where there is little activity in *Hizikia* cultivation.

Nori from Porphyra *species*

Japan produces about 600 000 wet tonnes of edible seaweeds annually, around 75 percent of which is for nori – the thin, dark, purplish seaweed found wrapped around a rice ball in *sushi*. Nori is produced from species of *Porphyra*, which are red seaweeds. *Porphyra* has been cultivated in Japan and the Republic of Korea since the seventeenth century; there are natural stocks, but even at that time they were insufficient to meet demand. Cultivation was developed intuitively, by observing the seasonal appearance of spores, but the complex life cycle of *Porphyra* was not properly understood until the 1950s. Since that time, cultivation has flourished, and now accounts for virtually all the production in China, Japan and the Republic of Korea. In 1999, the combined annual production from these three countries was just over 1 000 000 wet tonnes. Nori is a high-value product, worth approximately US$16 000/dry tonne, compared with kombu at US$2 800/dry tonne and wakame at US$6 900/dry tonne.

Extracts from seaweeds – hydrocolloids

Agar, alginate and carrageenan are three hydrocolloids that are extracted from various red and brown seaweeds. A hydrocolloid is a non-crystalline substance with very large molecules, which dissolves in water to give a thickened (viscous) solution. Agar, alginate and carrageenan are water-soluble carbohydrates used to thicken aqueous solutions, to form gels (jellies) of varying degrees of firmness, to form water-soluble films, and to stabilize certain products, such as ice-cream (they inhibit the formation of large ice crystals, allowing the ice-cream to retain a smooth texture).

The use of seaweeds as a source of these hydrocolloids dates back to 1658, when the gelling properties of agar, extracted with hot water from a red seaweed, were first discovered in Japan. Extracts of Irish moss, another red seaweed, contain carrageenan and were popular as thickening agents in the nineteenth century. It was not until the 1930s that extracts of brown seaweeds, containing alginate, were produced commercially and sold as thickening and gelling agents. Industrial uses of seaweed extracts expanded rapidly after the Second World War, but were sometimes limited by the availability of raw materials. Once again, research into life cycles has led to the development of cultivation industries that now supply a high proportion of the raw materials for some hydrocolloids. Today, approximately 1 million tonnes of wet seaweed are harvested annually and extracted to produce the above three hydrocolloids. Total hydrocolloid production is in the region of 55 000 tonnes per year, with a value of US$585 million.

Agar

Agar production (valued at US$132 million annually) is principally from two types of red seaweed, one of which has been cultivated since the 1960s, but on a much larger scale since 1990. Two genera, *Gelidium* and *Gracilaria*, account for most of the raw material used for the extraction of agar, with *Gelidium* species giving the higher-quality product. All *Gelidium* used for commercial agar extraction comes from natural resources, principally from France, Indonesia, the Republic of Korea, Mexico, Morocco, Portugal and Spain. *Gelidium* is a small, slow-growing plant and, while efforts to cultivate it in tanks and ponds have been biologically successful, they have generally proved uneconomic. *Gracilaria* species were once considered unsuitable for agar production because the quality of the agar was poor. In the 1950s, it was found that pre-treatment of the seaweed with alkali before extraction lowered the yield but gave a good-quality agar. This allowed expansion of the agar industry, which had been previously limited by the available supply of *Gelidium*, and led to the harvesting of a variety of wild species of *Gracilaria* in countries such as Argentina, Chile, Indonesia and Namibia. Chilean *Gracilaria* was especially useful, but evidence of overharvesting of the wild crop soon emerged. Cultivation methods were then developed, both in ponds and in the open waters of protected bays. These methods have since spread beyond Chile to other countries, such as China, Indonesia, the Republic of Korea, Namibia, the Philippines and Viet Nam, usually using species of *Gracilaria* native to each particular country. *Gracilaria* species can be grown in both cold and warm waters. Today, the supply of *Gracilaria* still derives mainly from the wild, with the extent of cultivation depending on price fluctuations.

Alginate

Alginate production (valued at US$213 million annually) is by extraction from brown seaweeds, most of which are harvested from the wild. The more useful brown seaweeds grow in cold waters, thriving best in waters up to about 20 °C. Brown seaweeds are also found in warmer waters, but these are less suitable for alginate production and are rarely used as food. A wide variety of species are used, harvested in both the northern and southern hemispheres. Countries producing alginate include Argentina, Australia, Canada, Chile, Ireland, Mexico, Norway, South Africa, the United Kingdom (Scotland and Northern Ireland) and the United States. Most species are harvested from natural resources; cultivated raw material is normally too expensive for alginate production. While much of the *Laminaria* cultivated in China is used for food, when there is surplus production this can also be used in the alginate industry.

Carrageenan

Carrageenan production (valued at US$240 million annually) was originally dependent on wild seaweeds, especially *Chondrus crispus* (Irish moss), a small seaweed growing in cold waters, with a limited resource base in France, Ireland, Portugal, Spain and the east coast provinces of Canada. As the carrageenan industry expanded, the demand for raw material began to strain the supply from natural resources. However, since the early 1970s the industry has expanded rapidly following the availability of other carrageenan-containing seaweeds that have been successfully cultivated in warm-water countries with low labour costs. Today, most raw material comes from two species originally cultivated in the Philippines, *Kappaphycus alvarezii* and *Eucheuma denticulatum*, but which are now also cultivated in other warm-water countries such as Indonesia and the United Republic of Tanzania. Limited quantities of wild *Chondrus* are still used; attempts to cultivate *Chondrus* in tanks have been successful biologically, but it has proved uneconomic as a raw material for carrageenan. Wild species of *Gigartina* and *Iridaea* from Chile are also being harvested and efforts are being made to find cultivation methods for these.

Other uses of seaweed

Seaweed meal

The production of seaweed meal, used as an additive to animal feed, was pioneered in Norway in the 1960s. It is made from brown seaweeds that are collected, dried and milled. Drying is usually by oil-fired furnaces and costs are therefore affected by the price of crude oil. Approximately 50 000 tonnes of wet seaweed are harvested annually with a yield 10 000 tonnes of seaweed meal, which is sold for around US$5 million.

Fertilizers

The use of seaweeds as fertilizers dates back at least to the nineteenth century. Early usage was by coastal dwellers, who collected storm-cast seaweed, usually large brown seaweeds, and dug it into local soils. The high fibre content of the seaweed acts as a soil conditioner and assists moisture retention, while the mineral content is a useful fertilizer and source of trace elements. In the early twentieth century, a small industry developed based on the drying and milling of mainly storm-cast material, but it dwindled with the advent of synthetic chemical fertilizers. Today, with the rising popularity of organic farming, there has been some revival of the industry, but not yet on a large scale; the combined costs of drying and transportation have confined usage to sunnier climates where the buyers are not too distant from the coast.

Liquid seaweed extracts are the growth area in seaweed fertilizers. These can be produced in concentrated form for dilution by the user. Several can be applied directly onto plants or they can be watered in, around the root areas. Several scientific studies have proved the effectiveness of these products, and seaweed extracts are now widely accepted in the horticultural industry. When applied to fruit, vegetable and flower crops, improvements have included higher yields, increased uptake of soil nutrients, increased resistance to certain pests such as red spider mite and aphids, improved seed germination, and greater resistance to frost. No one is really sure of the reasons for their effectiveness: the trace element content is insufficient to account for the improved yields, for example. Most of the extracts contain several types of plant growth regulator, but in this respect also there is no clear evidence that these alone are responsible for the improvements. In 1991, it was estimated that about 10 000 tonnes of wet seaweed were used annually to make 1 000 tonnes of seaweed extracts with a value of US$5 million. However, since that time the market has probably doubled as the usefulness of these products has become more widely recognized and organic farming has increased in popularity.

Cosmetics

Cosmetic products, such as creams and lotions, sometimes show on their labels that the contents include "marine extract", "extract of alga", "seaweed extract" or similar. This usually means that one of the hydrocolloids extracted from seaweed has been added. Alginate or carrageenan could improve the skin moisture retention properties of the product. In thalassotherapy, seaweed pastes, made by cold-grinding or freeze-crushing, are applied to the person's body and then warmed under infrared radiation.

This treatment, in conjunction with seawater hydrotherapy, is said to provide relief for rheumatism and osteoporosis.

Fuels

Over the last 20 years a number of large projects have investigated the possible use of seaweeds as an indirect source of fuel. The idea was to grow large quantities of seaweed in the ocean and then ferment this biomass to generate methane gas for use as fuel. The results have indicated that the process is not yet economically viable and that further research and development will be needed over the longer term.

Wastewater treatment

There are potential uses for seaweed in wastewater treatment. For example, some seaweeds are able to absorb heavy metal ions such as zinc and cadmium from polluted water. The effluent water from fish farms usually contains high levels of waste that can cause problems for other aquatic life in adjacent waters. As seaweeds can often use much of this waste material as a source of nutrients, trials have been undertaken to farm seaweed in areas adjacent to fish farms.

Antiviral agents

Antiviral activity has been reported for extracts from several seaweeds, although the tests have been either *in vitro* (in test tubes or similar) or on animals, with few advancing to trials involving people. A notable exception is Carraguard – a mixture of carrageenans similar to those extracted from Irish moss. Carraguard has been shown to be effective against human immunodeficiency virus (HIV) *in vitro* and against herpes simplex 2 virus in animals. Testing has advanced to the stage where the international research organization, the Population Council, is supervising large-scale HIV trials of Carraguard, involving 6 000 women over four years. Extracts from the brown seaweed, *Undaria pinnatifida*, have also shown antiviral activity; an Australian company is involved in several clinical trials, in Australia and the United States, of such an extract against HIV and cancer. The Population Council's trials against HIV involve the vaginal application of a gel containing carrageenan.

Because antiviral substances in seaweeds are composed of very large molecules, it was thought they would not be absorbed by eating seaweed. However, it has been found in one survey that the rate of HIV infection in seaweed-eating communities can be markedly lower than it is elsewhere. This has led to some small-scale trials in which people infected with HIV ate powdered *Undaria*, with a resulting decrease (25 percent) in the viral load. Seaweeds may yet prove to be a source of effective antiviral agents.

Global aquaculture outlook: an analysis of production forecasts to 2030

INTRODUCTION

Population growth, urbanization and rising per capita incomes have led the world fish consumption to more than triple over the period 1961–2001, increasing from 28 to 96.3 million tonnes. Per capita consumption has multiplied by a factor of 1.7 over the same period and in many countries this trend is expected to continue in forthcoming decades. In the context of stagnant production, or slow growth from the capture fisheries, only aquaculture expansion can meet this growing global demand. Acknowledging the challenges that this relatively new industry may face in coming years and the need to prepare for the sustainable growth of the sector, FAO carried out a study on the global aquaculture production outlook to evaluate its potential to meet projected demand for food fish in 2020 and beyond.[55]

[55] This article is a summary of FAO. 2004. *Global aquaculture outlook in the next decades: an analysis of national aquaculture production forecasts to 2030*. FAO Fisheries Circular No. C1001. Rome. (In press)

One of the means of assessing whether forecasts of aquaculture expansion are achievable is to examine national aquaculture plans. With their expected aquaculture output, national plans can provide insights into future directions. Production targets can be aggregated and compared with existing general equilibrium forecasts. This approach was used to answer two questions: do individual countries have the ambition to expand to meet global demand forecasts, and are their projections realistic? Is the "sum" of national production forecasts compatible with projected increases in demand for food fish?

Major aquaculture producers were requested to provide their aquaculture development strategies and plans, with quantitative production targets if available.[56] Information on global supply and demand forecasts was compiled from three sources (Ye in FAO, 1999; IFPRI, 2003; Wijkström, 2003).[57] This information was subsequently used as a benchmark against which the realism and relevance of national projections were measured.

GLOBAL FORECASTS

Global fisheries production reached 130.2 million tonnes in 2001, having doubled over the previous 30 years.[58] However, a significant part of the increase came from aquaculture. While output from capture fisheries grew at an annual average rate of 1.2 percent, output from aquaculture (excluding aquatic plants) grew at a rate of 9.1 percent, reaching 39.8 million tonnes in 2002. This growth rate is also higher than for other animal food-producing systems such as terrestrial farmed meat.[59] Much of this expansion in aquaculture has taken place in China, whose reported output growth far exceeded the global average. However, if figures for China are excluded, world aquaculture output growth during the last 30 years was more moderate, showing declining rates of expansion (6.8, 6.7 and 5.4 percent annual growth rates for the periods 1970–80, 1980–90 and 1990–2000, respectively).[60]

Future global aquaculture production

Table 13, which presents three global forecasts of food fish demand, demonstrates that even if output from capture fisheries continued to grow at 0.7 percent annually, it alone would be incapable of meeting projected demand for food fish. This table also highlights the impact of price assumptions on the projections. Two forecasts, made by Wijkström (2003) and Ye (in FAO, 1999), assume constant relative fish prices. Their projections of world fish consumption are based on demand variables (population growth and per capita consumption) and exclude variations in real and relative prices. One forecast by Ye assumes that even if per capita consumption of food fish remains at its 1995/96 level of 15.6 kg per person, population growth will generate a demand for food fish (126.5 million tonnes) that exceeds the 99.4 million tonnes available in 2001.

