7. Fuel use in shrimp fisheries

GENERAL

Fuel use is as central an issue in the economics and dynamics of many fisheries as it is in the production of similar food items, such as beef and poultry. With regard to food, fisheries globally dissipate 12.5 times the energy they provide in the form of edible protein energy (Tyedmers, Watson and Pauly, 2005). The issue of fuel use in fisheries has increased in prominence in recent years to the point of being covered in the FAO Code of Conduct for Responsible Fisheries, quoted below.

States should promote the development of appropriate standards and guidelines which would lead to the more efficient use of energy in harvesting and post-harvest activities within the fisheries sector.

Recent reviews of energy use in fisheries that have special relevance to the capture of shrimp are: Wilson (1999), Tyedmers (2004), Tyedmers, Watson and Pauly (2005), and Smith (2007).

Tyedmers (2004) indicates that energy input into fishing operations includes direct inputs, such as those used to move the vessel through the water and deploy fishing gear, as well as indirect inputs used in building vessels and providing gear, bait and ice. General points on fisheries energy inputs include the following.

- Regardless of the scale of total energy inputs to commercial fisheries, direct fuel inputs typically account for 75–90 percent of the total industrial energy[10] inputs to fishing.
- It is evident that the energy performance of many fisheries, and in particular those targeting species for human consumption, has deteriorated over time as abundance and catch rates have decreased and technology sophistication increased.
- Total energy use in commercial fisheries can range over three orders of magnitude. Some industrial fisheries dissipate as little as 1.5 gigajoules (GJs)[11] per tonne of fish landed. In contrast, fisheries for high-value species for direct human consumption commonly dissipate energy in excess of 1 000 GJs per tonne.
- Relative fuel consumption still compares favourably with other animal protein production systems. With an energy used/energy produced ration of 0.095 (about 10 percent), the fuel consumption in 29 North Atlantic fisheries appears to be about five times more efficient than beef production, 4.5 times more than lamb production, three times more than chicken production, 1.5 times more than swine production and much more efficient than most aquaculture systems (Tyedmers, 2004).

There are many sources of differences in fuel efficiency that are relevant to shrimp fisheries.

- Some species require more fuel than others to be captured. Capturing deep-sea species far offshore usually takes more fuel than for coastal penaeid shrimp.
- Some areas, with high ocean dynamics (e.g. off Somalia or Mauritania) or dangerous ecosystems (Arctic, Antarctic), will require larger vessels for safety reasons and more fuel per tonne caught than, for instance, coastal areas and estuaries.

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[10] It should be noted that fuel used for primary fish "production" usually includes catching, on-board processing, storage and transportation to concentrated landing points. This must be taken into account when making comparisons within the sector (i.e. between large- and small-scale fisheries) and between sectors (i.e. comparing with other sources of protein).

[11] One GJ is equal to 950 000 British thermal units.

- Smith (2007) cites another study (Institute of Fishery Technology in Trondheim, Norway), which indicates that otter trawlers used four times as much weight of fuel to catch 1 tonne of fish as local coastal gillnet and line vessels. A recent World Wide Fund for Nature (WWF) report (Binet, 2007) cites a French study that shows proportionally greater fuel costs for fishing gear that is towed. Fuel represented 24 percent of total costs for vessels over 12 m in length using towed gear, but only 11 percent for those using set gear.

The combination of these factors leads to differences in fuel efficiency among ecosystems, areas or countries. Tyedmers, Watson and Pauly (2005) state, for example, that purse seine fisheries for species such as herring and menhaden that are for reduction to fishmeal and oil typically use under 50 litres of fuel per tonne of fish landed, whereas fisheries for shrimp, tuna and swordfish frequently consume over 2 000 litres per tonne. Smith (2007) cites two studies that compare fuel usage in Malaysia and the North Sea (Table 9).

The above studies indicate that fuel use by shrimp trawling is greater than in other fisheries. Some other types of shrimp fishing are, however, much more energy-efficient. More paste shrimp (*Acetes*) is captured than any other shrimp in the world (Chapter 3, section *Catches by shrimp species*) and most of the catch is by passive fishing gear, especially stow nets in China (Chan, 1998), which are very fuel-efficient. On the other hand, the use of outboard engines in several small-scale shrimp fisheries is likely to be more fuel-intensive than industrial-scale shrimp trawling.

The fuel use by various forms of shrimp trawling can differ vastly, even in the same general area. Clay (1996) shows that offshore shrimp vessels in Texas, United States use more than ten times the amount of fuel per kg of shrimp than do inshore vessels. Where fuel consumption of a particular fishery is high, that fishery usually produces relatively valuable shrimp. In the Texas example, the offshore vessels catch large shrimp, valued at about four times that of the small inshore shrimp.

It is clear that such broad comparisons are useful if they underline an alternative way of obtaining the same benefits with less fuel. In this respect, it seems obvious that the technique used to produce menhaden fishmeal cannot be easily used for deep-sea shrimp or tuna; that swordfish and deep-sea shrimp cannot be caught with stow nets; and that inshore United States shrimpers could hardly target offshore shrimp with their fuel-efficient boats.

Krampe (2006) examines fishing fuel and gives a history of the price increase (Box 17). In summary, crude oil prices increased 400 percent from 1998 to 2005, and rose further in the first half of 2006. Smith (2007) considers the fuel price increases in 2006 and concludes that much is caused by the lack of capacity in most of the elements of the fuel supply process, especially the low amounts of critical elements. These include exploration carried out in the 1990s; present production capacity; super-tankers; and oil-refining capacity caused by hurricane damage in the Gulf of Mexico. Additional crude oil price increases occurred in 2007. Crude oil hit a record high of US$78.77 a barrel in early August 2007 in the United States. Reuters (2007) indicates that various factors were responsible: real and threatened disruptions to crude oil supplies; constraints at refineries in consuming countries; resilient global fuel demand; and a flow of investor money into oil.

TABLE 9
Comparing fuel usage by method

Area	Fishing method	Fuel (kg) per catch (kg)
Malaysia	Lines	0.16
	Traps	0.20
	Gillnets	0.19
	Purse seines	0.21
	Trawls	0.33
North Sea	Beam trawling	2.42
	Bottom trawling	1.19
	Shrimp trawling	1.17
	Mid-water trawling	0.57
	Gillnetting	0.67
	Danish pair seining	0.68
	Danish seining	0.17

Source: Smith, 2007.

COUNTRY EXPERIENCE

In the ten study countries (Part 2), a number of energy issues emerged. Rising fuel prices for shrimp fishing and

BOX 17
Oil price increases

Relative to today, oil prices were very stable from 1947 to 1972. During this period, there was a surplus of oil. Then, in 1972, the continuing increase in demand began to push up the price of oil significantly, which rose from US$3 to US$15 a barrel. Throughout the 1970s, demand continued to rise as did oil prices. After the Iranian Revolution, from 1979 to 1980, the cycle shifted and demand for oil declined for the next several years. This marked the beginning of a 17-year period of mostly depressed oil prices, which finally bottomed out in 1998. Then, from 1998 to early 2003, as global demand expanded, nominal oil prices doubled from US$15 to US$30 per barrel. By 2005, nominal prices doubled again, from US$30 to over US$60 a barrel, and have continued to escalate into the current period – with no apparent end in upward prices in sight.

Source: Krampe, 2006.

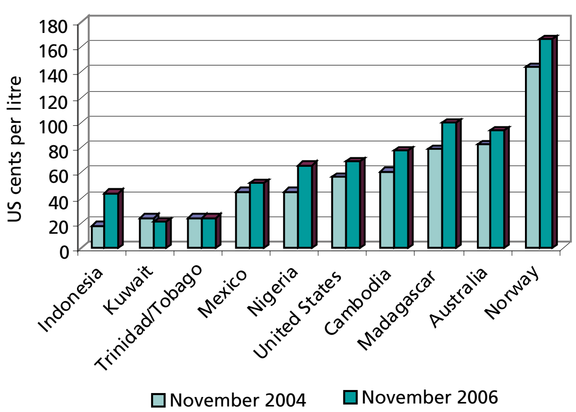
associated financial difficulties were the most prominent energy-related feature, the only exception being Kuwait. The typical situation was in Australia, where the Australian Fisheries Management Authority (AFMA, 2005a) summarized the situation: "Fuel is a huge expense and the cost base of producing a kilo of prawns is on an upward spiral against the prices flat-lining or declining". Other fuel issues in the country studies are described below.

- There have been numerous attempts to mitigate the effects of the fuel price rise.
- The actual price paid for fuel for fishing in a particular country often depends more on taxes/subsidies than on whether that country is a net importer or exporter of fuel.
- The fuel price increase produces an incentive to reduce bycatch in order to reduce costs, because less bycatch means less drag and associated fuel consumption.
- The fuel price increase may also produce an incentive to increase revenues, reducing discards when they can be properly marketed instead.
- A rise in fuel cost has minimal effect on non-motorized shrimp fishing and may make it relatively more profitable.
- Many small-scale shrimp fisheries depend on outboard motors, a form of propulsion that is not very fuel-efficient.
- Because many shrimp capture fisheries are more fuel-intensive than shrimp aquaculture, rising fuel prices can create additional problems for captured shrimp in its competition with the farmed product.

When fuel cost increases coincide with subsidy reductions, the effects can be devastating. In Indonesia, the average annual fuel cost for an industrial otter trawl shrimp vessel operating in the Arafura Sea tripled in 2005, from about US$210 000 to US$625 000 (Part 2).

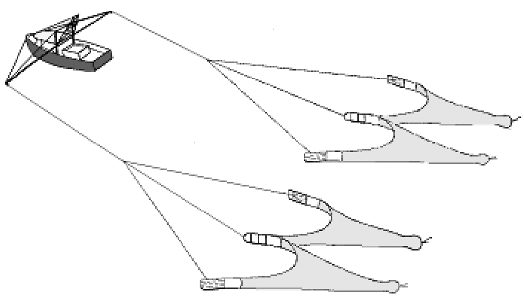
Another important feature of the ten countries studied is the difference in fuel prices. Unfortunately, there is no readily available source of information on current fishing fuel prices. Figure 23 is taken from

FIGURE 23
Retail cost of automotive diesel fuel, November 2004 and November 2006



Source: Metschies, 2007.

FIGURE 24
A quad-rig trawl arrangement



Source: Sterling, 2005.

a worldwide study of the retail price of automotive diesel. The cost of this diesel can differ from that for fishing vessels, especially in Europe, where automotive fuel is significantly higher than that for fishing operations. Nevertheless, there is a general impression that many of the countries that compete with each other in international shrimp markets have vastly different fuel costs.