Prices, and their effect on consumer demand and aquaculture supply, are an integral part of the International Food Policy Research Institute (IFPRI) equilibrium model. The baseline forecast predicts an increase in the real price of both high-value and low-value food fish by 2020, and also an increase in its relative price (compared with substitutes). This increase has a dampening effect on demand in two ways. First, given the high price elasticity of demand for fish, an increase in real price will reduce

[56] Many countries replied to the request. However, only 11 documents (from Bangladesh, Brazil, Canada, Chile, China, Egypt, India, Indonesia, the Philippines, Thailand and Viet Nam) were ultimately used as they were obtained within the time limit of the study and contained quantitative production targets.

[57] FAO. 1999. *Historical consumption and future demand for fish and fishery products: exploratory calculations for the years 2015/2030*, by Y. Ye. FAO Fisheries Circular No. 946. Rome; IFPRI. 2003. *Fish to 2020: supply and demand in changing global markets*, by C. Delgado, N. Wada, M. Rosegrant, S. Meijer and M. Ahmed. International Food Policy Research Institute (IFPRI), Washington, DC.; U.N. Wijkström. 2003. Short and long-term prospects for consumption of fish. *Veterinary Research Communications*, 27(Suppl. 1): 461–468.

[58] 2001 is the most recent year for which fisheries production figures are available in FAOSTAT.

[59] FAO. 2003. *Aquaculture production statistics 1988–1997*. Rome.

[60] Source: Fishstat Plus (v. 2.30) of 21.06.2004.

the quantities demanded. Second, an increase in the relative price of fish, with positive cross-elasticity coefficients (at least for poultry), will encourage substitution towards cheaper alternatives. In spite of these factors, global per capita consumption of fish in the baseline scenario is projected to continue rising (to 17.1 kg per year). An extreme scenario is a negative growth in production for all capture fishery commodities, including fishmeal and fish oil.[61] This would have such significant effects on reduction fisheries, fishmeal and food fish prices that demand would be dampened. Under this scenario, per capita consumption in 2020 would actually be less than in 2001. However, increases in the real price of fish do provide an incentive to aquaculture, given that its supply elasticity coefficient is higher than that of capture fisheries. If higher prices spur technological innovations and needed investment, aquaculture could expand more quickly than the baseline, with a possible output of 69.5 million tonnes by 2020.

To visualize the consequences of all three forecasts on aquaculture output, two scenarios are considered. In the first case, "growing fisheries", output of food fish from the capture fisheries is assumed to increase at IFPRI's 0.7 percent rate until the forecast horizon date. Under this assumption, the food fish derived from the capture fisheries is deducted from the projected demand, and the residual is the amount required from aquaculture. All results require a higher aquaculture output than the 2001 total of 37.9 million tonnes. If food fish output from the capture fisheries does not increase at the rate projected, the demand gap to be filled by aquaculture will be higher than shown. This is explored in the "stagnating fisheries" scenario, which assumes that the output of food fish from capture fisheries does not increase beyond 2001. Quantities

Table 13
Projections of food fish demand

Forecasts and forecast dates	Price assumption	By the forecast date		Required from aquaculture by the forecast date[4]				
				Growing fisheries		Stagnating fisheries		
		Global consumption	Food fish demand	Total output	Growth rate	Total output[5]	Growth rate	Average annual increase
		(kg/year/capita)	*(million tonnes)*	*(million tonnes)*	*(percent)*	*(million tonnes)*	*(percent)*	*(million tonnes)*
IFPRI (2020)								
Baseline	Flexible real and relative prices	17.1	130	53.6[3]	1.8	68.6	3.5	1.7
Lowest[1]		14.2	108	41.2	0.4	46.6	1.4	0.6
Highest[2]		19.0	145	69.5[3]	3.2	83.6	4.6	2.4
Wijkström								
(2010)	Constant	17.8	121.1	51.1[3]	3.4	59.7	5.3	2.4
(2050)	Constant	30.4	270.9	177.9[3]	3.2	209.5	3.6	3.5
Ye (2030)								
	Constant	15.6	126.5	45.5[3]	0.6	65.1	2.0	1.0
	Constant	22.5	183.0	102.0[3]	3.5	121.6	4.2	2.9

[1] Assumes an "ecological collapse" of the capture fisheries.
[2] Assumes technological advances in aquaculture.
[3] Assumes a growth of output of food fish from the capture fisheries of 0.7 percent per year to the forecast date.
[4] From 2000, 35.6 million tonnes, three-year average of aquaculture output.
[5] Assumes zero growth in food fish from the capture fisheries after 2001.
Source: Calculated from IFPRI (2003); Wijkström (2003) and Ye in FAO (1999).
Full source details are given in footnote 57, p. 108.

[61] This scenario was labelled as "ecological collapse" under the IFPRI projections. Although suggesting a dramatic decline and pessimistic outlook for capture fisheries, technically, it is not a complete collapse.

required from aquaculture under this scenario may, however, be overstated as price increases will reduce demand. Were the capture fisheries to stagnate after 2001 rather than grow until 2020, food fish prices would increase more than estimated. Because of own-price elasticity and cross-price elasticity, this increase would have a dampening effect on demand for food fish.

REGIONAL PERSPECTIVES

An analysis of country plans in a regional context has also been undertaken. In 2001, Asia produced 88.5 percent of world aquaculture output (excluding aquatic plants). Europe's output, during the same year, represented 3.4 percent. Norway is Europe's largest producer and has ambitious forecasts for expansion. However, the future of the 15 members of the EU pre-2004 is less promising as growth rates are projected to fall. Latin America and the Caribbean, on the other hand, has experienced rapid expansion of its aquaculture output (16.4 percent per year during the 1990s). Despite its total output remaining much smaller than Asia's (2.9 percent of global aquaculture output excluding aquatic plants) in 2001, the region's share of global value was higher at 7 percent.

All regions are forecast to experience continued expansion (Table 14) but, according to the baseline and IFPRI's highest forecast, Asia will continue to produce the bulk of aquaculture output by 2020.

Contrasting these results with goals set in national plans and strategies, projections for China and Latin America and the Caribbean appear low, whereas those for

Table 14

Food fish from aquaculture: actual and forecast, by region

	Actual in 2001		IFPRI output forecast for 2020[a]				Alternative forecast	
			Baseline		Highest			
	Output	Share of global output	Output	Growth rate 2001–20[b]	Output	Growth rate 2001–20[b]	Output	Growth rate 2001–20[b]
	(million tonnes)	*(percent)*	*(million tonnes)*	*(percent)*	*(million tonnes)*	*(percent)*	*(million tonnes)*	*(percent)*
China	26.1	68.8	35.1	1.6	44.3	2.8		
Europe[c]	1.3	3.4	1.9	2.0	2.3	3.0	1.5[d]	0.8
India	2.2	5.8	4.4	3.7	6.2	5.6	4.6[e]–3.3[f]	8.5[e]–8.2[f]
Latin America and the Caribbean	1.1	2.9	1.5	1.6	2.1	3.5	24.8[g]	18
South Asia (excl. India)	0.7	1.8	1.2	2.9	1.7	4.8		
Southeast Asia	2.9	7.7	5.1	3.0	7.3	5.0		
Sub-Saharan Africa	0.06	0.1	0.1	4.6	0.2	8.1		
Global	37.8	100	53.6	1.9	69.5	3.3		

[a] IFPRI, 2003; [b] Annual average growth rate 2001–20; [c] the fifteen countries of the EU in April 2004; [d] Failler in FAO, 2003; [e] period 2001–10, Gopakumar, 2003; [f] period 2000–05 for freshwater aquaculture, Gopakumar, *et al*., 1999; [g] Wurmann, 2003.

Sources: IFPRI, 2003 – see note 57 on p. 108.

C. Wurmann. 2003. *Acuicultura en América Latina y el Caribe: ¿Una industria con futuro?* AquaNoticias al día (available at http://www.aqua.cl/puntosvista.php).

FAO. 2003. *Fish consumption in the European Union in 2015 and 2030*, by P. Failler. Fisheries Circular 792/2. Rome. (In press)

K. Gopakumar. 2003. Indian aquaculture. *Journal of Applied Aquaculture*, 13(1/2): 1–10.

K. Gopakumar, S. Ayyappan, J.K. Jena, S.K. Sahoo, S.K. Sarkar, B.B. Satapathy and P.K. Nayak. 1999. *National Freshwater Aquaculture Development Plan*. Central Institute of Freshwater Aquaculture, Bhubaneswar, India.

countries from Southeast Asia and the EU pre-2004 seem to have been overestimated. China is clearly critical to regional (and global) forecasts. However, while historic growth rates cannot be maintained, an expected output growth rate of 2 percent per year until 2020 is plausible. Aquaculture plans for the two main Latin American producers (Brazil and Chile) strongly emphasize the promotion of the sector, which has been demonstrated in China as being key to successful aquaculture expansion.[62] This suggests that IFPRI's projections underestimate expected aquaculture output. Expansion by China and Latin America and the Caribbean would be sufficient to offset the slower than anticipated expansion in the EU and Southeast Asia.

NATIONAL FORECASTS: THE "SUM" OF NATIONAL PRODUCTION TARGETS

Based on the information extracted from the 11 national documents received on anticipated annual growth rates for the aquaculture sector, individual projections were calculated for the years 2010, 2020 and 2030 to allow summing-up projections from individual countries. A second step was to compare the "sum of the targets set in national plans" with projected requirements from aquaculture in 2010, 2020 and 2030 under the "growing fisheries" and "stagnating fisheries" scenarios set out in Table 13. Table 15 shows the results obtained, using, in addition to the above scenarios, two simulations for China: one that assumes an annual growth rate of aquaculture production of 3.5 percent, and a second of 2 percent.[63]

Based on the 11 country plan projections, the average annual growth rates for the aquaculture sector for the period 2010–30 (adjusted figure for 2030) will be:

- with China's growth assumed at 3.5 percent per year: 4.8 percent.
- with China's growth assumed at 2 percent per year: 4.5 percent.

Under the "stagnating fisheries" scenario and with China maintaining a growth rate of 3.5 percent, the countries studied would largely meet the projected requirements from aquaculture (115 percent) in 2020. In the case of Chinese aquaculture experiencing a slower growth rate, food fish requirements from aquaculture would only be met at 102 percent. Using the adjusted – and more realistic – annual growth rates for the period 2020–30 under Simulation 2, aquaculture may just provide the quantities of fish required in 2030 (97 percent of the requirements met). This highlights the continued dependence on China to supply the bulk of production. However, if Brazil and Chile fulfil their aquaculture production targets, they will increasingly weigh on the world aquaculture scene, particularly in relation to China and other Asian countries (Figure 39).

CONSTRAINTS TO GROWTH

Despite these encouraging results, it is wise to remain cautious as there may be limits to the expected growth of the sector. These limits may apply to both demand (consequences of variations in prices and international trade, compliance with HACCP standards and traceability regulations, consumer confidence) and supply (disease, social opposition such as that experienced in Canada[64] and Chile[65] impeding macroeconomic context and political instability, fishmeal availability – the latter being a much debated issue). Although more environmentally friendly approaches and environmental issues were placed high on national agendas, these issues may result in rises in costs

[62] FAO. 2003. *Aquaculture development in China: the role of public sector policies*, by N. Hishamunda and. R. Subasinghe. FAO Fisheries Technical Paper No. 427. Rome.

[63] These assumptions were based on our estimate that aquaculture in China would continue to grow but at a slower pace for the next 8–10 years, at an anticipated rate of 2–4 percent per year.

[64] Union of British Columbia Indian Chiefs. 2004. *Fish farms: zero tolerance – Indian salmon don't do drugs* (available at http://www.ubcic.bc.ca/UBCICPaper.htm; accessed September 2004).

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

Table 15
Comparison of the sum of national aquaculture production forecasts with quantities required from aquaculture to fulfil demand (Table 13) in 2010, 2020 and 2030

	2010	2020	2030	2030 adjusted[2]
	(thousand tonnes)			
1. OPTIMISTIC SCENARIO				
(capture fisheries growth rate = 0.7 percent/year)				
Simulation 1: using China growth rate = 3.5 percent/year				
Sum of national aquaculture production forecasts[1]	52 604	96 487	234 494	133 457
Quantities required from aquaculture	51 100	69 500	102 000	102 000
Percentage fulfilled by national forecasts	103%	139%	230%	131%
Simulation 2: using China growth rate = 2 percent/year				
Sum of national aquaculture production forecasts[1]	49 007	85 009	210 495	117 569
Quantities required from aquaculture	51 100	69 500	102 000	102 000
Percentage fulfilled by national forecasts	96%	122%	206%	115%
2. STAGNATING FISHERIES SCENARIO				
(capture fisheries growth rate = 0 percent/year from 2001)				
Simulation 1: using China growth rate = 3.5 percent/year				
Sum of national aquaculture production forecasts[1]	52 604	96 487	234 494	133 457
Quantities required from aquaculture	59 700	83 600	121 600	121 600
Percentage fulfilled by national forecasts	88%	115%	193%	110%
Simulation 2: using China growth rate = 2 percent/year				
Sum of national aquaculture production forecasts[1]	49 007	85 009	210 495	117 569
Quantities required from aquaculture	59 700	83 600	121 600	121 600
Percentage fulfilled by national forecasts	82%	102%	173%	97%

[1] Projected aquaculture quantities for the years 2010, 2020 and 2030 are the sum of national production targets, obtained for each country studied by applying their forecast annual growth rates linearly to their current aquaculture output to the year 2030. Forecasted annual growth rates (calculated on the basis of production target figures provided in national aquaculture development plans or expert opinion in the case of China and Egypt) were: Chile: 5.9%, Indonesia: 11.1%, India (freshwater subsector): 8.2%, Philippines: 15.1%, China: 3.5% and 2%, Egypt: 5.5%, Brazil: 22%, Canada: 11.5%, Vietnam: 10%, Bangladesh: 3.5% and Thailand: 1.7%.
[2] 2030 adjusted: national annual growth rates (taken from individual country plans) were reduced by 40 percent over the period 2020–30 to account for declining growth rates over time.
Source: Calculated from national documents and Table 13.

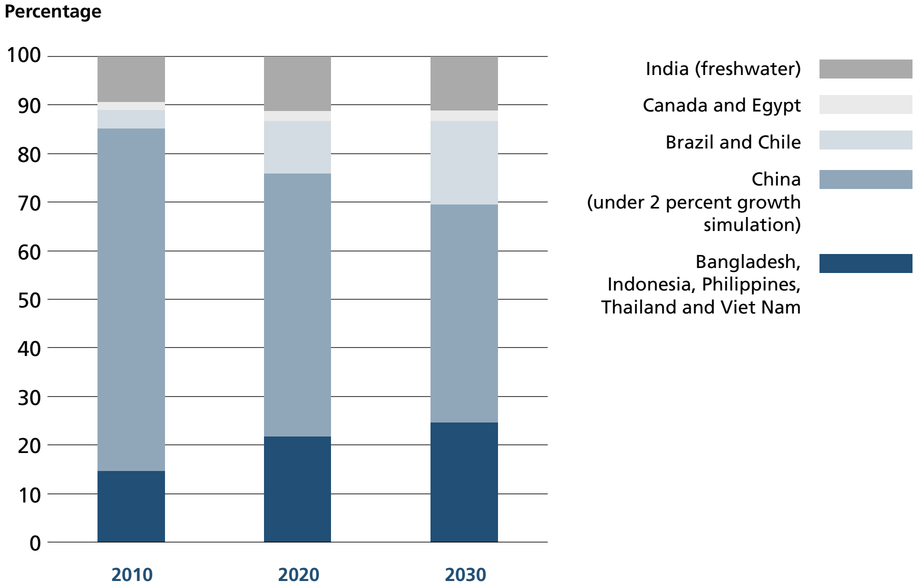
of production and initiate a decline in growth rates, necessitating a re-orientation of production.

While the above analysis looked strictly at the quantities of fish required, it is also necessary to consider the *species* that will constitute the bulk of future aquaculture production. Two species, namely carp and salmon, deserve a mention as they are among the most commonly produced fish and represent the two ends of the fish value spectrum.[66] In China, most of the carp production is consumed domestically. However, with an expected slowdown in demand for low-value fish products as a consequence

[66] IFPRI (op. cit., footnote 57, p.108) classified carps among the “low-value” species. This categorization has, however, to be nuanced to account for regions (in particular in some parts of Asia) where this species is highly valued.

Figure 39

Contribution of countries studied to aquaculture output forecasts



Note: Forecasts based on national aquaculture development plans (with adjusted growth rates for the period 2020–30).

of diet diversification and increased purchasing power, new markets will have to be found. These could be in locations where either consumer tastes are acquired and/or capacity to pay exists. Carp, however, was not considered as a strategic export by this country, despite foreseen increases in demand in South Asia and sub-Saharan Africa that are unlikely to be met by projected increases in production.[67] Carp is an important species in the diets of the poor but the lack of uniformity in markets and preferences, even within regions, should not be overlooked (Box 10).

Although carp supply is expected to continue its expansion (Bangladesh, China and Egypt have explicitly indicated their intention to boost their production), future demand for carp is likely to be constrained to specific geographical areas, mainly in developing countries. In contrast, the versatility of tilapia may prove more useful in targeting developed country markets.

A threat to the forecasted expansion plans of Latin America and the Caribbean is the future profitability of salmon farming. In 2001, salmonids were the principal species cultivated in the region, and this was almost exclusively accounted for by Chile. However, Canada and Norway have also planned to expand their production, which will put pressure on prices. The Chilean plan does acknowledge the need for new markets; of particular interest are Brazil and China, where increasing incomes and urbanization are creating new demand for high-value species. It is nevertheless questionable whether these expected increases in demand will be sufficient to maintain prices. Average costs have fallen appreciably as a result of selective breeding, but the most rapid gains may have already been made, resulting in decreasing profit margins.[68] These, in turn, would affect incentives to continue investing in the industry.

[67] Op. cit.; footnote 62, p.111; and IFPRI (2003), op. cit., footnote 57, p.108.

[68] Aerni, P. 2001. *Aquatic resources and technology: evolutionary, environmental, legal and developmental aspects.* Science, Technology and Innovation Discussion Paper No. 13. Cambridge, MA, USA, Center for International Development, Harvard University.

Box 10

Demand for carp

In India, for example, although annual fish expenditure was lowest among the poor and the very poor, most of the amount spent went on two Indian major carps, catla and rohu, indicating that increased production and improved access to this fish would benefit the poor.[1] This contrasted with Bangladesh, where rohu, catla and mrigal fetched higher prices and consequently, were bought by higher income groups.[2] In Europe on the other hand, consumers are not used to carp and this trend is not expected to change: a 0.1 per cent growth in consumption in low-value fishes to 2020 is indicated by IFPRI.

[1] R. Bhatta. 2001. Production, accessibility and consumption patterns of aquaculture products in India. *In* FAO. 2001. *Production, accessibility, marketing and consumption patterns of freshwater aquaculture products in Asia: a cross-country comparison*. FAO Fisheries Circular No. 973. Rome.
[2] M.F. Alam. 2002. Socioeconomic aspects of carp production and consumption in Bangladesh. *In* D.J. Penman, M.G. Hussain, B.J. McAndrew and M.A. Mazid, eds. 2002. *Proceedings of a Workshop on Genetic Management and Improvement Strategies for Exotic Carps in Asia, 12–14 February 2002, Dhaka, Bangladesh.* Mymensingh, Bangladesh, Bangladesh Fisheries Management Institute.

CONCLUSIONS

Findings suggest that answers to the two questions raised at the beginning of the study, namely: (1) do individual countries have a "realistic" ambition to expand their aquaculture production and (2) is the sum of national forecasts likely to be compatible with projected increases in demand for food fish, are generally positive. Countries do wish to expand aquaculture output and, with some exceptions, their assumptions were realistic. The examination of national plans and strategies has provided a valuable insight into the ambition and commitment of governments with regard to developing aquaculture, and most have appeared to endorse the sector's growth. National priorities for development, in particular with regard to the role of aquaculture in contributing to food security (often cited as one of the three reasons underlying a country's will to develop the sector, along with foreign exchange earnings and economic growth) were indicative of the realization that aquaculture can be an innovative motor of growth with many additional benefits, while revealing growing concerns over the overexploitation of capture fisheries and the motivation to find alternatives to declining catches.

As for the second question, the aggregation of national plans indicates that global forecasts may underestimate the supply of food fish coming from aquaculture. China's future expansion is critical, but using a modest 2 percent growth rate and without increases in food fish output from capture fisheries, results suggest that most of the demand projections will be met. From these findings, a conclusion, although sanguine, may be that the aquaculture sector could replicate the expansion of agriculture. However, much will depend on the realism of assumptions used to support projected targets, and countries formulating development plans for their aquaculture sector are encouraged to place a stronger emphasis on the rationale supporting their production forecasts. Such an emphasis will contribute to improved sector development planning, at an international scale, and to progress monitoring. Many factors affect the evolution of an activity such as aquaculture and setting realistic production targets is a difficult task. The sector is susceptible to unforeseen shocks – meteorological, pathological or economic – when countries compete in marketing a commodity and expand their production simultaneously.

While macro projection models used to estimate future supply were based on commodity prices, per capita incomes, rates of population growth and landings from capture fisheries, population density could be another factor to take into consideration in the setting of future production targets. This is apparent in the examples of Brazil and Norway, for which low population densities are seen as an asset to the further development of aquaculture while avoiding conflicts over resource use and social opposition typically encountered in more densely populated areas. Technological developments could bring answers to immediate concerns over resource use: for example, self-maintained offshore cages for intensive production, alleviating pressure from coastlines and inland waters, could significantly contribute to increases in aquaculture outputs and stabilization of fish prices. However, concerns may be voiced over the real motives behind this type of production and its market allocation. Targeting developed country markets with high-value fish exports is often a prime aim for many developing countries. Balancing both domestic needs for extra protein provision in LIFDCs, and foreign income generation from the same activity, is likely to involve delicate and politically challenging decisions.

Impacts of trawling on benthic habitats and communities

BACKGROUND

The effects of fishing and other anthropogenic activities on the marine environment have always been a source of great concern to fishers. Over the last two decades this concern has increased, with interest mainly focusing on the impacts of towed fishing gears such as trawls and dredges on benthic habitats and organisms. The rationale for this is multiple. On the one hand, benthic habitats provide shelter and refuge for juvenile fish and, on the other, the associated fauna provide food sources for several important demersal fish species. This means that negative impacts on benthic communities may cause a decline in marine resources, including those exploited commercially. Therefore, knowledge of the responses of these communities to disturbance from fishing gears is of great importance also to fishery managers.

Numerous investigations have been conducted on the impact of towed fishing gears on benthic communities during the last decade, but still little is known and few clear conclusions can be drawn. There are several reasons for this. First, benthic communities are complex and their large temporal and spatial variations may mask anthropogenic disturbances. Second, the studies show that the impacts of – or responses to – trawl gear vary greatly and depend on habitat type and disturbance regime (intensity and gear type). Consequently, considerable differences in responses to trawl impact can be expected when trawling is undertaken on virgin, unknown fishing grounds. Third, different methodologies have been used in the studies and many of those employed have serious limitations. This last point is of particular significance and means that the methodology used for any study should be reviewed and the results interpreted with caution.

However, the fact that the conclusions that can be drawn from such studies of benthic communities can be limited by methodological deficiencies is not always considered. (In fact, several recent review studies have been published without taking these caveats into account.)

A recent FAO study has attempted to remedy this situation by presenting a critical evaluation of the scientific approach and methodologies used in trawl impact studies.[69] It assesses the current knowledge of the physical and biological impacts of otter trawls, beam trawls and scallop dredges. Highlights of the study are provided below.

METHODOLOGIES

The methodology applied in impact studies should ideally:

- permit a study of trawling disturbance at a spatial and temporal scale representative of commercial fishing;
- include a comparison of the disturbed area with undisturbed control sites;
- use quantitative tools to sample benthic organisms.

To date, most impact studies have failed to meet one or more of the three requirements for an ideal study.

Two different approaches have been applied to investigate physical and biological impacts of trawl fisheries on benthic habitats and communities. One is to conduct experimental trawling on a site and compare the physical and biological parameters before and after the disturbance and/or with those at an adjacent and undisturbed control site. The second approach is to compare commercial fishing grounds that have been heavily fished with areas that are lightly fished or not fished at all.

The main problem with the first approach is that experimental trawling is commonly conducted along narrow corridors and completed within a short period of time. This means that this approach does not replicate the large-scale and long-term disturbances that occur in commercial fishing activities. The problem with the second approach is that commercial trawling effort is usually distributed erratically within fishing grounds and sampling under impact studies is not usually extensive enough to reveal the actual level of disturbance as there will be patches of low fishing effort within high-effort areas and vice versa. In addition, untouched control sites seldom exist at commercial fishing grounds. Unfortunately, both approaches to conducting impact studies depend on access to control sites because the lack of appropriate control sites may lead to overestimation of the effects of trawling on the benthic habitat.

PHYSICAL IMPACTS

Otter trawls, beam trawls and scallop dredges incorporate in their design different catching principles and therefore have different physical impacts on the seabed. Demersal otter trawls are designed to target fish and shrimps close to the seabed. They are rigged with different types of ground gear (e.g. bobbins, rock hoppers) and trawl doors, all of which are intended to keep the active part of the gear just above the seabed. The most noticeable physical effect of otter trawling is the creation of furrows (up to 20 cm deep) by the doors, whereas other parts of the trawl create only faint marks. Changes in sediment surface characteristics have also been demonstrated in some studies. On hard bottoms, the trawl gear may displace large boulders in its path. Studies have shown that trawl door marks disappear within five months in areas with strong currents, whereas in sheltered coastal areas faint marks can still be seen 18 months after trawling. The penetration depth and persistence of trawl marks depend on the weight and performance of the gear, sediment type and natural disturbance (e.g. current and wave actions).