MITIGATION OF FUEL COST INCREASES

A wide range of measures has been taken to reduce the impacts of fuel price increases on shrimp fishing, which can be classified in two general categories: measures that reduce fuel use (through operational and policy approaches), and measures that increase profitability to compensate for fuel cost increases. The latter are covered in Chapter 8, section *Improving profitability.*

The policy-level interventions to reduce fuel costs in shrimp fisheries (either mooted or implemented) include: subsidizing the cost of fishing fuel; reducing fuel taxation; allowing activities that have a result similar to reducing taxation (e.g. offshore fuelling); ensuring that the fuel cost benefits of currency appreciation are passed on to fishers; relaxing fishery management arrangements that cause greater fuel use; and providing low-interest loans for improving the fuel efficiency of vessels.

With regard to operational measures that reduce fuel consumption, Smith (2007) covers several generic measures applicable to many fisheries. These include optimization of vessel speed, hull shape/condition and propeller. Wilson (1999) indicates that on a typical fishing vessel, only about one-third of the energy reaches the propeller and, for a small trawler, only one-third of the energy reaching the propeller is useful for work such as dragging a net. Consequently, there is room for considerable improvement.

According to the ten countries studied, operational measures used in shrimp fisheries to mitigate fuel cost increases include: using multiple nets (Figure 24); lightening the fishing gear; using sled-type doors for otter trawling; switching from otter trawling to pair trawling; reducing bycatch; using improved netting material; avoiding trawling against tidal currents; basing shrimp vessels closer to fishing grounds; fuelling offshore; smuggling fuel; and remaining in port until the fuel and/or catch situation improves.

FUEL SUBSIDIES

Fuel subsidies deserve special mention. They appear to be the most important policy-level measure for mitigating the rising cost of fuel to the shrimp fleets, although in most cases the policy involved is much broader than shrimp fishing or even the fishing sector. Unfortunately, as mentioned above, there is no good up-to-date source for worldwide comparative information on fuel costs and associated subsidies for fishing activities. The retail price for retail automotive fuel is sometimes taxed at a higher rate than that for agriculture/fishing use. If it is assumed that there is at least some relationship between the taxes/subsidies on retail automotive fuel and that for fishing, then the global study of fuel prices (Metschies, 2007) can provide some insight into fuel taxes/subsidies for shrimp fishing.[12]

According to Metschies (2007), countries can be placed in four categories, from having very high diesel subsidies to very high diesel taxation. Countries with diesel

[12] In Europe, where fuel costs for automobiles are significantly higher than those for fishing operations, the results of a global study on automotive fuel have the least applicability to the fishing fuel situation.

TABLE 10
Fishing fuel subsidies of the major shrimp-producing countries

Countries with fishing fuel subsidies		Countries without fishing fuel subsidies		Countries with no information on fishing fuel subsidies	
Country	*Cents*	*Country*	*Cents*	*Country*	*Cents*
United States	0.06	Viet Nam	0	Greenland	N/A
Indonesia	0.07	Pakistan	0	Myanmar	N/A
Taiwan Province of China	0.09	Nigeria	0	Suriname	N/A
Spain	0.10	Guyana	0	Faeroe Islands	N/A
India	0.11	Germany	0	Estonia	N/A
Malaysia	0.11	Netherlands	0	Madagascar	N/A
Brazil	0.11	Mozambique	0	Venezuela (Bolivarian Republic of)	N/A
Thailand	0.13			Cambodia	N/A
Philippines	0.15				
China	0.18				
Canada	0.18				
Norway	0.18				
Mexico	0.18				
Argentina	0.18				
Iceland	0.18				
Republic of Korea	0.18				
Russian Federation	0.18				
Australia	0.20				
Japan	0.25				

Source: Sumaila *et al.*, 2006.
Note: units: US$ per litre.

subsidies or very high diesel subsidies on automotive diesel (which is assumed above to have at least some relationship to subsidies on fishing fuel) produce a substantial amount of the world's shrimp catch. Combining the information in Metschies (2007) with that of Table 4 (Chapter 3, section *Catches by country*), it can be seen that about half of all shrimp landings come from countries with subsidies or very high subsidies on automotive diesel.

Sumaila *et al.* (2006) report on a global study of fishing fuel subsidies in 144 coastal countries in 2000. A fishing fuel subsidy is defined in the study as the price differential, if any, enjoyed by the fishing sector in each country relative to other economic sectors. Of the 34 largest shrimp-producing countries (Table 4 in Chapter 3), the study shows that in 2000, 19 countries had fuel subsidies (from US$0.06 to US$0.25 per litre), seven had no subsidies and there was no information for eight countries. Table 10 shows the results.

The overall conclusions of Sumaila *et al*. (2006) also apply to shrimp fishing.

It is generally accepted that global fisheries are grossly overcapitalized, resulting in overfishing in most of the world's fisheries. Fuel prices have recently seen significant increases. Given that fuel constitutes a significant component of fishing costs, it is obvious that, other things being equal, increasing fuel prices will reduce overcapacity and overfishing, because they will reduce the profits that can be made, thereby driving marginal fishers out of fishing. But other things are hardly equal. Here, the willingness of governments to provide the fishing sector fuel subsidies reduce, if not completely negate, the conservation value of increasing fuel costs.

Despite numerous oil shocks during the last three decades, fishing capacity in many shrimp fisheries has continued to grow. A significant part of the effect of rising oil prices has been passed directly to the consumer through price increases and indirectly to society through subsidies.

8. Profitability of shrimp fishing and resource rent

COUNTRY EXPERIENCE

One of the main features to emerge in the examination of shrimp fishing in ten countries (Part 2) is the current low profitability of many commercial shrimp fishing operations. The typical situation is rising costs (mainly fuel) and falling revenue from shrimp sales (to some degree as a result of competition with lower-cost farmed shrimp) in an environment where there is overcapacity. Of the study countries, only Kuwait appears to be unaffected by the generally poor profit situation: fuel costs are low and stable; the Government provides subsidies to trawlers; and prices paid for shrimp on the domestic market are rising. Several other countries lie at the other end of the profitability spectrum, including the United States.

The current economic crisis faced by the domestic shrimp industry in the United States is unprecedented – in scope, magnitude and duration. Declining real and nominal prices, along with increasing costs of operation, have created large difficulties in maintaining financial solvency for commercial shrimp vessels in the Gulf of Mexico and southern Atlantic states region (Ward *et al*., 2004).

In a general sense, profitability of commercial shrimp is affected by several factors, the most important of which are fuel costs, catch rates, the price received for shrimp, and any subsidies. Over the last 25 years, fuel costs have generally risen (Chapter 7). Catch rates in open access fisheries (most of the world's shrimp fisheries) have tended to fall. Shrimp prices are more complex, with both rises and falls. The situation with respect to government subsidies is dynamic, with some being eliminated (e.g. fuel subsidy in Indonesia) and other schemes being instigated (e.g. "anti-dumping" duties in the United States).

Determining the profitability of shrimp fishing operations can be difficult, just as in many other fisheries. In countries where shrimp fishing profitability has been formally evaluated, many or perhaps most studies are hampered by using unverified vessel-supplied data in an environment where there are numerous incentives to under-report profits. The situation in Indonesia (Part 2) is typical of many developing countries: "A limited amount of information is available of the profitability of shrimp fishing in Indonesia. Where it is available, it is often not possible to establish the reliability of the sources, rigorousness of methodology used to calculate profit, and consequently the credibility of the results". On the other hand, work on profitability in Australia (Box 18) and Norway could be considered as a model for emulation.

In the absence of good data on the profitability of shrimp fishing, some conjecture on the financial health of various shrimp fleets is given on the basis of indirect indicators, such as fleet size, condition of vessels and CPUE.

- In Mexico, the change in number of vessels in each shrimp fleet is sometimes used as a crude indicator of profitability. It can be inferred from this that there has been no great change in profitability in the 1990s of the industrial shrimp fleets based in the states of Sonora, Sinaloa and Tampico.
- In Cambodia, despite the paucity of economic data, there are indications that the profitability of individual shrimp fishing operations is low. This assertion is based on several features of the shrimp fisheries in the country, including the open access nature of Cambodian coastal fisheries, rising coastal populations, low barriers to

BOX 18

Determining the profitability of shrimp fishing in Australia

The Australian Bureau of Agricultural and Resource Economics (ABARE) has been undertaking economic surveys of selected Commonwealth fisheries since the early 1980s and on a regular basis for particular fisheries since 1992. In 2005, ABARE surveyed two shrimp fisheries: the Northern Prawn Fishery and the Torres Strait Prawn Fishery. Galeano *et al.* (2006) describe the methodology and give the results of the 2005 work. Between February and June, an ABARE officer interviewed the owner of each shrimp boat selected in the sample to obtain physical and financial details of the fishing business for the survey years. Further information was subsequently obtained from accountants, selling agents and marketing organizations. This has enabled various indicators of financial performance, including boat business profit, profit at full equity and rate of return to boat capital to be determined.

Source: Galeano *et al.*, 2006.

participation, lack of non-fishing sources of livelihoods, rising proportion of trash fish in the catch and falling CPUE.

- In Nigeria, shrimp trawling in 2002 was close to break-even at best. The exit of many players from the industry that year supports the contention of low profitability.
- In Australia, despite decades of intense management, profitability remains elusive, with an excess of capacity, partly created by effort creep.

It is interesting to note that many current shrimp trawl fisheries were established when other forms of trawling became unprofitable. Chemonics (2002) stated that in Nigeria the original focus of trawlers was finfish for the domestic market, with shrimp featuring as a bycatch. After a currency devaluation, fish sold locally could not even cover operational costs. Shrimp, which used to be a bycatch, became the focus because of its high export earnings. A switch from trawling for fish to trawling for shrimp also occurred without any devaluation in several Southeast Asian countries, as well as in some of the former French territories in West Africa. In China, in the mid-1970s, because the stock size of coastal demersal fish species was depleted by trawling, fishers started exploratory shrimp fishing using beam trawls, which proved successful. Shrimp fisheries expanded rapidly and extended further seawards (Chen, 1999).

The “discovery” of coastal shrimp fisheries may be a case of ecological relationships assisting the profitability of shrimp trawling. The removal of large predatory fish by trawling during the years preceding the shrimp fishing boom appears to have resulted in less predation on shrimp, reducing its fishing mortality and increasing its abundance. Although this phenomenon can have a positive effect on profitability and development, it can also result in important changes in the marine ecosystem brought on by trawling.