Beam trawls and scallop dredges are used to catch species that stay on the bottom or are partly buried in the seabed. Accordingly, beam trawls have tickler chains and dredges with teeth that are designed to disturb the seabed surface and penetrate the upper few centimetres of the sediment. The most noticeable physical effects of beam trawling and scallop dredging are a flattening of irregular bottom topography and the elimination of natural features such as bioturbation mounds and faunal tubes. The penetration depth of the tickler chains of beam trawls varies between 1 and 8 cm, whereas scallop dredges show a slightly lower penetration depth. These marks may last from a few days in tidally exposed areas to a few months in sheltered bays.

[69] FAO. 2004. *Impacts of trawling and scallop dredging on benthic habitats and communities*, by S. Lokkeborg. FAO Fisheries Technical Paper No. 472. Rome. (In press)

BIOLOGICAL IMPACTS

The most serious effects of otter trawling have been demonstrated for hard-bottom habitats with vertical structures. In such habitats, the abundance of large sessile organisms such as sponges, anthozoans and corals has been shown to decrease considerably as a result of the passage of ground gear. Habitats dominated by large sessile fauna may thus be severely affected by trawling.

A few studies have been conducted to determine the impacts of experimental trawling on sandy-bottom (offshore) fishing grounds. These studies showed declines in the abundance of some benthic species. However, they seemed to recover within a year or less. They also indicated that trawling does not produce large changes in the benthic communities studied. The habitats, however, showed considerable temporal and spatial variability in the numbers of species and individuals. Such habitats may be resistant to trawling because they are subjected to a high degree of natural disturbances such as strong currents and large temperature fluctuations.

The impacts of shrimp and nephrops trawling on soft bottoms (i.e. clay, silt) have been thoroughly studied through numerous investigations, but clear and consistent effects were not demonstrated in these studies. Although changes in several benthic species were observed during the course of the research, few consistent and unambiguous effects could be attributed to trawling disturbance. However, these soft-bottom habitats showed pronounced temporal changes in many benthic species as a result of natural variability; changes caused by trawling may be masked by this variability and therefore difficult to demonstrate.

The relatively few studies carried out to determine impacts of beam trawling were conducted mainly in the North Sea and the Irish Sea, where certain areas of the seabed have been intensively trawled for many decades. These studies demonstrated a considerable decrease in abundance of several benthic species (sometimes by as much as 50 percent). Also, clear evidence of the short-term effects of intensive beam trawling was demonstrated. The long-term effects were not studied owing to the lack of undisturbed areas suitable for use as control sites.

Studies on scallop dredging are far more numerous than those on beam trawling. The effects of scallop dredging seem to be similar to those for beam trawling, with a considerable decrease in abundance of several benthic species. However, reductions in population density caused by dredging were often small compared with reductions arising from temporal and spatial changes. Disturbances by scallop dredging or beam trawling were found to cause no effects in areas exposed to natural disturbances (e.g. wave actions and salinity fluctuation), confirming the general trend that exposed habitats seem to be resistant to disturbances imposed by towed gears.

CONCLUSIONS

Knowledge of how towed fishing gears affect different habitat types is still rudimentary. In fact, few, other than general, conclusions can be drawn on the responses of benthic communities to trawling disturbances. This lack of knowledge can mainly be attributed to the complexity and natural variability of benthic communities, and to the fact that the methodology applied in most studies conducted to date has limitations and deficiencies. Moreover, it can be both difficult and demanding to conduct these types of studies.

Hard-bottom habitats dominated by large sessile organisms are most severely affected by otter trawling, whereas only subtle effects have been demonstrated on soft bottoms. Also, beam trawling and scallop dredging have been shown to cause changes in benthic communities.

The documentation of the impacts of trawling on certain habitat types gives rise to an interesting and challenging management issue: how are associated fish populations and other exploited marine resources affected by changes in the benthic community structure? Our knowledge of the linkage between benthic habitat complexity and the dynamics of fish populations is weak, and the potential impacts of trawling can thus not be fully established until this linkage is better understood.

Measurement of fishing capacity

THE FISHING CAPACITY MANAGEMENT PROBLEM

Declining yields, shrinking stock biomass and uncertain profitability are characteristics common to many commercial fisheries. In those that are unmanaged or managed as *de facto* open-access fisheries, the race for fish soon tends to create a fishing capacity that is larger than that needed to catch the sustainable yield. Overcapacity develops in the form of overexpanded harvesting (and processing) capacity. If this is uncontrolled, this capacity generally leads to overfishing.

The problems of overcapacity and capacity management have become key issues for fisheries management in the new millennium. Overcapacity and overfishing are really symptoms of the same underlying management problem – the absence of well-defined property or user rights. If fishers enjoyed exclusive and more secure rights, they would be able to adjust their harvesting capacity to the quantity of fish available and not be stimulated to invest in excessive capacity in order to catch the fish before someone else does.

It can be argued that if rights-based management systems were to be introduced, then the problem would largely be solved and there would be little need to consider fishing capacity as an issue.

In recent years, governments in many countries have strengthened use rights in fisheries. Change is slow, however. There are political, social and economic reasons for this. Concerns about food security and the economic and financial impacts of adjustment on fisheries and fishing communities are also important considerations for fisheries managers. These impacts are not confined to the commercial sector, but affect all consumptive and non-consumptive users of living marine resources, including recreational fisheries and the general public.

The trend towards providing stronger use – or property – rights in fisheries will probably continue. Nevertheless, it is likely that for some fisheries, exclusive use rights will not be considered feasible for technical, social or political reasons. In such situations, capacity management must occur through a combination of input and output controls so that excessive levels of fishing effort do not develop and cause both total yields of fish and economic benefits to fall well below their potential levels.

To manage capacity, managers need to know how much fishing capacity exists and then determine for each fishery the level of capacity (i.e. the target level of capacity) that best meets the management objectives. FAO has reviewed various methods for measuring fishing capacity.[70] A definition of fishing capacity and different ways to measure it are described below.

WHAT IS FISHING CAPACITY?

Different groups of people generally have a different understanding of capacity. Fishing technologists often consider fishing capacity as the technological and practical feasibility of a vessel achieving a certain level of activity – be it days fishing, catch or processed products. Fisheries scientists often think of fishing capacity in terms of fishing effort, and the resultant rate of fishing mortality (the proportion of the fish stock killed through fishing). Fisheries managers generally have a similar view of fishing capacity, but often link the concept directly with the number of vessels operating in the fishery. Many managers express fishing capacity in measures such as gross tonnage or as total effort (e.g. standard fishing days available). Most of these ideas reflect an understanding of capacity primarily in terms of inputs (an input perspective).

[70] FAO. 2000. *Report of the Technical Consultation on the Measurement of Fishing Capacity, Mexico City, 1999*. FAO Fisheries Report No. 615. Rome; FAO. 2003a. *Measuring and assessing capacity in fisheries: issues and methods*, by S. Pascoe, J.E. Kirkley, D. Gréboval and C.J. Morrison-Paul. FAO Fisheries Technical Paper. No. 433/2. Rome; FAO. 2004. *Measuring and assessing capacity in fisheries: basic concepts and management options*, by J.M. Ward, J.E. Kirkley, R. Metzner and S. Pascoe. FAO Fisheries Technical Paper No. 443/1. Rome. (In press); FAO. 2003b. *Measuring capacity in fisheries*, by S. Pascoe and D. Gréboval, eds. FAO Fisheries Technical Paper No. 445. Rome.

Box 11

Additional fishing capacity terminology

Capacity utilization. The degree to which the vessel is utilized. From an input-based perspective, capacity utilization may be expressed as the ratio of the number of days actually fished to the number of days the boat could potentially fish under normal working conditions. From an output-based perspective, capacity utilization is the ratio of the actual catch to the potential catch (if fully utilized).

Excess capacity. A common, essentially short-term, phenomenon in all types of industry. In general, excess capacity may be defined as the difference between what a production facility could produce if fully utilized during a given period and what has actually been produced in that same period. In fisheries, lower prices or temporarily higher costs (e.g. fuel price increases) may result in boats operating less frequently than expected under average conditions. If the prices and costs return to normal levels, then this form of excess capacity is self-correcting. Excess capacity can also be caused by fisheries management. Stock recovery programmes may impose restrictions on catch or effort that result in the vessels being underutilized during the recovery process, but allow vessels to be fully utilized when the stocks have increased. In such circumstances, the existence of excess capacity is not problematic. However, if the effort or catch restrictions are likely to persist into the future, then it is likely that excess capacity is an indicator of overcapacity in the fishery.

Fishing effort. The amount of time and fishing power used to harvest fish.

Fishing power. Fishing power is determined *inter alia* by gear size, boat size and horsepower.

Overcapitalization. Overinvestment in assets (capital). In its simplest form, overcapitalization exists if the fleet size is greater than that required to harvest a particular yield.

Overfishing. Normally expressed in terms of fishing mortality levels, that is, in terms of how many fish are killed. If total fishing mortality (harvesting) is at a rate that exceeds the maximum level that the stock can withstand on a sustainable basis (i.e. the maximum sustainable yield), then there is overfishing.

In contrast, economists tend to consider capacity as the potential catch that could be produced if the boat were to be operating at maximum profit or benefit (an output perspective).

To reflect these different views of fishing capacity, an FAO technical consultation developed a definition of fishing capacity that is both input (e.g. effort, boat numbers, etc.) and output (catch) based:

> *[Fishing capacity is] the amount of fish (or fishing effort) that can be produced over a period of time (e.g. a year or a fishing season) by a vessel or a fleet if fully utilized and for a given resource condition.*[71]

[71] Op. cit., see FAO (2000) in footnote 70.

Indicators will generally be used, to monitor and measure fishing capacity, ranging from vessel characteristics (gross tonnage, horsepower) to potential effort or potential catch (adjusting for full utilization).

The term "overcapacity" conveys the fact that fishing capacity is greater than some desirable level of fishing capacity (the target capacity). This may be either a long-term target sustainable yield – reflected in the short term in a total allowable catch (TAC) – or a related long-term target for fixed inputs employed in the fishery.

MEASURING CAPACITY

Quantitative capacity measures

Measuring excess capacity or the degree of capacity utilization is relatively easy as it does not require any knowledge of the state of resources *per se*. It is sufficient to estimate actual levels of fishing inputs use (using indicators for vessels, gear or effort) or output (using catch as indicator) and to compare these actual levels with potential ones, under the assumption of unrestricted but normal full use of the available inputs (actual levels of capacity).

In order to measure overcapacity quantitatively in any particular fishery two numbers are needed: the actual level of capacity[72] and the target level of capacity. The extent of overcapacity is established by comparing these two numbers. Establishing a target level of exploitation (target catch, corresponding effort level and minimum corresponding fleet size) is required to set a target level of capacity. Except for simple fisheries, quantitative estimation of capacity is relatively difficult.

Given the complexity of estimating potential catch (e.g. for multispecies fisheries), several techniques have been developed to assist in the quantitative measure of excess fishing capacity and overcapacity. These include data envelopment analysis (DEA), stochastic production frontiers (SPF), and peak-to-peak (PTP) analysis.[73]

Overcapacity measures that utilize DEA have been developed to measure overcapacity levels in fisheries relative to a biological target level of yield[74] or to an economic target level of yield such as maximum economic yield (MEY).

Bioeconomic models have also been used to estimate input-based measures of overcapacity or overcapitalization. Using such models, the fleet size and configuration that best conform to the management objectives can be estimated and compared with current fleet sizes and configurations to derive an estimate of the level of overcapacity and overcapitalization.[75]

All of these approaches have both strengths and weaknesses, and the choice of the appropriate method will vary depending on the nature of the fishery, the data available, and the intended use of the capacity measure.

Subjective capacity measures

Quantitive data is needed to develop quantitative estimates of fishing capacity. As quantitative data may not be readily available, managers will need to develop non-quantitative estimates of fishing capacity. Subjective measures and qualitative indicators of capacity levels are also needed.

[72] When potential catch is used as an indicator of actual capacity, adjustment will be required to reflect changing resource conditions (catch rates).

[73] Details on how these measures are estimated are presented in J. Kirkley and D. Squires. 1999. Measuring capacity and capacity utilization in fisheries. *In* FAO. *Managing fishing capacity: selected papers on underlying concepts and issues,* edited by D. Greboval. FAO Fisheries Technical Paper No. 386. Rome; and in FAO (2004), op. cit., see footnote 70, p.118. Examples of applications using these techniques are also presented in FAO (2003b), op. cit., see footnote 70, p.118.

[74] J. Kirkley, J. Ward, J. Waldron and E. Thunberg. 2002. *The estimated vessel buyback programme costs to eliminate overcapacity in five federally managed fisheries.* Final contract report to the National Marine Fisheries Service, Silver Spring, Maryland. Gloucester Point, Virginia, USA, Virginia Institute of Marine Science.

[75] An example of the application of a bioeconomic model for that purpose is presented in FAO (2004), op. cit., see footnote 70, p.118.

Rapid appraisal techniques and expert knowledge (e.g. the Delphi method) have been used to derive subjective estimates of a wide range of indicators. However, such techniques should only be employed when the analyst has access to individuals or organizations that have a profound knowledge of the concerned fisheries and that are able to provide information on historical change.

Qualitative capacity indicators

Qualitative assessments of overcapacity can be based on verifiable indicators, although, clearly, no single indicator can be sufficient to determine overcapacity in a fishery. A combination of indicators, each indicating change over time, will be needed to determine qualitative capacity levels in fisheries and may include:

Biological status of the fishery. If signs of overfishing are observed for the target species in a directed fishery, it is probable that overcapacity exists – especially against a background of increasing capacity.

Harvest/target catch ratio. Overcapacity is likely to exist when harvest levels regularly exceed the target catch – with a harvest-to-target catch ratio significantly exceeding one. However, this indicator must be considered in the context of the management of the fishery. If a fishery is closed before the target catch is exceeded, the harvest level will not exceed the target, and no apparent overcapacity will be observed. Also, this indicator is not sensitive to any discarding that may take place in a fishery managed through quotas and is therefore not a good indicator of overcapacity in fisheries that are managed through TACs or quotas. In addition, if the fishery has been overfished, and the harvest level is below the target level, the measure may be less than one in spite of the presence of overcapacity.

TAC/season length. Using the ratio of the TAC level to the season length, an increase over time of this ratio indicates overcapacity.

Conflict. Controversies surrounding the setting of the TAC and the suballocation of TACs among different user groups may also indicate overcapacity in a fishery.

Latent permits. A relatively large number of latent permits, or a low ratio of active to total permits, indicate overcapacity in a fishery, and if this ratio declines, the likelihood increases that overcapacity exists in the fishery.

Catch per unit of effort. A decline over time in catch per unit of effort (CPUE) against a background of stagnating catches generally implies overfishing and, most likely, overcapacity. However, fluctuating TACs under a constant fishing mortality management strategy could mask this effect, and CPUE trends may remain constant or increase for schooling species even though overall stock abundance is declining.

Value per unit of effort. The value of catches per unit of effort (VPUE) may be a potential indicator of overcapacity in multispecies fisheries, especially if the VPUE decreases as overall CPUE stagnates or decreases. VPUE is a useful capacity indicator in fisheries where it is impractical to record the catch of each species separately, but recording the total value of sales is feasible.

Re-estimating discards in the world's marine capture fisheries

BACKGROUND

UN General Assembly resolutions, the Kyoto Declaration[76] and the Code of Conduct for Responsible Fisheries are among the international instruments that have highlighted the need to reduce or minimize discards. FAO is mandated to report periodically to the UN on the implementation of the resolutions and has been at the forefront of efforts to draw attention to wastage of fishery resources as a result of discarding, and to promote efforts to reduce or minimize discards.

Changes in the patterns of fishing activities throughout the world have influenced discarding practices. An FAO study was therefore undertaken to update the previous FAO estimates of discards in the world's marine capture fisheries and to review trends and issues related to discards.[77]

The quantification of discards and knowledge of trends in discarding practices are of value in the design of fisheries management regimes and initiatives to promote responsible fishing operations and catch utilization. Discarding also raises a range of issues with regard to the interpretation, application and monitoring of the Code of Conduct, and to promoting both sustainable fisheries and food security.

Previous estimates[78]

The previous FAO assessment (1994) estimated global discards to be 27 million tonnes (ranging from 17.9 to 39.5 million tonnes). It was based on data from the 1980s and early 1990s. A subsequent FAO estimate, presented in *The State of World Fisheries and Aquaculture 1998*, suggested a reduced estimate of 20 million tonnes. A further study by Alverson (1998) indicated that the 1994 assessment was an overestimate.

Method

Discards are defined as being "that portion of the catch which is returned to the sea" for whatever reason.[79] Aquatic plants and animals are excluded from the estimate.

The study is based on the premise that discards are a function of a fishery, defined in terms of an area, a fishing gear and a target species. An inventory of the world's fisheries and associated catch and discard information was compiled in a "discard database". The information on catches and discards was obtained from published national and regional fisheries reports and statistics, from papers published in scientific journals, from "grey" literature and Internet sources, and through direct contacts with national and regional fisheries institutions. The discard database references the sources of the information for each fishery. Records can thus be checked, updated, or replaced as further information on each fishery becomes available.

It is assumed, that for a given fishery, there is a linear relationship between landings and discards at the aggregate level. In other words, the discard rate calculated in a study of a fishery (a sample) was applied to the total landings of the fishery to calculate the total quantity of discards. In the absence of information to the contrary, artisanal fisheries were generally assumed to have a low (1 percent or less) or negligible discard rate.

As most discard studies focus on fisheries with high discard rates, the results may be biased in favour of such fisheries. However, this potential bias is partially offset by the inclusion of numerous artisanal fisheries.

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[76] The Kyoto Declaration and Plan of Action were adopted at the International Conference on the Sustainable Contribution of Fisheries to Food Security, held in Kyoto, Japan, from 4 to 9 December 1995.

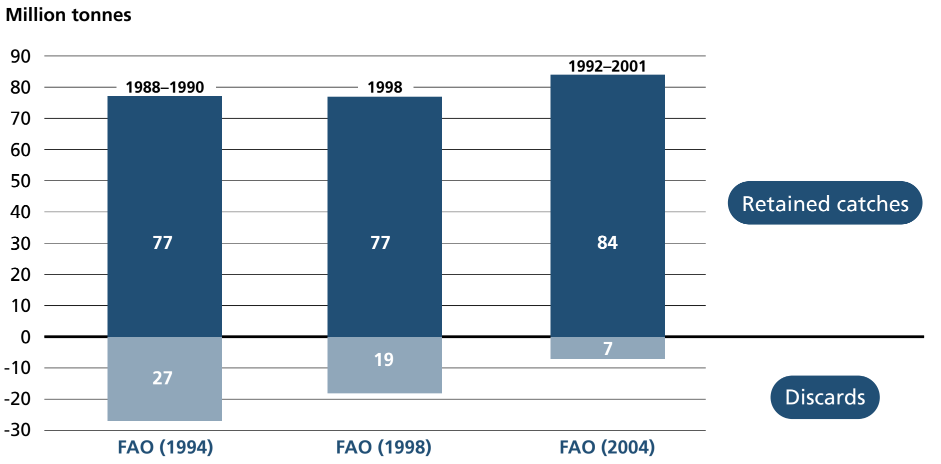
[77] FAO, 2004. *Discarding in the world's fisheries: an update*, by K. Kelleher. FAO Fisheries Technical Paper No. 470. Rome. (In press)

[78] Sources of the estimates referred to in this paragraph are, respectively, FAO. 1994. *A global assessment of fisheries bycatch and discards*, by D.L. Alverson, M.H. Freeberg, S.A. Murawaski and J.G. Pope. FAO Fisheries Technical Paper No. 339. Rome; FAO. 1998. *The State of World Fisheries and Aquaculture 1998*. Rome; and D.L. Alverson. 1998. *Discarding practices and unobserved fishing mortality in marine fisheries: an update.* Report prepared for the NMFS. Washington Sea Grant Publication WSG 98-06. Seattle, USA, Washington Sea Grant.

[79] FAO. 1996. *Report of the Technical Consultation on Reduction of Wastage in Fisheries*. Tokyo, Japan, 1996. FAO Fisheries Report No. 547. Rome.

Figure 40

Comparison of discard estimates and retained catches



Source: Full source details are given in footnotes 77 and 78.

MAIN FINDINGS

The global estimate

The global summed discard rate is 8 percent (quantity of discards as a percentage of the total catch).

Applying the 8 percent global aggregate discard rate estimated in the study to a ten-year (1992–2002) average of the global nominal catch reported in FAO Fishstat,[80] the total extrapolated discards is calculated to be 7.3 million tonnes. Some caution is required in extrapolating to the total global catch, as some major fish producer countries[81] are underrepresented in the discard database.

Discards by area

The highest quantities of discards are in FAO Areas 27 (Northeast Atlantic) and 61 (Northwest Pacific), which jointly account for 40 percent of the discards. Areas with low discards include Southeast and East Asia, small island nations in the South Pacific and Caribbean, and countries with a "no discards" policy.

Discards by type of fishery

Trawl fisheries for shrimp and demersal finfish account for over 50 percent of the total estimated discards while representing approximately 22 percent of total landings in the discard database. Tropical shrimp trawl fisheries have the highest discard rate and alone account for over 27 percent of the total estimated discards. Penaeid shrimp fisheries in Indonesia, South America and the United States jointly account for approximately 1 million tonnes of discards. Coldwater shrimp trawl fisheries have considerably lower discard rates. However, the rates can vary from over 80 percent for some *Nephrops* trawl fisheries to less than 6 percent for many *Pandalus* fisheries.

Demersal finfish trawls account for 36 percent of the estimated global discards. In particular, trawlers targeting flatfish and deep-water species may discard more than 50 percent and 39 percent of their catches, respectively.

Most purse seine, handline, jig, trap and pot fisheries have low discard rates. If the carcasses of finned sharks are considered as discards, then the summed discard rate in tuna longline fisheries is 29 percent.

[80] Fishstat Plus (v. 2.30) of 24.07.2003. The nominal (or retained) catch excludes marine animals and plants.

[81] These include New Zealand, the Philippines, the Republic of Korea and the Russian Federation. The EU member countries and India have only partially been covered. A number of smaller fish-producing countries are not included.

Figure 41

Estimated average yearly discard quantities
and discard rates in major ocean areas, 1992–2001

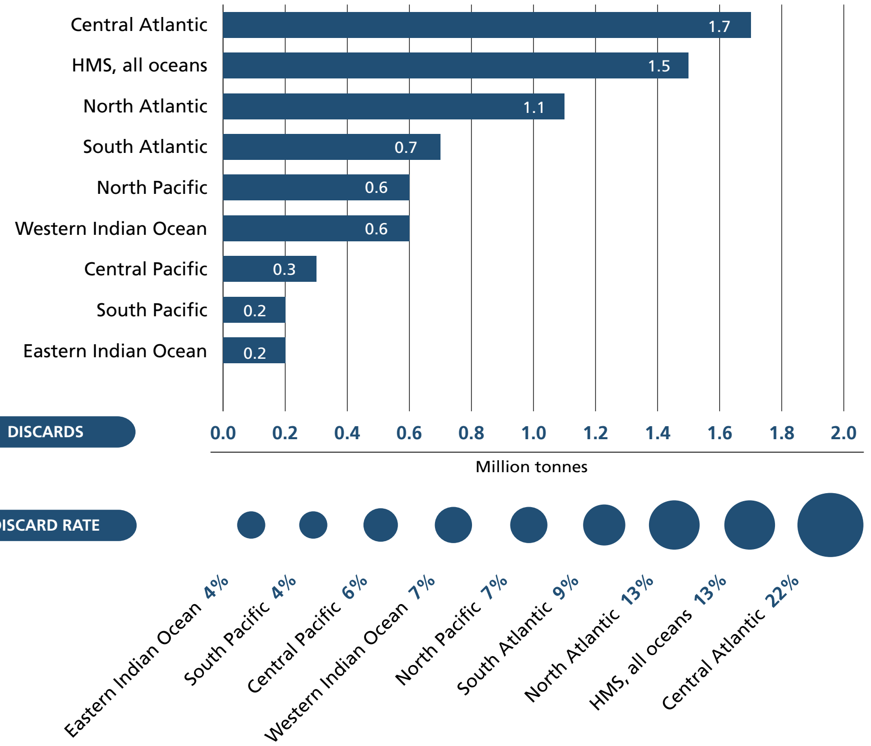
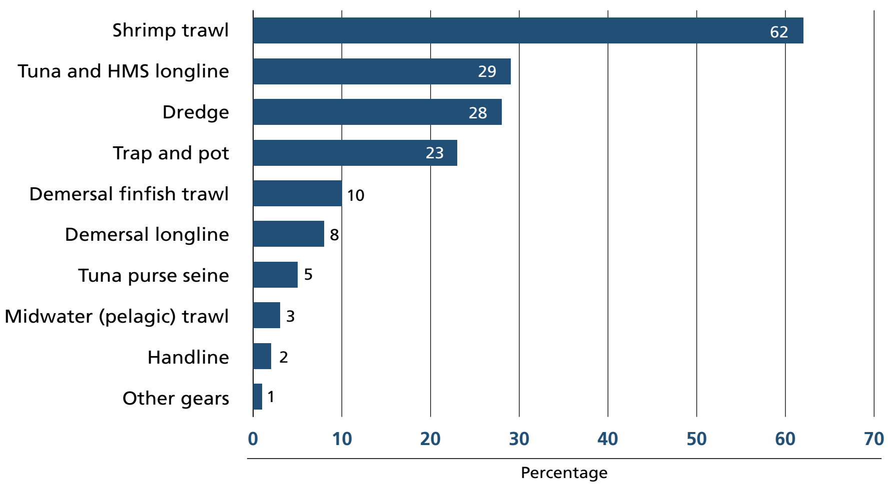


Figure 42

Discard rates by major gear type



Note: HMS = highly migratory species.