In the shrimp industry, the harvesting sector is not the only segment to experience low profitability. IntraFish (2005) reports financial difficulties in processing cold-water shrimp in the main producing countries: Canada, Greenland, Iceland and Norway. There is increasing competition from tropical species that are generally larger. In recent years, a major shrimp processor closed nine cold-water shrimp processing plants, including three in Norway. Hempel (2001) indicated that eight shrimp peeling plants in Norway also closed recently. It should be noted, however, that non-fisheries factors (such as high labour costs in a labour-intensive industry) could also be responsible for these shrimp processing difficulties.

IMPROVING PROFITABILITY

A number of measures to improve the current situation of poor profitability have been implemented or suggested. The most important are increased attention to fuel costs (discussed in Chapter 7), fleet reduction, market promotion, subsidies and import barriers.

Considerable optimism is shown by both fishery managers and commercial operators in many parts of the world that reducing the number of vessels participating in a fishery will increase the profitability of the remaining vessels. This is often expressed in general terms but, in Nigeria and the United States, there has been some quantitative work.

- *Economic revival (of the shrimp fisheries in Nigeria) will depend upon either prices rising or catch rates improving, as there is little scope to reduce costs. If prices don't rebound, then the principal option facing the industry must be to reduce overall capacity to allow unit catch rates to increase for the remaining vessels, a situation that may be faced by much of the world's shrimp fisheries. This is already happening with the Nigerian fleet – and an indication of the eventual impact on the fleet if prices remain at current levels can be estimated as follows: to restore profitability, catch rates would need to increase by 50 percent (i.e. from 60 to 90 tonnes per boat per year). This would imply a fleet reduction of at least 35 percent, or reducing the fleet to around 100–110 boats* (Chemonics, 2002).
- Ward *et al*. (2004) examined the economics of the Gulf of Mexico and Southern Atlantic States Shrimp Fishery. Simulation analysis found that with low shrimp prices, economic profits are negative and, at the end of 2004, a reduction of 30 percent of permits/licences of the large vessels would be needed to yield positive economic profits in 2005. For small vessels, positive economic profits can be achieved only for the 50 percent fleet reduction.

Reductions in shrimp fleet sizes to improve profitability have been undertaken in several locations, including Australia and the industrial fisheries in Madagascar. On the other hand, small-scale shrimp fisheries are often unprofitable, but there are few cases, if any, where management has reduced small-scale shrimp fishing fleets to improve economic performance.

Reduction in fleet size or capacity (e.g. through vessel numbers or gear restrictions) will not necessarily increase profitability in the long term. In input-controlled fisheries, which cover most shrimp fisheries, the incentive remains to innovate and rearrange inputs to become relatively more effective. Each operator introducing an innovation (e.g. a new net or otter board design) will enjoy a short-term benefit, but this will diminish as others adopt the new technology and effort creeps forwards, eroding profitability as fishing capacity increases and CPUE falls or seasons shorten.

Market promotion exercises have been carried out in several countries to improve profitability. The Mexican Shrimp Council (*Consejo Mexicano del Camarón*) and Ocean Garden Products of San Diego, the largest Mexican shrimp importer in the United States, launched a marketing campaign in March 2004 to promote the flavour and texture of shrimp from Mexico. The campaign, touted as "The Naked Truth About Shrimp", is designed to give farmed and wild Mexican shrimp the brand recognition that products such as Colombian coffee and Mexican tequila already enjoy.

When you've got something this good, why cover it up? Our south-of-the-border beauties come from the most pure ocean waters of a sun-drenched climate. This nutrient-rich environment paired with the VIP treatment means our happy swimmers come to you perfect in taste and texture – as is. All you'll ever really need are a few culinary essentials to bring out their natural flavor. Simple is good. Naked is best (www.mexicanshrimp.org).

At least some of the premium price paid for Madagascar shrimp in Europe has been obtained through market promotion exercises. The Norwegian Seafood Export Council has also carried out some effective publicity work for cold-water shrimp (Figure 25).

FIGURE 25
Promoting Norwegian shrimp

Source: Courtesy of Alf Boerjesso, Norwegian Seafood Export Council.

Some market promotion exercises are quick to take advantage of new opportunities. In September 2007, the marketing group Wild American Shrimp (WASI, affiliated with the Southern Shrimp Alliance [Chapter 5, section *United States anti-dumping action]*) launched a marketing campaign and fund-raising activities associated with new concern in the United States over the safety of Chinese seafood products. WASI feels that this is creating a new selling opportunity for shrimp caught in the United States. To take advantage of this situation, WASI indicates that it needs additional funds to the US$10 million in federal grants received over the last four years for the marketing campaign (IntraFish, 2007).

When profits collapsed in the United States shrimp fishing industry, several measures were proposed by NMFS, including a major marketing programme. Analysis of this proposal (Ward *et al*. 2004) showed that market promotion efforts would have to result in a 15 percent increase in ex-vessel price to eliminate the negative economic profits for smaller vessels. A 5 percent increase in ex-vessel price would increase revenues by 2.25 percent and employment by 2.24 percent. Significantly, the analysis concluded that market promotion and other attempts to improve prices would not be successful unless the number of vessels participating in the shrimp fisheries is limited.

Subsidies are another mechanism that has been used to improve the profitability of shrimp fishing. Most of the obvious subsidies are related to fuel costs (Chapter 7), but others are granted on a per vessel basis, or consist of measures such as tax waivers, low interest loans or provision of infrastructure. Many, but not all, subsidies are harmful (Box 19). Several types of subsidy interventions have been used for shrimp fishing, including those to reduce costs of shipbuilding (Australia), to import vessels (India) and to fit out vessels (Nigeria). In general, the fully or overexploited nature of many shrimp fisheries has tended to reduce government enthusiasm for subsidies, while shocks such as fuel prices and competition with farmed shrimp have resulted in more pressure on governments to grant subsidies.

Subsidies to shrimp fisheries are especially sensitive. Kura *et al*. (2004) make a strong case that government fishing subsidies are a leading factor in the excess capacity of the world's fleets. It is well known that many, if not most, of the world's shrimp fisheries suffer from overcapacity. It is therefore ironic that many of these fisheries continue to receive various types of subsidies.

The boldest move to improve profitability of shrimp fishing in recent years has probably been the initiative in the United States to restrict the import of farmed shrimp on the basis that it has been dumped on the market. In December 2003, the Southern Shrimp Alliance (SSA), a lobbying organization formed by shrimp fishers and processors in eight southern states, filed an anti-dumping petition with the United States Department of Commerce against shrimp farms in Brazil, China, Ecuador, India, Thailand and Viet Nam. In July 2004, the Department imposed duties varying up to 113 percent on these countries. SSA claimed it was seeking protection from an unfair trade practice, but some commentators saw it as a form of unfair protection from foreign competition. The United States shrimp industry is likely to have profited in three ways from the tariff: from reducing the quantity of imported product on the United States market; from a United States law (the "Byrd Amendment"), which gives the duties

BOX 19

The good, the bad and the ugly of fisheries subsidies

It is often unclear which specific subsidies are harmful and to what extent, particularly in the case of indirect subsidies such as port improvements or government-sponsored trade promotions. But there are a few types of subsidies that clearly contribute to overfishing. One is the group of subsidies that encourages continued growth of fishing fleets, even when fish stocks are already overexploited by existing capacity. These subsidies often consist of grants or low-interest loans to purchase or upgrade fishing vessels. They were originally conceived by governments as incentives to develop their industrial fishing sectors, but have not been withdrawn even though most national fleets in the developed world suffer from overcapacity. Some fishing subsidies doled out in developed countries actually have a negative effect on small-scale fishers in developing countries. In contrast to these harmful subsidies, some government-subsidized programmes clearly contribute to better fisheries management. For example, well-designed "vessel buy-back" programmes, where the government pays fishers to retire fishing vessels, can help shrink the size of the fishing fleet and reduce pressure on fish stocks. Government-sponsored research on fishing gear and methods can improve the selectivity of the gear and determine how best to deploy it in order to cut down on bycatch and waste.

Source: Kura *et al.*, 2004.

collected to the aggrieved United States party (some US$150 million); and from a deal between SSA and foreign producers (worth several million) to avoid reappraisal of the dumping duties (The Economist, 2006).

Although SSA efforts were initially successful, subsequent analysis shows that foreign entrepreneurs reacted creatively to thwart the United States restrictions. Shrimp buyers in the United States switched to new suppliers of frozen shrimp, and foreign producers subject to the tariff switched production to shrimp products exempt from the tariff. The amount of shrimp imported into the United States actually increased – including that from many countries subject to the anti-dumping measures.[13] Action by the United States Government also reduced the impact: in February 2007, the "Byrd Amendment", was repealed and in August 2007, Ecuador was removed from the list of countries subject to the extra duty (Mathews and Dunaeva, 2007).

RESOURCE RENT

Resource rent can be defined as the difference between the revenue from a fishery resource and the total costs of exploiting the resource. In a broader sense, if non-monetary costs and benefits are considered, rent can be considered as the net economic return from a fishery to society. In limited access fisheries, resource rent can be kept by fishers (as super profits) or collected by management authorities (and returned to the public) through licence fees.

Good management regimes tend to increase rent; others, especially open access, can dissipate it. Accordingly, changes in rent can be an indicator of the economic performance of a fisheries management agency. For example, the performance of the AFMA in managing several shrimp fisheries under its jurisdiction is to some extent determined by changes in resource rent levels of these fisheries.

[13] O'Sullivan (2005) states that the United States import share by the six countries affected by the anti-dumping measures actually increased from 62.4 percent in 2003 to 65.4 percent in 2005.

Resource rent has not been determined for many shrimp fisheries in tropical countries. The situation in Indonesia seems typical where, according to the Director of the Centre for Marine and Fisheries Socio-Economic Research, there have been few rent studies on any of the fisheries (A. Purnomo, personal communication, December 2005). Elsewhere, many fishery managers encountered during the present study are only vaguely aware of the concepts related to resource rent. Few managers appear to use the amount of rent when managing shrimp fisheries. Chapter 4 indicates that in many countries, the gross value of the shrimp catch is often used by fisheries managers for making decisions, such as trade-offs between fisheries, simply because the numbers are available and comparable. This is unfortunate, because resource rent is in many respects a better indicator of the value of a fishery to society.[14]

Information on resource rent is readily available for several shrimp fisheries in developed countries.

- Galeano *et al.* (2004) give the rent in the NPF ($A33 million of resource rent in the 2001/01 season), the Torres Strait Prawn Fishery ($A2.8 million in the 2001/01 season), and the Southeast Trawl Fishery ($A2 million average for several years).
- Ward (2006) determines the resource rent level for the Gulf of Mexico shrimp fishery in the United States at US$2.11 billion. By introducing optimal yield management strategies and property rights into the fishery, a rent of US$4.19 billion could be obtained.
- Christensen and Vestergaard (1993) state that in 1991 the rent in the Greenland Shrimp Fishery in the Davis Strait was between US$33.8 million and US$104.8 million.