Small-scale fisheries generally have lower discard rates than industrial fisheries. The small-scale fisheries account for at least 11 percent of the discard database landings and in aggregate have an estimated discard rate of 3.7 percent.

Major trends

Two discard estimates have been made with respect to the periods 1988–90 and 1992–2001. A number of factors complicate direct comparisons between the estimates: (1) the methodology has changed to a more robust fishery-by-fishery estimate; (2) the first estimate had a range of 17.9 to 39.5 million tonnes with a mean of 27 million tonnes, while the second had a range of 6.9 to 8.0 million tonnes; (3) the landings data used in the extrapolations needed to estimate global discards in both periods were affected by uncertainty related to IUU fishing and by possible overestimation of landings by China. But, although a time series at the global level is not available, evidence from numerous fisheries clearly indicates that there has been a substantial reduction in discards since the 1994 assessment was made. There are two major reasons for this: a reduction in bycatch due to the use of more selective fishing gears, the introduction of bycatch and discard regulations and improved enforcement of regulatory measures; and the increased retention of bycatch for human or animal food, as a result of improved technologies and expanding market opportunities.

Bycatch reduction

Many factors have contributed to bycatch reduction. In particular, the promotion of the Code of Conduct for Responsible Fisheries has increased public and international awareness of discards as being morally unacceptable waste. Scientific concerns over the unaccounted mortalities of juvenile fish and fishers' concerns over the impact of unsustainable fishing practices on ever-scarcer fish resources have resulted in a broad range of bycatch and discard reduction initiatives. Economic factors such as the costs of sorting catches, crew shortages, efforts to comply with ecolabelling requirements and the introduction of quotas on bycatch species have all contributed to reductions in unwanted bycatch. Improvements in fisheries management and improved enforcement of regulations have also played an important role. In several countries, the common concerns of government and industry have led to the joint formulation of bycatch reduction strategies and implementation of mutually agreed measures. Major fisheries in which discards have significantly declined include the Gulf of Mexico shrimp trawl, Alaskan groundfish fisheries, Canadian fisheries, fisheries in the NAFO area, a number of Australian fisheries and fisheries in countries with a "no discards" regime (e.g. Iceland, Namibia and Norway).

However, some fisheries have contributed to increases in discards, notably deep-water fisheries and fisheries where severe quota restrictions have resulted in more discarding of smaller specimens (highgrading). Overfishing has also contributed to increases in discards, particularly where an increasing proportion of the target species is composed of juveniles. Certain regulations, such as those on minimum landing size, or more effective enforcement of such regulations, have also contributed to increases in discards.

Bycatch retention

Many species and types of fish that were previously considered to be bycatch are now included in a broader range of target species. The extent to which increases in retained catches may be attributed to increased landings of previously discarded species requires further analysis. Lack of time series again preclude empirical assessment at a global level, but evidence strongly suggests the increased utilization of bycatch in many fisheries, particularly in:

- South, Southeast and East Asian fisheries, which (with some exceptions) have very low or negligible discard rates. The increased utilization can partly be attributed to increased demand for aquaculture feed and innovations in product development;

- African industrial trawl fisheries, which are marketing increasing quantities of bycatch, particularly on African urban markets;
- factory vessels involved in at-sea processing to produce *surimi* and related products.

The following count among the numerous reasons for increased bycatch utilization:

- population and income increases leading to greater demand for fish products, particularly in developing countries;
- the development and transfer of technologies for the use of small-sized fish to produce value-added products;
- the development of consumer markets for unfamiliar or previously discarded species;
- reductions in quotas or target species catches as a result of overfishing, which frees up hold capacity and allows increased retention of lower-valued bycatch;
- the trend towards shorter fishing trips to improve fish quality, which may also create "spare" hold capacity that can be used for bycatch;
- increased at-sea collection of bycatch, particularly in tropical shrimp trawl fisheries in Africa and in Central and South America;
- changes in management regimes that encourage, facilitate or even oblige landings, or at-sea collection of bycatch;
- changes in regulations, e.g. a decrease in minimum landing size to ensure compatibility with trawl mesh sizes, and the issue of permits to transfer target, or bycatch, quotas between vessels or fishers;
- economic incentives to maximize returns from the catch.

Further efforts to promote bycatch utilization are likely to reduce discards further, particularly in LIFDCs, in Africa and in Central and South America.

In contrast to the trend towards full utilization of almost all harvested species in many Asian countries, many Western fisheries focus on increasing selectivity and on bycatch reduction.

IMPLICATIONS AND ISSUES

Policy implications

The "no discards" approach

A number of countries have instituted fisheries policies and management regimes based on the principle of "no discards". A "no discards" policy implies a paradigm shift in approaches to fisheries management. It moves the focus of management measures from landings to catches and from fish production to fish mortality. Fishers are obliged to make efforts to avoid catching unwanted fish. Such a policy is also in conformity with the precautionary approach: by regarding "no discards" as the norm, any discarding then requires adequate justification. Complementary measures are necessary to apply a "no discards" regime successfully. Minimum landing size regulations must be removed and provisions made to market all landings.

Balancing bycatch reduction and utilization

The biological and social principles upon which an appropriate balance between bycatch reduction and utilization can be based require further analysis and the development of decision frameworks. A more precise interpretation of the "ecosystem approach" in relation to bycatch reduction and utilization is required, with particular regard to the relative merits of selective and non-selective fishing. The conservation implications of a strategy of "total utilization" of bycatch also require further attention.

Endangered species

The incidental catch and subsequent discard of charismatic, protected or endangered species, such as turtles, marine mammals and seabirds, are likely to have an increasing impact on fishing activities and trade in fish products. The absence of a neutral and internationally accredited mechanism for the compilation of information on incidental catches of many of these species, and for the examination and promotion of best practices in mitigation measures, may impede rational discussion and the development of solutions. The impact of discards on biodiversity and ecosystem change remains poorly understood.

Technical implications

Measuring discards

A complex of biological, economic and regulatory factors determine the decisions of fishers to discard. These factors are generally specific to each fishery and the decision to discard may vary by fishing trip, fishing operation, season or fisher. Consequently, discard information has a high level of inherent variability, often requiring extensive discard sampling to generate accurate assessments of quantities. On-board observer reports are considered indispensable for accurate estimation of discards. Relationships between discard rates and other variables (e.g. landings, duration of trip, length of trawl tow, market prices) tend to be weak. Accordingly, raising or extrapolating discard estimates derived from samples to the level of the fleet, or the fishery, may have a high degree of error, particularly if the sampling protocol is inadequate.

National fisheries statistics are not generally collected, compiled and presented on a fishery-by-fishery basis, so that extrapolation of discards to the level of the fishery may also be problematic. There are several advantages in compiling national fisheries statistics on a fishery-by-fishery basis. In particular, it may focus attention on the definition of coherent management units, link trends in landings to fishery-specific management measures and facilitate consideration of bycatch and discards in resource assessments.

Use of discard estimates

Discards may account for a significant mortality in fisheries. For numerous reasons, discard estimates may not be included in stock assessments, in determination of TACs, or in quota management. In general, the fisheries management “accounting toolkit” for discards is deficient.

Development of guidelines

The development of guidelines, or a review of best practices, should be considered, particularly with regard to the following:

- discard sampling;
- raising discard sample estimates to the fleet or fishery level;
- the use of discard estimates in stock assessments;
- the inclusion of discard estimates in fishery management plans and accounting for discards in TACs and quotas;
- the development of bycatch management plans;
- the introduction and adoption of bycatch reduction and mitigation technologies.

Future discard estimates

Future compilations of discard estimates at a global level can be closely linked to the developing FAO Fisheries Global Information System (FIGIS) inventory of fisheries. Cross-linkage with Fishstat may help identify trends in landings of hitherto discarded fish. The closer involvement of member countries and RFBs in verifying and updating the information in the discard database can give a broader “ownership” base to the discard data. Further efforts to obtain discard information from countries and fisheries where such information is lacking can help focus attention on discard- and bycatch-related issues. Complementary periodic reviews of information on the survival of discards, non-discard sources of unobserved fishing mortalities and the impact of discards on ecosystems will further contribute to the knowledge required to manage fisheries sustainably.

Fisheries subsidies

INTRODUCTION

Fishery subsidies were recognized by FAO as a stimulus to overcapacity and overfishing in *Marine fisheries and the law of the sea: a decade of change*.[82] That 1992 document helped to focus attention on the depleted state of many of the world's major commercial marine fish stocks. The most shocking aspect of the report was its emphasis on the substantial deterioration of the situation since the halcyon days when, having reached agreement at the Third United Nations Conference on the Law of the Sea, most coastal states assumed control over fisheries to 200 nautical miles from their shores. The report concluded that the existence of subsidies had negated the desired, and anticipated, role of extended fisheries jurisdiction in developing and maintaining sustainable fisheries.

Interest in fishery subsidies has grown during the last dozen years, with such intergovernmental agencies as the World Bank, the Organisation for Economic Co-operation and Development (OECD), the United Nations Environment Programme (UNEP) and FAO[83] focusing on fishery subsidies and publishing documents to bring the problem to the attention of the public. The Fourth Ministerial Meeting of the WTO, held in Doha in 2001, resulted in an explicit directive to the negotiators in the subsequent round of international trade talks to improve WTO discipline to control fishery subsidies. The Plan of Implementation of the 2002 World Summit on Sustainable Development, held in Johannesburg, re-emphasized the Doha Declaration's call for the WTO to act with respect to fishery subsidies.

DEFINITION

But what are fishery subsidies? They can be defined as narrowly as government financial transfers to the industry and as broadly as any government action that modifies the potential profits earned by the firm in the short, medium or long term. Regardless of the definition used, subsidies can alter the actions of firms in ways that interfere with international trade and affect fishing effort and, ultimately, the sustainability of the fish stock. They are introduced for presumably socially beneficial reasons and are not inherently evil. Those that violate the conditions of the international Agreement on Subsidies and Countervailing Measures are clearly actionable under current WTO rules and are inherently in violation of international standards. But not all subsidies fall into this class. The problems of non-actionable subsidies arise when the context in which they were implemented has changed to the extent that they become a threat to stock sustainability. For instance, with the extension of fisheries jurisdiction to the 200-mile limit, a coastal state might have wanted to replace a foreign distant-water fleet with a domestic fleet which, among other things, it would find easier to control for purposes of fishery management. Society might view favourably a subsidy with that objective. Over time, however, the subsidy might become so embedded in the thinking of the operators of fishing enterprises that it becomes difficult to eliminate it once the goal, in this case the development of a domestic fleet, has been reached. Pursuing the example a little further, because the subsidy encourages the building of domestic vessels, if it is not removed at the appropriate time, boatbuilding will embed excess capacity in the industry and the existence of that excess capacity will lead to overfishing.

After the declaration of the 200-mile limit in the United States and Canada, for instance, government policies (subsidies) were adopted that encouraged the

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[82] FAO. 1992. *Marine fisheries and the law of the sea: a decade of change*. Special Chapter of *The State of Food and Agriculture 1992*. FAO Fisheries Circular No. 853. Rome.

[83] FAO. 2003. *Introducing fisheries subsidies*, by W.E. Schrank. FAO Fisheries Technical Paper. No. 437. Rome.

development of domestic fishing fleets. These were long-lasting and, by the early 1990s, Canada was forced to close its major Atlantic cod fisheries to commercial fishing because the stocks had been decimated. Similarly, by 1999, one-third of the stocks controlled by the United States Government whose status was known were considered to have been overfished. Subsidies no doubt played their role in these events.

JUSTIFICATION AND HISTORY

There are at least three potential justifications for subsidies. First, there is the infant industry concept wherein the government must provide seed capital if a domestic industry is to take hold in the face of existing foreign competition. Second, a large and important firm may encounter temporary financial difficulties which, if the firm went out of business, could spill over and damage other, healthy, aspects of the economy. By temporarily offering subsidy protection, the government might protect the entire economy. Third, subsidies can be used to encourage firms to behave in environmentally friendly ways.

Forty years ago, subsidies were generally seen as being socially useful, largely under the infant industry argument. With the passage of years, and changing views of the role of government in the economy, subsidies are less often seen as socially useful – although many find the environmental justification of subsidies to be compelling. Subsidies have to be judged in the social context in which they are embedded. Will they accomplish their purpose? If they do ultimately accomplish their purpose, will it be possible to abolish them before the point at which they may start to do harm? Are there alternative ways for the government to accomplish its goals?

Regardless of whether these questions have been asked and suitably answered in specific cases, the history of fishery subsidies is a long one, as will be seen from the following examples.