[14] Between the mid-1980s and the early 1990s, FAO promoted the use of bioeconomic models (and related software) for this purpose, developing pilot applications in Mexico, Madagascar and Kuwait (Willmann and Garcia, 1985; Sparre and Willmann, 1992).

9. Biological aspects of shrimp

Fisheries biologists have made considerable progress in understanding the life histories of many of the important species of shrimp. In the early days of shrimp fishing, biologists had poor knowledge of shrimp biology, including the complex larval life, growth and mortality rates, life span, migration and habitat requirements (Iversen, Allen and Higman, 1993). After many decades of research, "most of the big unknowns were solved" (S. Garcia, personal communication, 2006), which contributes greatly to the improvement of the assessment and elaboration of advice for the management of shrimp fisheries.

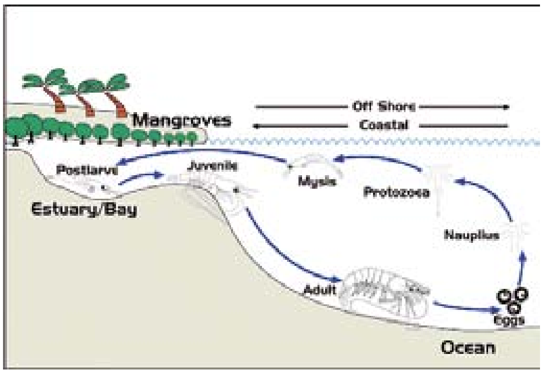
BASIC BIOLOGY AND LIFE HISTORIES

There are major biological differences between the main groups of shrimp. For the purpose of this discussion, economically important shrimp is divided into three groups:

- penaeid shrimp (primarily the genera *Penaeus, Metapenaeus, Parapenaeopsis* and *Trachypenaeus*);
- caridean shrimp (primarily the families Pandalidae and Crangonidae; and
- sergestid shrimp (the genus *Acetes*).

Drawing upon a variety of sources, Cascorbi (2004b), reviews the major biological characteristics of the three major species of *penaeid shrimp* in the Gulf of Mexico, much of which are applicable to warm-water shrimp in other regions. Most shrimp is omnivorous, catching or scavenging whatever plant or animal material is readily available. The sexes are separate and females tend to be larger than males. Males and females clasp to copulate and then the female broadcasts fertilized eggs into the water column. All three major penaeid shrimp in the Gulf are extremely prolific, releasing between 500 000 and 1 million eggs per spawning. The eggs drift with the plankton and may settle to the seafloor. They hatch within 24 hours. Newly hatched shrimp larvae bear little resemblance to their elders; in the three important penaeids of the Gulf, larvae must undergo 11 moults to attain final form as a juvenile shrimp. The tiny shrimp larvae drift with the plankton, where they are important food for many fishes and invertebrates. Postlarvae (PL) individuals – tiny but shrimp-like – seek sheltered estuaries in which to grow to adulthood, making estuarine habitat very important to penaeid species. The annual abundance of penaeid shrimp is closely tied to natural factors such as average temperature, amount of rainfall and the number and intensity of storms, which affect the survival and recruitment of the larvae. Young penaeids are sensitive to changes in water salinity. The main Gulf shrimp is short-lived, completing its life cycle in 18–24 months and reaching sexual maturity in 6–12 months.

FIGURE 26
Life cycle of penaeid shrimp



Roberts (2005) and Iversen, Allen and Higman (1993) have reviewed the literature of caridean shrimp biology (the genus *Pandalus*). The main commercially important pandalid shrimp is nearly all protandrous hermaphrodites: juveniles usually mature as males, breed as males for one or two years, and then transform and breed as females for another year or two. The males transfer sperm to the females, who may store the sperm for some time. The females then extrude the eggs, fertilizing them as they lay them. Clutch size ranges from a few hundred eggs to about 4 000, very few compared with the tens of thousands or more eggs released by warm-water shrimp. The female pandalid attaches her fertilized eggs to her abdominal appendages, where they remain, protected by the mother and aerated by her swimming, until the larvae break free. Newly hatched shrimp larvae bear little resemblance to their elders; each must undergo up to 12 moults to attain final form as a juvenile shrimp. Pandalid shrimp generally live much longer than penaeid shrimp – many important species live for about six years and enter fisheries at about two years of age. Many marine species prey on pandalid shrimp. Several authors have suggested that the collapse of Atlantic cod populations off Canada and in the Barents Sea may have led to an increase in biomass of *Pandalus borealis*, but results of studies to date are equivocal.

PICES (2001) summarizes the basic biological features of the genus *Acetes* of sergestid shrimp. Spawning occurs twice a year, with spring/summer and summer/autumn generations, and most of both broodstocks die after reproduction. During the spring, gonads mature after wintering, and spawning begins in June. The spring stock grows quickly in the summer and reproduces to form the autumn generation. In akiami paste shrimp, the longest life span is only one year; the sex ratio is about 1:1; the body length of mature male and female individuals ranges from 17 to 32 mm and 18 to 43 mm, respectively; and size frequency structures of two generations are different. Female body lengths of the spring stock range from 25 to 40 mm and the range is dominated by 31 to 32 mm shrimp. Female body lengths of the autumn stock range from 12 to 30 mm and are dominated by 20–30 mm shrimp. Mating activity takes place about 15 days prior to spawning, in batches and always at night. Typical spring females produce 7 700 to 8 700 eggs, while a 30–mm autumn female would produce 6 800 eggs. Akiami paste shrimp is a weak swimmer and does not make long-distance migrations, but there is a seasonal movement between shallow (summer) and deep waters (winter). The shrimp filters feed on phytoplankton (diatoms) and detritus, but also actively preys on zooplankton. The diet composition changes with habitat and seasons.

Some biological characteristics of shrimp have important fisheries management implications. Penaeid shrimp fisheries generally exploit a single year class. The annual yield is therefore largely a function of the importance of annual recruitment, which is widely influenced by environmental conditions (often rainfall or temperature during a critical period). The consequences are highly variable annual catches. This fact has many consequences for stock assessment, modelling, effort control and management strategy (Garcia, 1989). The postlarvae of many penaeids move to inshore areas where they grow to maturity and subsequently move back to deeper water. As small-scale shrimp fishing is often done in shallow, sheltered, inshore areas, fishing on different size shrimp often equates to competition between industrial and small-scale fleets. Management measures based on shrimp size also have some tendency to partition the resource between the various scales of fishing operations.

Cold-water shrimp has attracted less biological investigation, but nevertheless, some of the research findings affect management strategies. Pandalid shrimp are fast-growing and early-maturing and produce several thousand young. These and other life history characteristics, such as environmental sex determination, make them inherently resistant to fishing pressure (Roberts, 2005).

With regard to *Acetes* shrimp, much less biological information is available. Because the shrimp has a short life span, its abundance may be easily affected by natural conditions and human activities. As a result, its annual abundance and landings fluctuate extensively (PICES, 2001).

TABLE 11
Some differences in the main groups of shrimp

Aspect	Penaeid	Caridean	Sergestid
Species items of commercial importance (groups with more than 3 000 tonnes in the 2005 FAO statistics)	Many in several genera	*Pandalus borealis, Crangon crangon, Pandalus* spp., *Pandalopsis* spp., *Heterocarpus reedii*	Sergestidae, *Acetes japonicus*[1]
Percentage of global commercial catch	Slightly more than half	Slightly less than one fifth	Slightly more than one quarter
Body size	Small to large	Very small to large	Small to microscopic; body strongly compressed laterally
Sex	Separate sexes	Nearly all protandrous hermaphrodites	Separate sexes
Reproduction	Eggs released directly into water – fertilized on release	Females carry eggs until hatching	Eggs released directly into water
Life cycle	Short (<3 years)	Mostly long (3–8 years)	One year or less
Habitat zone	Mainly tropical and temperate	Mainly temperate and arctic	Mainly tropical and temperate

[1] PICES (2001) indicates that the akiami paste shrimp (*Acetes chinensis* and *Acetes japonicus*) overlaps in its geographic ranges and is generally not distinguished in landing statistics.

The three main economically important groups of shrimp are distinct with respect to biological and other attributes, some of which are given in Table 11. These differences have major implications for the strategies used in their management.

IMPORTANT ISSUES RELATING TO SHRIMP RESOURCES AND BIOLOGY

In the ten study countries in Part 2, a number of issues related to shrimp biology and biological research were identified. One of the most striking features is the generally poor biological condition of the shrimp resources in developing tropical countries. The information in Part 2 can be summarized as follows.

*Indonesia.*There does not appear to be much potential for expansion of shrimp catches in the country. In many areas, shrimp resources appear to be considerably overexploited. A decade ago, an FAO project suggested that effort should be reduced by about 50 percent of the effort in 1993 in order to keep the catch around MSY.

Cambodia. Despite the paucity of data, overexploitation of shrimp resources is suggested by several indicators, including the open access nature of Cambodia’s coastal fisheries, the rising coastal population, low barriers to participation, lack of non-fishing sources of livelihood, low profitability, rising proportion of trash fish and perceptions of falling CPUE.

Madagascar. A large decrease in landings in 2004 and 2005 indicates a need for a new and detailed analysis of shrimp stocks.

Mexico. For Mexico’s Pacific coast shrimp resource, it has been concluded that catches of Mexican Pacific shrimp have reached their maximum and that fishing effort should not be increased in any region or on any species. Some of the stocks are at a biomass level below maximum productivity.

Nigeria. An FAO report (FAO, 2000c) concludes that it is clear that current output level of the shrimp fishery is considerably beyond potential long-term yield estimates.

Trinidad and Tobago. Brown shrimp is one of the dominant species exploited by both the trawl fleets of Trinidad and Tobago and the Bolivarian Republic of Venezuela in the Orinoco-Gulf of Paria region. A study using 1973–2001 data indicates that the *Farfantepenaeus subtilis* resource is severely overfished and that overfishing has been taking place since the 1970s.

Another prominent issue is the lack of research, or even basic data collection, in many countries where the resource is important (see Chapter 14).

BOX 20
Assessment of Australia's Northern Prawn Fishery

Assessments of the dynamics and status of the Northern Prawn Fishery target species is undertaken by the Northern Prawn Fishery Assessment Group on an ongoing basis. Logbook and research data are used in the assessments with extensive modelling work developed for the major prawn species. Results of each assessment are published annually and include an analysis of previous and current stock assessments, implications for management, economic status and environmental factors affecting prawn stocks. Catch, effort and CPUE trends for target prawn species are monitored, and persistent downward trends over three or more years are investigated to determine whether there is a biological problem with stocks. Research into improved stock assessment techniques is ongoing. Extensive modelling is used, in particular for tiger prawns, where there is a clear stock recruitment relationship. These models are regularly peer-reviewed.

Source: Department of the Environment and Heritage, 2003.

STOCK ASSESSMENT

The biological condition of various shrimp fisheries is currently being assessed to varying degrees, ranging in sophistication from little, if any, data collection and virtually no assessment in some countries, to the assessment process for Australia's NPF (Box 20), which has been described as the most comprehensive for any shrimp population assessment in the world (AFMA, 2001a).

Because of the great differences in assessment between warm- and cold-water shrimp fisheries, they are discussed separately below.

Warm-water shrimp

Stock assessment on warm-water shrimp resources ranges from simple trends in CPUE to extremely complex stock assessment models. CPUE trends have the advantage of being simple, easy for developing country managers to use, and readily understandable by fishers and the general public. However, as noted earlier, they are prone to error and need frequent adjustment to account for effort creep driven by technical innovation. The more sophisticated models are able to integrate many different types of information on shrimp resources and can give potential yields from a fishery.

Garcia (1989) notes that because seasonal and age-specific fishing patterns have marked consequences on annual yield in weight and value, an important role of stock assessment for warm-water shrimp is to determine the most appropriate age at first capture to reach a specific management objective. This implies the use of bioeconomic yield-per-recruit modelling with pre-season surveys. Gulland and Rothschild (1984) place the various models used for resources assessment in general, and shrimp stock assessment in particular, into two general categories.

- *Production models*. As generally applied, these relate the catch to fishing effort in one season. These models do not take explicit account of the effect of fishing on different size groups, but demand fewer data than age- or length-structured models, and are therefore widely used.
- *Age- or length-structured models.* These are based on the yield-per-recruit calculations of such researchers as Ricker and Beverton and Holt and are essential to study the effects of changes in fishing practices that involve changes in the pattern of distribution of fishing mortality with age. Yield-per-recruit or other measures of output (catches by age or size class) can be obtained for a particular input.

BOX 21
Modelling of the shrimp fishery in Negombo Lagoon

A model was formulated to investigate the likely outcomes from changes in the fisheries inputs, particularly the consequences to catch weights and CPUEs from applying different fishing efforts. The model is of the length-based "Thompson and Bell" type. The biological inputs concern growth in length, the conversion of length to individual weight, and the natural mortality at age constants, among others. The outputs from the model were estimated catch numbers, catch weights and catch values, the associated CPUEs and the shrimp length frequencies. These outputs are for each of the six main shrimp species and eight gear types. Three hypothetical scenarios were examined with the model.

- In the first scenario, the fishing effort with stake nets was varied, while the efforts for the other gears were maintained at the contemporary levels. The results indicated that substantially increased catches were likely from increased stake net effort. Reducing the stake net effort produced near-proportional reductions in stake net catch, associated with very marginally increased CPUEs (in the trawl fisheries).
- In the second scenario, the fishing effort with trammel nets was varied. The estimated decrease in trammel net CPUEs from increased effort was judged as likely to be unacceptable. The loss of catch from reduced effort was found to be greater than the increase in catch from the other gears.
- In the third scenario, the combined fishing efforts for the trawl fisheries were varied. The findings indicated that the potential to increase the mechanized trawler catch is negligible. There seems to be some scope to increase the catch from non-mechanized trawlers.

Source: Sanders, Jayawardena and Ediriweera, 2000.

For example, a length-structured model was developed for the shrimp fishery in Negombo Lagoon, 40 km north of Colombo in Sri Lanka. Sanders, Jayawardena and Ediriweera (2000) describe the model and its application (Box 21).

Despite the limitations of using CPUE to gauge the conditions of shrimp resources, the reality is that many, if not most, shrimp fisheries in developing countries (almost all of which are warm-water fisheries) are heavily dependent on CPUE trends for their management. In these situations, two avenues of enhancement should be considered:

- the use of the somewhat more sophisticated yield-per-recruit analysis ("the next step up from using CPUE"), which is sometimes cited as a characteristic of an effectively managed penaeid fishery (R. Shotton, personal communication, 2006);
- the use of some index of recruitment success (i.e. related to rainfall or based on pre-season surveys), which can significantly improve any forecasting of future yields (S. Garcia, personal communication, 2006).

Cold-water shrimp

Roberts (2005) and Koeller *et al.* (2000) review stock assessment for cold-water shrimp fisheries. Because of its commercial importance, pandalid shrimp has received considerable attention from fisheries organizations such as the International Council for the Exploration of the Sea (ICES), the Northwest Atlantic Fisheries Organization (NAFO), and the North Pacific Marine Science Organization (PICES). Assessments of cold-water shrimp stocks generally consist of monitoring population changes using catch rate series and, in some cases, research surveys. They provide general information on population structure and recruitment, significant changes in which are used to identify when a change in quota or effort is needed. Biological reference points and formal yield projections are not common.

TABLE 12
Year class strength of the northern shrimp stock for the 2006 season

Year class	Year class initial year class strength (based on prior assessments)	Current year class strength (based on 2005 assessment)
2000	Virtually absent	Have passed out of 2006 fishery
2001	Moderate	Strong Assumed to be 5-year old females
2002	Virtually absent	Very weak Assumed to be 4-year old females
2003	Weak to moderate	Strong Assumed to be 3-year old males and transitionals
2004	Not available	Strong Juveniles

Source: ASMFC, 2006

TABLE 13
Assessment of northern shrimp in Canada's Hopedale and Cartwright Channels

Index	Observation	Interpretation
Fishery data		
Spatial pattern	The offshore component of fisheries expanded to shelf edge.	This reflects discovery of high concentration of shrimp along shelf slope during exploratory fishing in 1992 and 1993, areas previously thought unproductive.
Temporal pattern	A winter/spring fishery for the offshore fleet since 1995; previously a summer/fall fishery. Inshore vessels fish during summer/autumn.	High concentration of shrimp available throughout the year.
Male abundance	Catch rates of males increased during the 1990s. The 1991 year class dominated the males in 1995 and 1996; the 1993 year class in 1997 and 1998; and the 1994 year class in 1999.	Good recruitment of year classes produced in the early 1990s resulted in high catch rates of males over the past several years.
Female abundance	Catch rates of females increased from around 1993 to 1997, and stabilized in 1998 and 1999.	Continued good recruitment since the late 1980s is responsible for the increase in spawning stock throughout the 1990s. Spawning component remains healthy.
Sex inversion	The mean size of females and the median size at sex change have declined since 1996; these data are from the offshore vessels only.	This likely reflects a change in growth and size at sex change.
Research data		
Biomass/ abundance index	Estimate declined from 1996 to 1998 and increased in 1999. Broad 95 percent confidence intervals in this area, especially in 1996.	There is greater uncertainty because distribution is continuous with another area (area 6), but more patchy in the northern channels.
Spatial pattern	Shrimp is distributed widely throughout the management area, but very high catches occur in some locations.	With the current low survey coverage and the relationship with the southern area, results must be interpreted cautiously.
Recruitment (male age structure)	Males dominated by the 1993 year class in 1996 and 1997 surveys. The 1994 year class was prominent in the 1998 survey and the 1994 and 1995 year classes were prominent in the 1999 survey. No recruitment estimate.	Most of the 1994 year class will recruit to the female group in 2000.
Spawning stock (females)	Females in 1999 were composed of year classes produced prior to 1994, but most were assumed to belong to the 1993 year class.	Female biomass/abundance will be maintained in 2000.
Other factors		
Predation	Abundance of known predators in the offshore areas such as cod, redfish, skate and American plaice remains low.	Predation mortality remains low relative to periods of high predator abundance.
Environment	Positive correlation was observed between ice cover and CPUEs six years later.	Catch rates could decline gradually or remain stable over the next several years, assuming predator abundance remains low.
Industries perspectives	Catch rates from the 2000 fishery over a broad area for January/February are reported to be higher than for the same months in previous years.	Stock remains healthy.

Source: DFO, 2007.

Christensen and Vestergaard (1993) comment on aspects of stock assessment of the large *Pandalus borealis* fishery between Canada and Greenland. They state that ageing the shrimp constitutes one of the major tasks of assessment of the stock. Ageing difficulties have been a hindrance for the application of analytical assessment models and, as a consequence, the annual catch quotas have been based on logbook information of commercial fishery catches.

Unlike many of the penaeid fisheries, which typically involve shrimp species with short life cycles, northern shrimp populations can be tracked by year class. Table 12 provides a comparison of year class strength in the Gulf of Maine northern shrimp stock, as determined by prior assessments and the 2005 assessment. It shows how fishing pressure and environmental conditions can affect the stock over time. Changes in the 2001 and 2003 year classes are indicators of a recovering stock. These, together with increase in biomass, were the basis for increasing the fishing season to 140 days for the 2006 season.

Canada's Northern Shrimp Fishery is one of the most thoroughly assessed cold-water shrimp fisheries in the world. DFO (2007) indicates that fishery data, research data and other factors are used to assess the stock status. Table 13 summarizes the factors that have led to the conclusion that the stock of northern shrimp in the Hopedale and Cartwright Channels is in a favourable condition.

10. Impacts of shrimp fishing on the bottom habitat

GENERAL

Concerns over the impacts of fishing gear on the sea bottom and benthic fauna have been around for a long time and have often been expressed by fishers themselves ever since mobile bottom gears were introduced. In 1376, a commons petition to the King of England complained "that the great and long iron of the wondyrchoun runs so heavily and hardly over the ground when fishing that it destroys the flowers of the land below water there ..." (Austers, Malatesta and Babb, 1994). The "wondyrchoun" (wonderful machine) was a beam trawl (Sharp, 2000). The King's response, although couched in antiquated terms, is essentially the same as that still being used today, "Let commission be made by certain qualified persons to inquire and certify to the truth of the allegation made, and thereon let right be done in the Court of Chancery". In other words, let's do an environmental impact assessment before we act (BoFEP, 2000).

The degree to which shrimp trawling alters the seabed has generated a substantial amount of polarized discussion and controversy. On the one hand, scientists have shown the strong impact of trawling on the bottom, and advocacy institutions have equated trawling "to harvesting corn with bulldozers that scoop up topsoil and cornstalks along with the ears", and stated that "bottom trawling is the most important human source of physical disturbance on the world's continental shelves" (Safina, 1998).