Within 20 years of the establishment of the Massachusetts colony in 1620, fishermen were being subsidized by exemptions from military duty and from certain taxes. In the seventeenth century, England granted monopolies to stimulate the fisheries of what is now Atlantic Canada. In the middle of the nineteenth century, Norway engaged scientists to investigate fluctuations in fish catches, marking the beginning of a long programme of government support to Norwegian fisheries. The modernization of Icelandic fisheries received a stimulus when, towards the end of the nineteenth century, a government bank extended loans for the purchase of fishing vessels. Peru, in the early 1970s, introduced a plan to develop its fisheries for the purpose of supplying fresh and frozen fish products to the domestic market. This plan included a government-financed investment programme in fisheries infrastructure and equipment. In the 15 years following 1960, the Chilean Government used a subsidy programme of income tax and import duty exemptions to develop its fisheries. For a quarter of a century beginning in the mid-1960s, Brazil developed its fisheries through a variety of tax exemptions. The list can go on and on, including subsidies in developed and developing countries, and from hundreds of years ago to this day.

MEASUREMENT OF SUBSIDIES

The measurement of subsidies has been complicated by the diversity of subsidy definitions, a lack of data and, when international bodies have undertaken subsidy measurements, inconsistencies generated by the variety of concepts the individual countries are prepared to consider as subsidies. When subsidies are measured, the cost to government of financial transfers, or of waived receipts, usually provides the basis for the computations. There have been several major attempts to measure fishery subsidies in this way; in particular, a book on the subject by M. Milazzo published by the World Bank is the seminal work in the field.[84] In addition, the OECD has compiled and published a list, by country, of government financial transfers to the fishing

[84] M. Milazzo. 1998. *Subsidies in world fisheries: a re-examination.* Washington, DC, World Bank.

industry; the Asia-Pacific Economic Co-operation group of countries have published a study of the nature and extent of subsidies in the fisheries sector of its member countries; and FAO has prepared a detailed guide to help countries to measure their fisheries subsidies. The gathering of the data constitutes an important first step, but is only a first step. Subsidies themselves are not of primary interest. What is of primary concern is their effect on the behaviour of people and firms. Do the subsidies negatively affect international trade? Do the subsidies encourage firms and fishers to take actions that are detrimental to the stocks of fish that they catch?

Certain subsidies, for instance a boat bounty whereby government pays a certain share of the cost of building and equipping a fishing vessel, theoretically would lead to overfishing. After all, the costs facing the fisher or fishing firm are reduced, the firm's anticipated profits rise, and there would be a double stimulus for overfishing: first, with positive unit profits from catching fish, profits would increase as more fish are caught; and, second, the firm would want to keep its capital employed. Unless scientists were able to make an airtight case for limiting fishing, owners of this excess capital would try to convince fishery managers not to limit fishing. Because scientists are immersed in a world of uncertainty, they cannot offer such an airtight case and often fishing continues at an excessive level until it is too late – the fish stock has approached the state of commercial extinction. While this is the theoretical argument, there are cases, such as that of Newfoundland's northern cod stock, where it has clearly happened. There are, of course, additional factors that lead to the decline of a fish stock: scientific error (as opposed to uncertainty), political pressure from communities that depend on the fishery for their economic livelihood, IUU fishing, and environmental factors such as climatic conditions, excessive predator numbers and insufficient prey, among others. The empirical questions are: to what extent do subsidies actually affect overfishing? What is the contribution of the subsidy to the firm's anticipated profits (it is, after all, the anticipation of profits that will lead the firm to take action)? To what extent does the anticipated change in the firm's profits lead it to overfish? Such analysis is at an early stage.

INTERNATIONAL CONFERENCES

The year of *decade of change*, 1992, was a watershed in the history of fisheries management. In May of that year, an International Conference on Responsible Fisheries met in Cancún, Mexico. Concerned with maintaining fish as a major source of human nutrition, the importance of preserving the marine environment, and problems of excess capacity in fisheries, the conference asked FAO to prepare what was to become the International Code of Conduct for Responsible Fisheries, approved by FAO member countries three years later. Later in the year, the Earth Summit was held in Rio de Janeiro. Although no direct mention of fisheries or fishery subsidies was made, the Rio Declaration on Environment and Development was broad enough to encompass problems of fisheries. In December 1995, the Kyoto Conference on the Sustainable Contribution of Fisheries to Food Security strengthened the call for responsible fisheries. The Reykjavik Conference on Responsible Fisheries in the Marine Ecosystem, in 2001, reinforced the urgency of the need for improved fishery science and monitoring to continue the implementation of the International Code of Conduct for Responsible Fisheries. Finally, the Doha Ministerial Conference in the same year explicitly brought fishery subsidies to the forefront of consideration.

THE POLITICAL DEBATE

There has been great frustration with the apparent inability of existing international arrangements to control overfishing. Because of the existence of strong enforcement procedures under the WTO, there has been interest by a number of nations to find a legitimate way for the WTO to become involved in sustainability issues. As early as 1999, five nations presented a submission to the WTO's Committee on Trade and the Environment urging governments to pursue work with the WTO to achieve the gradual elimination of environment-damaging and trade-distorting fishery subsidies. These discussions continued until the Doha Declaration in 2001 intensified the urgency of the matter. The issue subsequently came under the purview of the WTO's Negotiating Group on Rules. Eight nations – Australia, Chile, Ecuador, Iceland, New Zealand, Peru, the Philippines and the United States – made a submission that started by noting that commercial fisheries are often exploited or potentially exploited by more than one nation. As a result, the argument continued, fishery subsidies have implications for trade far beyond the distortion of competitive relationships. In most industries, subsidies that encourage production impinge on trade only at the market level; they have no effect on the trading partners' ability to produce the goods. With shared fishery resources, a trading partner's ability to produce fish products may be hindered if one country subsidizes the fishery to the extent that the resource is diminished. Thus, the eight countries supported the Doha Declaration's appeal for strengthening the WTO's disciplines with regard to fisheries.

Opposition to the proposal came from countries that, among other arguments, suggested that the new UN Fish Stocks Agreement should be given time to see if it will prove effective. This Agreement was intended to solve exactly the problems that the eight nations raised. From October 2002 to July 2003 there was a second flurry of correspondence addressed to the WTO's Negotiating Group on Rules. The United States proposed a "traffic light" system whereby a certain category of subsidies would face a red light (i.e. they would be forbidden) and a second category of subsidies would face an amber light (where the subsidy would be considered as presumptively harmful). The European Communities presented an alternative proposal which stressed a simple dichotomy of subsidies into "prohibited" and "permitted" classes. The discussion is continuing via correspondence, so far, from Argentina, Chile, Iceland, Japan, the Republic of Korea, New Zealand, Norway and Peru. In addition, a group of "small vulnerable coastal states" has sought differential treatment on such matters as access fees, development assistance, fiscal incentives to domestication and fisheries development, and artisanal fisheries. Only time will tell whether or not the WTO "disciplines" will be adapted to the special problems of fisheries.

African freshwaters: are small scale-fisheries a problem?

INTRODUCTION

During the last decade fisheries comanagement has often been proposed as a means of moving away from the failures of past management approaches. Although it is presented as an alternative, comanagement continues to share with more conventional management the fundamental assumption that increased fishing effort causes biological and economic overfishing and therefore represents the major challenge in terms of achieving the sustainability of fisheries. The regulation of fishing effort thus remains the essential means to avoid "tragedies" and improve efficiency and peoples' living conditions. However, comanagement differs from conventional management in its assumption that once people have been convinced of the positive effects of effort reduction, fisheries will arrive at some form of community-based regulation.

Recently, ecologists and social scientists in the fields of African pastoralism and forestry have started to challenge such assumptions and question the extent of anthropogenic impact on the regenerative capacity of tropical pastures and forests.[85] They have shown how abiotic variables related to climate variability and change may

[85] See, for example, I. Scoones, ed. 1995. *Living with uncertainty: new directions in pastoral development in Africa*. London, Intermediate Technology Publications; and J. Fairhead and M. Leach. 1996. *Misreading the African landscape: society and ecology in a forest-savanna mosaic*. Cambridge, UK, Cambridge University Press.

be much more important to the dynamics of the ecosystem than has been generally assumed. The effects of such variables may even outweigh anthropogenic impacts, and the resulting dynamics, at the very least, make it difficult to perceive trends resulting from human activity. Similar questions are now being raised in relation to African fisheries and in 2003 FAO published the findings of a group of African and European researchers,[86] whose work focused mainly on fisheries in medium-sized water bodies in Malawi, Zambia and Zimbabwe, although it also drew upon material from the other fisheries in the region. The principal questions asked were:

- How have catches and fishing effort changed in the Southern African Development Community (SADC) freshwater fisheries over the last 50 years?
- What are the main causes behind these changes?
- How does fishing effort influence the regeneration of the stocks?
- To what extent are existing and proposed management regulations in fisheries consistent with the conclusions derived from the answers to the three previous questions?

CHANGES IN CATCHES AND FISHING EFFORT OVER THE LAST 50 YEARS

According to FAO, freshwater catches in 12 SADC countries steadily increased from 168 000 tonnes in 1961 to 598 000 tonnes in 1986. Since then catches have stabilized between 600 000 and 700 000 tonnes. The increases over time have resulted partly from exploitation of new water bodies (e.g. Lakes Kariba and Cabora Bassa) and partly from fishing previously untouched stocks, especially small pelagics. Fishing effort on already exploited stocks has continued to increase during the same period although with large variations among water bodies. In Lake Mweru, for example, the number of fishers has steadily increased, while in the nearby Bangweulu swamps, it has remained fairly stable over a long period. In Lake Kariba, fishing effort on the inshore stocks has fluctuated considerably and is probably not much higher today than it was just after the lake was filled in the late 1950s. In Lake Malombe, the number of fishers steadily increased through the 1970s, but stabilized in the 1980s and 1990s and has decreased in recent years.

Large differences in effort dynamics are apparent with reference to "population-driven" and "investment-driven" changes of fishing effort. The first concept refers to changes in the number of harvesters while the latter relates to changes in investments and technology. All fisheries have elements of both types of change, but their relative importance varies considerably, and in SADC freshwaters population-driven changes have dominated during the last 50 years. This means that harvest technology and overall production costs per fishing unit have often remained relatively stable or declined, while the number of harvesters has grown or fluctuated. Lake Malombe and other cases connected to the (unsuccessful) development of "modern" fisheries by foreign entrepreneurs are exceptions in that investment-driven changes have dominated and technological changes have constituted the most important element of development.

The variation in effort levels may be dramatic. For instance, in Lake Kariba the number of fishers decreased by 75 percent in less than five years after 1963, but increased by 150 percent in the course of seven years during the 1980s. The fisheries are dominated by simple and inexpensive technologies that entail low entry costs and facilitate human mobility in and out of the fisheries. From an economic stance, anyone can become an independent fisher within a few years. This mobility may be the reason for Daniel Pauly's argument that the entry of people marginalized in terms of other

[86] FAO. 2003a. *Management, co-management or no management? Major dilemmas in southern African freshwater fisheries. 1. Synthesis report,* by E. Jul-Larsen, J. Kolding, R. Overå, J. Raakjær Nielsen and P.A.M. van Zwieten. FAO Fisheries Technical Paper No. 426/1. Rome; and FAO. 2003b. *Management, co-management or no management? Major dilemmas in southern African freshwater fisheries. Case studies,* by E. Jul-Larsen, J. Kolding, R. Overå, J. Raakjær Nielsen and P.A.M. van Zwieten, eds. FAO Fisheries Technical Paper No. 426/2. Rome.

resources or occupations causes the biggest worries in small-scale fisheries all over the world.[87] He argues that small-scale fisheries have become a "last resort" and that the accumulation of destitute people in the sector ultimately leads to what he terms "Malthusian overfishing".

Fishers exploiting SADC freshwaters demonstrate an even greater mobility. As described above for Lake Kariba, people not only move into most fisheries – they also move out of them. People even leave those fisheries where effort is steadily growing. In Lake Mweru, for example, more than 3 000 fishers left the fisheries in a period where the total number of producers grew by 2 300. Fisheries in SADC freshwaters do not function as a last resort, but as a temporary safety valve – they provide an occupation that people can join and leave according to their needs.

CAUSES BEHIND THE PATTERNS OF CHANGE IN FISHING EFFORT

Growth of effort is often considered inevitable because it is related to demographic growth (population-driven) and to increased demand for fish (investment-driven). However, these explanations neither account for variations over time, nor do they explain the differences between water bodies. Furthermore, investment-driven growth seems to be the exception, despite a general increase in demand for fish in the region as a whole.

Changes in population-driven effort are mainly induced by a combination of variations in ecological productivity and opportunities in other sectors. The sudden reduction in productivity after Lake Kariba was filled, combined with good opportunities in other sectors, led to the dramatic reduction in fishers after 1963. Similarly, the crisis in the Zambian economy after 1974 led many people to join the Kariba fisheries. More than 80 percent of fishers who arrived in Kariba in the 1980s had previously worked in Copperbelt Province or in Lusaka. The same crisis led people who had lost their jobs in Copperbelt to introduce the new fishery for chisense in Lake Mweru. There is little doubt that the SADC freshwaters serve as an important safety-valve for numerous people in times of economic distress – but entering the fisheries is not irreversible.

Local access-regulating mechanisms based on ethnic or community identity are found everywhere, although they may differ in how effectively they control the recruitment of new fishers. In Malombe, such mechanisms have, for many years, excluded owners originating from outside the fishery. In Lake Kariba it was only in the early 1960s and during the last decade that local access regulations have been successful in excluding outsiders; elsewhere they seem to have been of little relevance.