Regarding more specifically tropical shrimp fisheries, participants at regional workshops on reducing the impact of tropical shrimp trawl fisheries in Latin America, Africa, the Middle East and Southeast Asia, recognized the lack of knowledge in participating countries, the possible importance of such an impact in some areas and the need for more research (FAO, 2000a). This lack of information (and potentially of consensus) could complicate the agreement needed for a participative ecosystem approach to fisheries.

It is obvious, however, that there must be some physical impact and, as stated by Hall (1999), "it would be quite foolish to deny that benthic communities are substantially altered by towing a fishing gear over them". However, agreeing on the seriousness of the impact in different habitats and on the objective assessment of the long-term consequences on target productivity as well as on biodiversity is complicated by the diverse perspectives of the stakeholders (ecologists, conservationists, gear technologists, fishery scientists, fishery managers, fishing industry and the general public). These include different appreciations of the short- and long-term societal costs and benefits of shrimp fishing, different concepts of economic development and different views about intangible values of the ecosystem.

From a purely technical perspective, there are debates over: the scientific rigour of past impact studies; the frequent absence of non-impacted ground to be used as control; the chronic difficulty in separating fishing effects from other environmental impacts; the need to quantify an impact prior to raising concern (giving due consideration to the precautionary approach, however); and the impact of trawling in relation to that of natural phenomena such as waves (e.g. on shallow soft bottoms). On a different level, Leadbitter and Oloruntuyi (2002) cite a likely major philosophical difference causing the divide: "Given the fact that the modification of terrestrial habitats is vital to both agriculture and human settlement, the concern over the modification of benthic marine/estuarine habitats is often difficult for many to understand". Whatever the cause, the fact remains that there are indeed major differences of opinion over the physical impacts of shrimp trawling.

An overriding fact, however, is that governments have committed themselves to sustainable development, responsible fisheries and sustainable use of biodiversity, and there is moral pressure to do so. The different aspects of the question are discussed below.

DESCRIBING THE IMPACT

Johnson (2002) proposes a scheme for categorizing the various types of physical effects of fishing gear in general on benthic habitats.

- *Alteration of physical structure*. Physical effects of fishing gear can include scraping, ploughing, burial of mounds, smoothing of sand ripples, removal of stones or dragging and turning of boulders, removal of taxa that produce structure, and removal or shredding of submerged aquatic vegetation.
- *Sediment suspension*. Resuspension of sediments occurs as fishing gear is dragged along the seafloor. Effects of sediment suspension can include: reduction of light available for photosynthetic organisms; burial of benthic biota; smothering of spawning areas; and negative effects on feeding and metabolic rates of organisms.
- *Changes in chemistry*. Fishing gear can result in changes to the chemical makeup of both the sediments and overlying water mass through mixing of subsurface sediments and interstitial water. This could facilitate the remobilization of contaminants.
- *Changes to the benthic community*. Benthic communities are affected by fishing gear through damage to the benthos in the path of the gear and disturbance of the seafloor to a depth of up to 30 cm. Many kinds of epibenthic animals are crushed or buried, while infauna is excavated and exposed on the seabed, often damaged.
- *Changes to ecosystem*. The use of some types of fishing gear can affect benthic community composition and habitat. It is possible that these changes at the community level in turn result in effects on harvested populations and ecosystems.

Prado and Valdemarsen (2001) describe in general terms the bottom impacts of different types of fishing gear, five of which are sometimes used for shrimp fishing (Table 14).

Barnette (2001) gives a general synopsis of the physical effects of otter trawling. Otter trawl doors, mounted ahead and on each side of the net, spread the mouth of the net laterally across the seafloor. The spreading action of the doors results from the angle at which they are mounted, which creates hydrodynamic forces that push them apart and, in concert with the trawl door's weight, also push them towards the seabed.

TABLE 14
Bottom impacts of various types of fishing gear

Fishing gear	Bottom impact
Bottom otter and beam trawls	• Compress and penetrate the upper sediment layers
	• Scour the sediment
	• Flatten existing surface structures
	• Disturb the surface structures, including burrows
	• Break up sedimentary layering
Seine net[1] (Danish/Scottish)	• Minor: seines normally have light bottom contact
Traps/pots	• Minor: mainly effects of ropes and anchors on the seabed
Beach seine	• Minor: some impacts on the habitat of juveniles in shallow waters

[1] In Southeast Asia, the use of seines for shrimp fishing is common: there are over 18 000 units of "demersal Danish/lampara seines" in Indonesia, much of which are used for shrimp fishing.
Source: Modified from Prado and Valdemarsen, 2001.

The doors, because of their design and function, are responsible for a large proportion of the potential impact inflicted by a trawl. The footrope runs along the bottom of the net mouth and may be lined with lead weight, rollers and other devices that may or may not reduce bottom impact. On a relatively flat bottom, it is often expected that the footrope will not have a major effect on the seabed and its fauna, but the impact of tickler chains may not be insignificant. However, in areas of complex, three-dimensional benthic habitat, with elevated animal colonies, the footrope has more impact. Additionally, even though the footrope may cause little physical substrate alteration on relatively flat bottoms, aside from smoothing and minor compression, it can lead to sediment "packing" after repeated trawling activity. Such compression can also result from the dragging of a loaded net (codend) along the bottom. The remaining path of the trawl is influenced by the ground warps which, while not in direct contact with the seabed, can create turbulence that resuspends sediments. Trawl gear, particularly the trawl doors, penetrates the upper layer of the sediments, which liquefies the affected sedimentary layers and suspends sediment in the overlying water column. This sediment "cloud" generated by the interaction of the trawl gear with the benthos and the turbulence created in its wake contributes to fish capture.

The State of World Fisheries and Aquaculture (FAO, 2004) describes the impact of the beam trawl, another shrimp fishing gear that causes concern over its effects on the sea bottom. Beam trawls are used to catch species that stay on the bottom or are partly buried in the seabed. Accordingly, beam trawls have tickler chains designed to disturb the seabed surface and penetrate the upper few centimetres of the sediment. The most noticeable physical effects of beam trawling 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 from 1 to 8 cm. Løkkeborg (2005) compares the physical impacts of otter trawling and beam trawling. Furrows and berms created by the trawl doors are the most conspicuous physical impacts from otter trawls. The doors of otter trawls probably penetrate deeper into the sediments than beam trawls, but the area disturbed by the trawl doors comprises only a small proportion of the total area swept by the trawl. The main physical impact of beam trawling seems to be a flattening of the bottom topography, whereas the doors of otter trawls create irregular features on the seabed. Figure 27 shows the difference in sediment disturbance between a standard flat otter board (left) and that of a new design. Larger and heavier gear will obviously have much greater impact than small ones.

There is not much information in the literature concerning the effects of non-mobile shrimp fishing gear on the seabed. In examining the situation in the North Pacific, Roberts (2005) states that it is generally accepted that pots and traps have relatively little impact on the seafloor, but impacts are not completely benign, especially in cases where the gear is used in coral or hard bottom areas, as is the case in spot prawn traps. In Indonesia, there is widespread use of shrimp gillnets. The potential impact of these entangling nets in the country where 30 690 units of the gear are used (unpublished 2003 statistics, Ministry of Marine Affairs and Fisheries) is unknown.

FIGURE 27
Sediment disturbance by two otter board types

Source: Sterling, 2005.

DEVELOPED VS DEVELOPING COUNTRIES

In examining shrimp fishing closely in ten countries (Part 2), a striking feature is that issues and concerns related to the physical impacts of shrimp fishing gear lead to different reactions in developed and developing countries. In general, in developed countries there is a large and growing awareness and concern over the physical impacts, accompanied by a substantial amount of research aiming at assessing and reducing the impact. This is not usually the case in developing countries. Despite a general awareness that shrimp trawls and associated dragging gear may result in some damage to the bottom, research on the subject and mitigation issues typically receive low priority. Examples from Australia and Nigeria highlight the differences.

- In Australia, the subject of the impact of shrimp trawling on the physical environment is addressed in many reviews of specific Australian fisheries and in targeted research. Several reviews indicate that shrimp trawling is most definitely having an impact, but that the effects are mitigated to some extent by the fact that the actual trawling only covers a portion of the fishery area, and the intensity of trawling is decreasing as management measures reduce fishing activity.
- In Nigeria, there have been no specific studies on the effects of shrimp trawling on the ocean bottom, but there is a general perception that the groundropes, tickler chains and doors of shrimp trawl nets that are dragged over the sea bottom to catch shrimp disturb the soft bottom. The shrimp industry acknowledges that some problems exist and indicates a willingness to work with the government to address environmental concerns.

RESULTS OF RESEARCH ON PHYSICAL IMPACTS

The otter trawl is probably the most studied fishing gear type in history. Much of the research concerns the effects of the gear when it contacts the seabed, a subject that many acknowledge as being extremely difficult to study. Despite this difficulty, it is important to review some of the significant and/or representative studies in order to put into perspective the various conflicting statements with actual research findings. Furthermore, from a fisheries management perspective, NRC (2002) points out that it is both possible and necessary to use the available information, however rudimentary, to manage the effects of trawling on the seabed more effectively.

CSIRO and QDPI carried out five years of research on the environmental effects of trawling on the far northern Great Barrier Reef Marine Park (GBRMP) (CSIRO, 1998). The study covered 10 000 km^2 in an area closed to trawling since 1985, known as the Green Zone. The project surveyed the physical and biological makeup of the study area, conducted experiments to simulate the physical impact of trawling on seabed animals and plants, compared the biology of areas open to trawling with those closed to trawling, and investigated prawn trawl bycatch. Because this work represents the world's largest and most comprehensive study of the environmental effects of trawling and the first study on the effects of prawn trawling in the tropics, the results deserve special mention. With respect to the physical impacts of trawling, the research undertook a repeat-trawling experiment that indicated that a single trawl removes from 5 to 25 percent of the benthos, depending on the species. Repeated trawling has a cumulative effect; for example, around seven trawls over the same ground will remove about half the benthos. Although, over the last 20 years, 50 to 70 percent of trawled grids have been trawled only lightly each year, the cumulative effect is severe depletion of vulnerable types of fauna (i.e. those easily removed and/or slow to recover). This has probably caused substantial changes in the composition of the faunal community. The overall faunal biomass may have been reduced by about 20 percent and may now be dominated by "weedy" species (CSIRO, 1998).

Although concerns have been expressed over the methodology of the above CSIRO/QDPI research, in many respects it represents the state of knowledge gained from a study on the physical impacts of shrimp trawling in the tropics. It is interesting to note that the results of this particular study have been selectively used both to support claims of vast destruction by trawlers (e.g. comparisons with forest clear-cutting) and to refute these claims.

Barnette (2001) considered approximately 600 studies on the fishery-related habitat impacts of fishing gear and subsequently carried out a major review of the fishing gear utilized within the Gulf of Mexico and off the southeast coast of the United States, and their potential impacts on essential fish habitat. With respect to otter trawling, the report concluded that the fishing method has the potential to reduce or degrade structural components and habitat complexity by removing or damaging epifauna, smoothing bedforms that reduce bottom heterogeneity and removing structure-producing organisms. Trawling may change the distribution and size of sedimentary particles, increase water column turbidity, suppress growth of primary producers and alter nutrient cycling. The magnitude of trawling disturbance is highly variable. The ecological effect of trawling depends upon site-specific characteristics of the local ecosystem such as bottom type, water depth, community type and gear type, as well as the intensity and duration of trawling and natural disturbances. Several studies indicate that trawls have the potential seriously to impact sensitive habitat areas such as submerged aquatic vegetation, hard bottom and coral reefs. In regard to hard bottom and coral reefs, it should be recognized that trawlers do not typically operate in these areas because of potential damage to their gear. However, during the last decade, as a response to decreased biomass on conventional grounds, technological innovations have been adopted that allow trawls to be used over very rough bottoms. Although trawl nets have been documented to impact hard coral reefs, typically resulting in lost gear, these incidents are usually accidental. Low profile, patchy hard bottom as well as soft coral (including cold corals) and sponge habitat areas are more safely accessible to trawls and therefore more impacted.

It may be concluded that trawls have a minor overall physical impact when employed on shallow, bare, sandy and muddy substrates (the three-dimensional fauna of which might have been eliminated decades ago), but the impact of this physical perturbation on the infauna and productivity merits further clarification (see Chapter 9). In addition, even if the local impact is easy to imagine and has been documented, the overall impact on regional ecosystem productivity (considering the patchiness of fishing) remains to be assessed. In general, few studies document recovery rates of habitat after trawl perturbation and those available did so only after a single perturbation, not reflecting the reality of ongoing and cumulative fishing impacts.

The NRC was asked by the NMFS to study the effects of bottom trawling and dredging on seafloor habitats. The review was conducted by 12 eminent specialists over a period of 18 months. The resulting report (NRC, 2002) was reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the NRC's Report Review Committee. In summary, the report indicates that a complete assessment of the ecosystem effects of trawling requires three types of information: gear-specific effects on different habitat types (obtained experimentally); frequency and geographic distribution of bottom tows (trawl fishing effort data); and physical and biological characteristics of seafloor habitats in the fishing grounds (seafloor mapping). The report acknowledges the lack of much required data in the three areas. Within the limitation of the available data, the report concludes that:

- trawling and dredging reduce habitat complexity;
- repeated trawling and dredging result in discernible changes in benthic communities;
- bottom trawling reduces the productivity of benthic habitats;
- the effects of mobile fishing gear are cumulative and are a function of the frequency with which an area is fished;

- fauna living in low natural disturbance regimes are generally more vulnerable to fishing gear disturbance;
- fishing gears can be ranked according to their impacts on benthic organisms; and
- benthic fauna can be ranked according to their vulnerability.

An overall management-related conclusion is that available data are not sufficient to optimize the spatial and temporal distribution of trawling and dredging to protect habitats and sustain fishery yields.

In a report prepared at FAO's request, Løkkeborg (2005) examines the impact of trawling and dredging by reviewing published studies. Major emphasis was placed on critically examining the various methodologies used. The report promotes the concept that few general conclusions can be drawn regarding responses of benthic communities to the impacts of trawling disturbances.

This lack of knowledge is due to the complexity and natural variability of these communities, and to the fact that it is very difficult and demanding to conduct studies of them. With respect to the methodology used by previous studies, trawl impacts are investigated either by conducting experimental trawling and assessing the responses of the benthic community, or by using historical effort data and comparing fishing grounds that are subjected to low and high fishing intensities. The former approach provides exact data on the disturbance regime, but does not replicate real fisheries, whereas the latter method seldom provides suitable control sites.

Although there are many differences, the research cited above and several other studies seem to agree on a few topics. Most researchers in this field would agree that it is difficult to design and implement studies on the physical impact of trawling gear that could lead to clear conclusions. Other apparent sources of agreement include the following.

- The various researchers studying the physical effects of trawl gear tolerate very different levels of inconclusiveness in their results, conclusions, and proclamations.
- The impacts of trawling depend on many factors, principally bottom type, water depth, community type and gear type, the frequency and intensity of trawling, and concurrent natural disturbances. The habitats least affected are those with soft substrates and areas affected by natural impacting forces such as wave action. Hard bottoms with large sessile organisms seem to be most affected.
- It is especially difficult to come to conclusions concerning recovery rates of trawl-disturbed habitats.

The considerable research on the physical impacts of trawling has yielded mixed results with different degrees of reliability. Many areas of debate remain and more research is needed. In a different sense, the level of concern and advocacy associated with this issue can be conducive to consensus-building. The situation is not uncommon in environmental impact analysis and has led to the adoption of the precautionary and adaptive approaches as a means to proceed towards management while minimizing risk to the ecological system and the human communities depending on them.

In his review of the physical impacts of fishing gear, Hall (1999) stressed that "putting experimental results into the appropriate context will always be difficult". An important issue arising from available knowledge is the ways and means to incorporate it into the fisheries management process, given its uncertainty. Johnson (2002) cites five reviews: Kenchington, 1995; Lindeboom and de Groot, 1998; Watling and Norse, 1998; Gray, 2000; and NRC, 2002 to support the contention that since some negative impacts from mobile fishing gear are likely to occur, management decisions need to be made without waiting for more scientific evidence. The precautionary approach adopted by FAO precludes waiting for definitive conclusions before taking action when a clear risk has been identified. The ecosystem approach also adopted by FAO offers the framework needed to research while managing, using planned experiments in an adaptive and participative process of decision-making.

MITIGATION

There are many measures, both applied and proposed, to reduce the physical effects of trawling. The report by the National Research Council (NRC, 2002) presents the most common interventions. It states that the effects of trawling should be managed according to the specific requirements of the habitat and the fishery through a balanced combination of the following management tools.

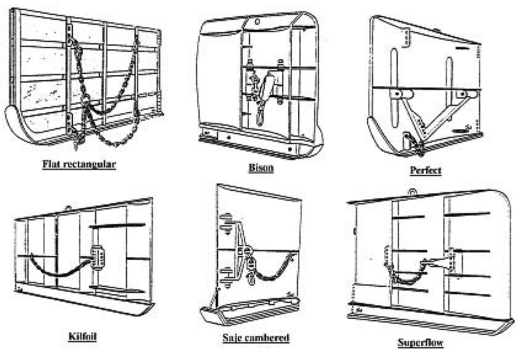
- *Fishing effort reductions*. Effort reduction is the cornerstone of managing the effects of fishing, including, but not limited to, effects on habitat. Both of the other management tools (gear restrictions or modifications and closed areas) can also require effort reduction to achieve maximum benefit. The success of fishing effort reduction measures will depend on the resilience and recovery potential of the habitat.
- *Modifications of gear design or gear type.* Gear restrictions or modifications that minimize bottom contact can reduce habitat disturbance. Shifts to different gear types or operational modes can be considered, but the social, economic, and ecological consequences of gear reallocation should be recognized and addressed. In shrimp fisheries with output controls, more efficient gear could lead to less fishing and less contact with the seabed.
- *Establishment of areas closed to fishing*. Closed areas are necessary to protect a range of vulnerable, representative habitats. Closures are particularly useful for protecting biogenic habitats (corals, bryozoans, hydroids, sponges, seagrass beds) that are disturbed by even minimal fishing effort. Because area closures could displace effort to open fishing grounds, effort reductions could be necessary in some cases to reduce habitat effects.

In addition to the common categories above, other mitigation measures are often mentioned in the literature. Total bans on trawling have been proposed, but implemented in only a few countries (discussed in Chapter 12). There is considerable mention of market-based methods, such as certification by the MSC. These are based on the premise that some consumers wish to buy marine products that do not contribute to destructive practices, which may result in higher prices for products that come from fisheries that, for example, do not have negative impacts on the sea bottom. Another mitigation mechanism is zonation, which allows for fixed gear-only areas in which trawling and other mobile gear are prohibited.

Kennelly and Broadhurst (2002) discuss the gear technology approach to mitigating physical impacts. They state that an alternative to management strategies such as closures involves the development of new technologies that reduce the impacts of fishing on ecosystems – similar to those to reduce bycatch problems. Recent trawl gear innovations to reduce physical impacts have emphasized otter board design to some extent. Sterling (2005) states that otter boards are responsible for much of the physical interaction with the sea bottom and, consequently, the gear technology approach to mitigation is largely focused on improving the performance of the boards. Figure 28 shows various otter board designs. Other shrimp trawl otter boards are designed to "fly" over the bottom. The use of canvas boards, popular some years ago, is being revived. Other gear-type physical impact mitigation measures include:

- the use of electric impulses to reduce the amount of tickler chains required;
- the use of drop chains, rather than weights integrated into groundrope, to reduce contact of the ground gear with the seabed;
- the use of wheels on the groundrope to reduce abrasion on the seabed;
- the use of semi-pelagic shrimp trawls in the Gulf of Maine and Newfoundland in which much of the gear is kept off the bottom (boards, lower bridles); and
- the proposed use of artificial reefs that would interfere with trawling to protect sensitive seagrass areas in Cambodia.

FIGURE 28
Some otter board designs



Source: Sterling, 2005.

Some observations can be made on the various measures to mitigate the physical impacts of trawling. There appears to be considerable faith in the possibility of developing an alternative to shrimp trawling and trawling in general, especially among environmental groups. The reality is that, despite this interest, no substantial progress has been made in replacing trawl gear and, after nearly a century, it remains the main producer of the important commercial shrimp species. On the other hand, some feel that a total shrimp trawl ban could provide a powerful incentive to develop such gear (J. Clay, WWF, personal communication, 2006).

There is considerable advocacy on the part of environmental groups to ban trawling in especially vulnerable areas. Hall (1999) takes the issue further, stating that "…. it is incumbent upon us to identify, not only sensitive areas, but also areas for which concerns are fewer".

Some of the more important mitigation mechanisms (e.g. effort reductions, protected areas) are also associated with management of other main areas of concern regarding shrimp trawling, such as bycatch/discards and impacts on biodiversity. This appears to provide additional justification for their implementation.

IMPACT ON BIODIVERSITY

Biological diversity is often defined as the variety of life in all its forms, levels and combinations, and includes ecosystem diversity, species diversity and genetic diversity. The important relationship between biodiversity and fisheries is emphasized by the attention given to it in the FAO Code of Conduct for Responsible Fisheries. With respect to biodiversity, the Code states *inter alia* that biodiversity of aquatic habitats and ecosystems be conserved and endangered species protected; and selective and environmentally safe fishing gear and practices be further developed and applied, to the extent practicable, in order to maintain biodiversity and to conserve population structure and aquatic ecosystems as well as to protect fish quality.