In contrast, when important investment-driven changes in the form of more capital-intensive harvesting methods occur, this seems to reduce population-driven growth. In Lake Malombe, the shift from gillnets to various seining methods that are much more capital-intensive, have substantially increased the costs of entry and thereby reduced the number of potential operators.

Access to financial capital is the major constraint affecting investment-driven growth of effort. Fishing activities are not in themselves sufficient to trigger expensive technological development: financial resources from outside always seem to be needed. In Lake Mweru, the financial needs of the Mpundu (*Labeo altivelis*) fishery initiated in the early 1950s were met by European entrepreneurs. In Lake Malombe, money to buy seines was found through surpluses generated from international labour migration.

The lack of financial resources and of investment-driven growth in the SADC freshwaters is a reflection of much more basic aspects of the societies, both at central

[87] D. Pauly. 1994. On Malthusian overfishing. *In* D. Pauly, ed. *On the sex of fish and the gender of scientists: essays in fisheries science*, pp. 112–117. London, Chapman and Hall; and D. Pauly. 1997. Small-scale fisheries in the tropics: marginality, marginalization and some implications for fisheries management. *In* K. Pikitch, D.D. Huppert and M.P. Sissenwine, eds. *Global trends: fisheries management*, pp. 40–49. Bethesda, Maryland, USA, American Fisheries Society Symposium 20.

and local levels. Analyses of the existing institutional landscape in SADC fisheries also demonstrate how difficult it is, at the local level, to identify institutions with well-defined social rules and with underlying norms that are commonly shared. Such difficulties are seen in the relationship between gear owners and active fishers in Malombe: this is often believed to be a straight employee/employer relationship, but the underlying norms that may serve to stabilize this relationship appear to be far from commonly shared and rules therefore continuously appear to be ambiguous and even contradictory. As a result, the owners experience great difficulty in controlling their crews and the fishers often feel betrayed and/or exploited by the owners.

EFFECTS OF FISHING EFFORT AND ENVIRONMENT ON THE REGENERATION OF FISH STOCKS

In all management approaches, a major role is given to fishing effort in explaining and predicting changes in the regeneration of individual fish stocks. However, efforts to set limits on fishing mortality based on classical stock assessment models have met with limited success in many African fisheries. A number of reasons intrinsic to ecosystem variability contribute to this failure. In the lakes studied, environmental drivers are often more significant than changes in effort in explaining changes in fish production. Although total yields in multispecies and multigear fisheries are surprisingly stable over a large range of effort, considerable changes in species and size composition take place, both as a result of fishing and of environmentally driven processes. Many stocks appear to be resilient, with a large capacity to bounce back after release of pressure. As a consequence, variations in effort levels, to some extent, are a reflection of variations in the productivity of the ecosystems (Figure 43), rather than vice versa as the classical models assume.

As environmental fluctuations significantly influence productivity, biological management of fish stocks must be based upon knowledge of long-term system variability and the responses of both fish and fishers to those dynamics. The information base containing that knowledge is composed of three elements: system variability, susceptibility of species to fishing, and selectivity and scale of operation of fishing patterns.

System variability

Long-term changes in water levels, associated with climate change, are significant in explaining stock changes. This is immediately clear for intermittent lakes like Mweru Wa Ntipa, and Chilwa/Chiuta, where, after refilling, fast regeneration and increase in productivity takes place. But such effects are not restricted to extreme cases. In all lakes catch rates prove to be significantly and positively related toπ water levels. In Lake Kariba, differences in size composition and catch rates among fished and unfished areas in the lake can be attributed to fishing, but here also overall fish production and lake levels indices strongly suggest that the environment is a dominant factor affecting stock fluctuations.[88] In Lake Tanganyika, large changes in catch rates of clupeid species over 40 years seem to be mainly environmentally driven with wind stress as a dominant driver.[89]

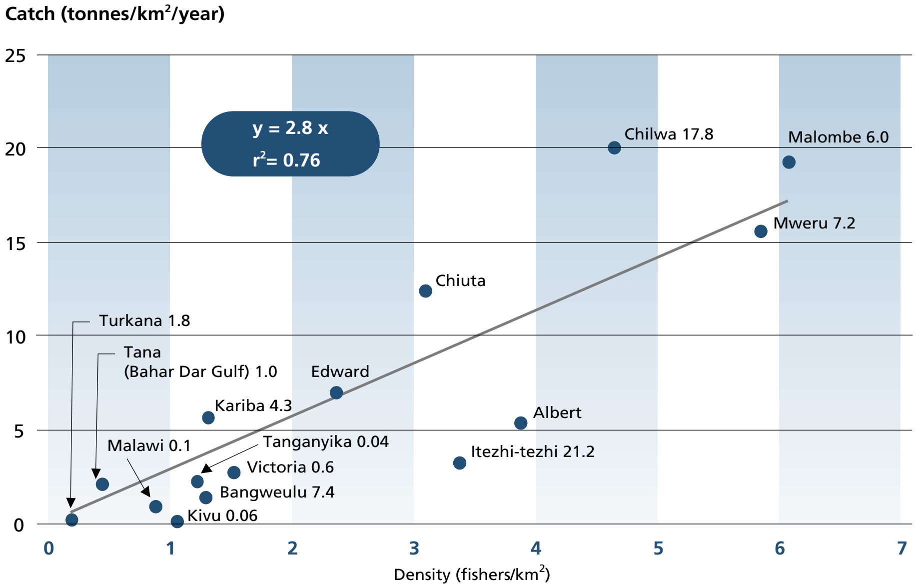
Freshwater lakes and rivers can be classified over a range from pulsed to constant environments. Where changes in water levels are the dominant environmental driver,

[88] L.P. Karenge, and J. Kolding. 1995. On the relationship between hydrology and fisheries in Lake Kariba, central Africa. *Fisheries Research*, 22: 205–226.

[89] P.A.M. van Zwieten, F.C. Roest, M.A.M. Machiels, and W.L.T. van Densen. 2002. Effects of inter-annual variability, seasonality and persistence on the perception of long-term trends in catch rates of the industrial pelagic purse-seine fisheries of Northern Lake Tanganyika (Burundi). *Fisheries Research* 54: 329–348; and P. Verburg, R.E. Hecky and H. Kling. 2003. Ecological consequences of a century of warming in Lake Tanganyika. *Science*, 301: 505–507.

Figure 43

Catch rates plotted versus effort density in 15 African lakes
(data from the period 1989–92)



The trendline indicates an average yield of about 3 tonnes/fisher/year irrespective of water body and country. The number shown alongside 12 of the lakes is the "stability" index in terms of relative lake lake-level fluctuations (RLLF) (mean annual lake–level amplitude/mean depth x 100). Excluding Itezhi-tezhi and Tana, the explained variation between annual catch rates (tonnes/fisher) and RLLF is 45 percent.

this can provide information on the relative stability of the system that can be related to both stock size fluctuations and overall productivity (Figure 43).

Susceptibility of species to fishing

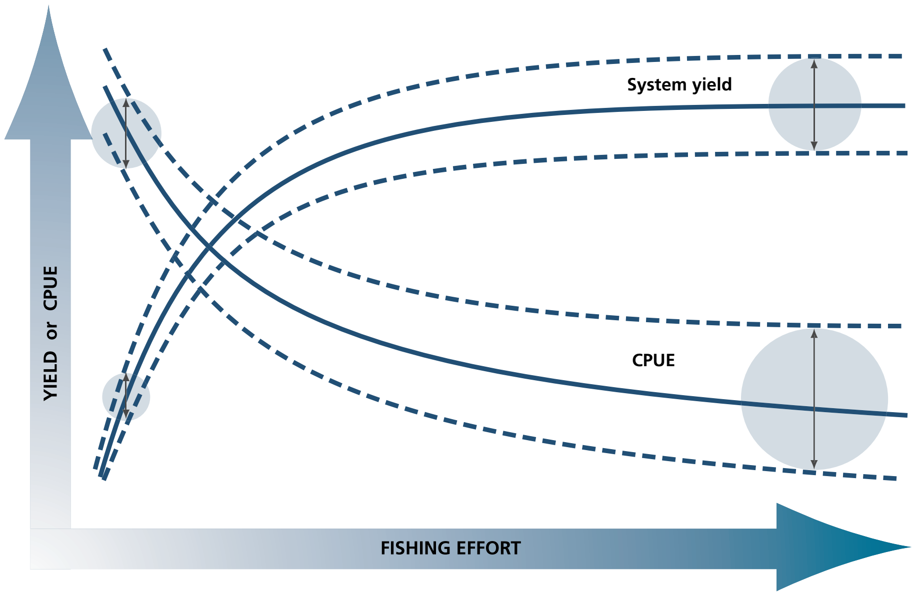
Underneath the apparent stability in system yields of the SADC freshwaters a bewildering array of changes can take place (Figure 44). While examples of serious declines of single stocks can be found, many fluctuate independent of effort. Biological characteristics play a role here, and some species are particularly "susceptible" to fishing: for instance large, slow-growing species such as the large, predatory *Lates* species in Lake Tanganyika clearly declined as a result of fishing; or species with particularly vulnerable stages such as the large cyprinid species that are easily caught during spawning migrations in Lakes Mweru, Malawi, Victoria and Tana. Most species, however, are remarkably resilient to increased effort and this characteristic is related to the system variability. The more a species is adapted to pulsed environments, the less relevant management becomes from a biological perspective. "Resilient" species such as tilapias have long dominated many African freshwater systems. Recently, however, shifts towards pelagic fast-growing, short-lived and "highly resilient" species, such as freshwater clupeids, have taken place in many lakes.

Selectivity and scale of operation of fishing patterns

Small-scale fisheries are able to adapt rapidly to changing circumstances, through change and diversification of fishing methods. In Lake Mweru, in response to the disappearance of large-sized *Oreochromis mweruensis* in the 1970s, the complete gillnet fishery decreased its mesh size in just a few years. Strong year-classes formed after years with high flood-pulses, and large-sized *O. macrochir* reappeared despite the increased effort. Not being caught by the dominant smaller mesh sizes, they formed

Figure 44

Generalized development of fishing yield and catch rate of a fishery with increasing effort



The broken lines represent increasing variation around the mean yield and catch rates over time (vertical arrows). The six characteristics set out below change with increased effort as indicated (High/Low). They refer to total fish biomass system (a, b, c and f) and to the fishery (d, e and f).

(a) Annual carry over of biomass	High	→	Low
(b) Target species susceptibility to fishing	High	→	Low
(c) Resilience to perturbations	Low	→	High
(d) Uncertainty(ies)	Low	→	High
(e) CPUE (mean return to the household)	High	→	Low
(f) Inter-annual variability	Low	→	High

the base of a renewed seine fishery. Many fishing methods, although sometimes forbidden formally, are selective (but invariably multispecies) and may even catch species that otherwise remain unexploited. Increased diversification of small-scale fishing patterns like the ones found in most SADC freshwaters seem to present only limited dangers. By hedging the inherent variability in a relative abundance of multispecies stocks, and opting to target many species and sizes simultaneously, an overall unselective fishing pattern emerges that appears to be ecosystem-conserving. The fish community structure will remain unchanged if all components are removed in proportion to their productivity. As system productivity and average catch rates seem to determine overall effort (Figure 43), the environment, to a large extent, appears to regulate small-scale fisheries. The danger would lie in an increase in the scale of operations arising from either investments in better technology or from more intensive use of existing technology when attempting to override the inherent variability in stocks.

CONCLUSIONS

Since the beginning of the 1900s, fisheries regulations in Africa have built up management systems based on an accepted wisdom regarding the relationship between fishing effort and biological productivity.

However, the ecological dynamics are complex and population-driven growth in effort may be less damaging than is generally considered. An increased perception of the natural variability, with vulnerable stages during periods of low productivity and uncertainties connected to the emergence of more efficient technologies, indicates a need for "early warning systems", in line with the elements outlined above.

The finding that effort dynamics depend as much on the general economic and social development in the region as they do on the fishing economy, implies the need for a much broader focus for monitoring fisheries. Economic analyses based on how people react and respond to macroeconomic changes are as important to understanding fisheries development as those based on current biological monitoring.

As long as changes in effort remain population-driven and the fishing pattern is small-scale and multigear, general regulations relating to effort are problematic. It will be difficult to show that reduced effort leads to improvements in both catch rates and total yield. Adaptive effort reduction may nevertheless be of local importance, either in particularly vulnerable periods, or as a means of coping with natural variations that occur under any type of management system. However, if effort dynamics become more investment-driven, the need for regulations will increase considerably. It should not be too difficult to decide how to answer the question of whether the SADC freshwaters should continue to serve as an economic safety-valve and a buffer for the people of the region, or whether its fisheries should develop into more industrial enterprises (and thereby exclude many of these people). In a situation characterized by serious and long-lasting macroeconomic recessions, it would appear essential that the buffer function be upheld. Besides, the freshwater fisheries will hardly become a driving force in the process for much needed economic reforms.