Biodiversity is an important issue in shrimp fishing; it is often claimed that shrimp trawling significantly reduces it. The fact is that shrimp are short-lived. Many species of the same assemblage have longer life cycles and are therefore more vulnerable to a fishing effort than would be sustainable for shrimp. This raises the issue of sustainably managing a mix of species with different ecological resiliencies (Sainsbury, Punt and Smith, 2000).

While it is obvious that indiscriminate trawling can easily threaten biological diversity (vulnerable species, endangered species, corals, sponges), the conclusions of some targeted research are often less than clear. From 1996 to 1999, research was carried out in the north of Australia on the ecological sustainability of bycatch and biodiversity in shrimp trawl fisheries. The Northern Prawn Fishery Management Advisory Committee (NORMAC, 2002) summarizes the results of a study in Australia involving shrimp trawling in the tropics, which is especially illustrative in this regard.

The vertebrate bycatch community was compared between areas open to trawling and areas that have been protected for 15 years, in the western Gulf of Carpentaria. If trawling had a large impact on biodiversity, we would expect to see fewer species, lower catch rates and smaller individuals in the open areas. This was not the case; there was no consistent difference in the number of species between open and closed areas *or in catch rates between open and closed areas. In general, the mean size of species was greater in the open areas. Although the results were equivocal with respect to the impact of trawling on biodiversity, this does not imply that trawling has no impact. Any differences between open and closed areas may be reduced by the low commercial effort in the open area, aggregated trawling, potential trawling in the closure, and the mobility of species. This, combined with high natural variation, may obscure any impacts of trawling.*

In this particular study, which was carried out in a country that has high scientific capacity, the simple change in the number of species proved problematic to study and highlights the difficulty in gauging the impacts of shrimp trawling on species diversity beyond the obvious impact on elevated structures. The comprehensive review by Løkkeborg (2005) also stressed the inconclusiveness of many similar analyses. The assessment of the impact on other components of biodiversity such as ecosystem and genetic diversity seem even more elusive. While the overall quality of the analyses might not always be adequate, some comprehensive and convincing analysis is available. The northwest shelf of Western Australia, for instance, provides a well-documented example of the impact of the demersal trawl fishery on the ecosystem. Sainsbury *et al*. (1997) show a 15-year decrease in *Lethrinus* and *Lutjanus* fish species and a change in the fish species composition and economic value of the community as a result of a complete erosion of their habitat by intense trawling. As a consequence, even though the original state of most fishing grounds is often unknown, the global scale of trawling and the available evidence of physical impact on hard bottoms and tridimensional faunas, and the impact of fishing on the food chain are such that Løkkeborg's review conclusions are not universally accepted (Sheppard, 2006; Gray *et al*., 2006).

Considering this situation, Enticknap (2002) makes an appropriate observation that is applicable to many trawl fisheries: the debate over the effects of bottom trawling is shifting away from whether or not it reduces marine biological diversity and habitat complexity and now focuses on where and to what degree the reduction in diversity is socially acceptable.

Reconciling the various points of view is essential in order to progress with enough scientific and social legitimacy. But it is most important to underline the fact that, even in the absence of global consensus, guidance is indeed available on how to proceed on a case-by-case basis, using the precautionary and ecosystem approaches to fisheries and, more specifically, the environmental impact assessment and the risk assessment methods that they provide.

11. Interactions between large- and small-scale fisheries

IMPORTANCE OF THE INTERACTION

Large- and small-scale fisheries interact in many ways, resulting in synergies as well as conflicts. Synergies may appear, for instance in the development of land-base infrastructure and the market, which facilitates small-scale fisheries development and profits in the wake of industrial development. Sources of conflict are numerous and generally relate to competition for resources and space. Synergies are usually ignored. Conflicts tend to be more visible (sometimes violent) and therefore better known. A recent report of the World Resources Institute (Kura *et al.*, 2004) reviews the major fisheries dilemmas of the world and asserts that in marine environments, the most documented conflict between large- and small-scale fishers occurs when industrial trawlers encroach upon near-shore fishing grounds where small-scale fishers operate. For shrimp fishing, the situation is especially difficult. Garcia (1989) states that shrimp fisheries are the major source of fisheries conflict and problems in the tropical zone.

Numerous cases of conflicts generated by shrimp trawling can be cited. Indeed, many of the international campaigns against the negative aspects of trawling focus on the interactions of this gear with small-scale fisheries. Box 22 is from the pamphlet "Squandering the seas: how shrimp trawling is threatening ecological integrity and food security around the world".

BOX 22

Some trawl conflicts with small-scale fisheries

In the Bay of Bengal, as a result of sustained (but not sustainable) shrimp trawling, the numbers of higher-value species such as red snappers, groupers and large croakers have fallen, leaving artisanal and subsistence fishers struggling to sell lower-value fish. Some can no longer make a living from fishing. Given that the fisheries sector contributes about 78 percent of animal protein intake in Bangladesh, coastal communities may well suffer from lowered dietary protein in the long term. In the Philippines, the encroachment of trawlers into prohibited zones has resulted in uneven catch and income for small-scale and subsistence fisheries. Equally striking stories come from the Bolivarian Republic of Venezuela, where growing shrimp trawling fleets often illegally fish in shallow coastal areas that had been reserved for artisanal fisheries. Again, these waters often serve as nursery sites for commercial species. Similarly, fishing for shrimp in equivalent zones in Cameroon has resulted in high bycatch of juvenile fish, causing conflict between trawlers and artisanal fishers. Shrimp trawlers not only remove fish biomass, but also damage local people's fishing gear, especially when it is fixed to the seabed (such as fish traps). This causes intense antagonism since fishers lose equipment needed to sustain their livelihoods.

Source: EJF, 2003b.

TYPES OF INTERACTIONS

Large-scale shrimp fishing, predominantly trawling, interacts with small-scale fisheries in several ways which, together with the associated impacts, includes the following.

- *Physical interactions.* Small-scale fishing gear may be destroyed by larger trawlers. For example, in Cambodia, much of the trawling is done illegally in areas where there is considerable small-scale fishing activity. Thus, trawlers often destroy the small-scale fishing gear and do not pay compensation to the fishers (Sour, 2005).
- *Sea safety.* Collisions between industrial shrimp vessels and small craft are a major cause of fatal accidents in small-scale fisheries. This is especially prevalent in West and East Africa (Båge, 2003a; Nageon de Lestang, 2007).
- *Targeting the same resources.* Various scales of fishing often compete in many regions. In most tropical countries, sequential fishing takes place at various stages in the shrimp life cycle (e.g. postlarvae, subadults, adults, mature females) in different environments, using different fishing gear and scales of fishing. As a result, there is a strong interaction between shrimp fisheries operating in the open sea, the bays and the estuaries (INP, 2000). In San Miguel Bay, the Philippines, for example, there are intense economic interactions between scales of fishers targeting the same resources: trawlers consisting of 89 units and belonging to only 40 households obtain 85 percent of pure profit, 42 percent of catch value and 31 percent of the total catch in the San Miguel Bay Fishery. The rest goes to 2 300 small-scale fishing units owned by 3 500 households and employing about 5 100 fishers (Silvestre and Pauly, 1997).
- *Interaction through bycatch*. The large bycatch characteristic of shrimp trawl fisheries is often a target of small-scale finfish fisheries (see Part 2, Nigeria).
- *Habitat disturbance*. Trawls, particularly when operating illegally close to the shore, can cause significant disturbance to the seabed. In Southeast Asia, trawling is held responsible for much of the degradation of seagrass areas, which are crucial for juveniles of species important to coastal fishers (Department of Fisheries, 2005).
- *Market interactions.* These can occur when industrial-scale shrimp fishing operations offload large quantities of shrimp and finfish on local markets and depress prices. In some countries (e.g. Papua New Guinea), this is the justification for not requiring the landing of bycatch from shrimp trawling ashore.

To be fair, it should be noted that not all negative interactions involving shrimp fisheries concern powerful industrial operators impacting weak small-scale fishers. Some of the small-scale shrimp fisheries (e.g. push netting in Southeast Asia) are likely to have major negative effects on other small-scale fisheries, either through habitat destruction or catches of juvenile fish. In some countries, there is a contention that small-scale shrimpers who catch juvenile shrimp in inshore areas negatively impact medium- and large-scale operations and markedly reduce the overall value of the fishery. Nageon de Lestang (2007) reports that in Madagascar, a major cause of accidents at sea is collisions between shrimp trawlers and small artisanal vessels with no lights, even though regulations require them.

In some cases, a symbiosis between scales of fishing occurs. Much of the bait shrimp for small-scale recreational fishing in some countries comes from large-scale operations. In the Gulf of Mexico, about 2 200 tonnes of shrimp for bait are caught each year. Large-scale shrimp trawlers often sell their bycatch to small-scale fishers at sea for resale ashore.

There are several other aspects of the impacts of large-scale shrimp fishing. In developed countries, the issue often concerns the impact on recreational fisheries, rather than on small-scale commercial or subsistence fisheries. The scales of fishing that interact are relative: the vessels used in the small-scale shrimp fisheries of coastal Norway are much larger than, for example, the shrimp trawlers of Southeast

FIGURE 29
Small-scale trawlers in the Gulf of Thailand

Asia (Figure 29) that are causing many of the problems with small-scale fisheries. Another notable aspect is that, despite the worldwide significance of these shrimp fishery interactions, careful analysis of conflict situations is not a prominent feature of shrimp fishery literature. One of the few exceptions is the trawl ban in Indonesia (Box 23). The ban was imposed primarily to reduce the impacts of trawling on small-scale fishing and has been extensively analysed.

MITIGATION OF NEGATIVE INTERACTIONS

The management of fisheries in general can have a number of different objectives. The role that conflict reduction plays as a management objective in shrimp fisheries is relatively large, much of which concerns the negative interactions between large- and small-scale fishing operations. This is not surprising considering the inherently political nature of the fisheries management process and the amount and type of conflict generated by shrimp fishing. As expressed by one Asian shrimp industry participant, "suboptimal shrimp resource use often gets a yawn, but violence between fishers gets the politicians moving". Bailey (1997) reports that in Malaysia, small-scale fishers responding to being pushed out of their traditional fishing grounds in the 1970s sunk over 60 boats and killed 23 fishers. He also reports that in Indonesia's Malacca Straits, the favourite weapon of small-scale fishers was the Molotov cocktail, which proved quite effective against wooden-hulled trawlers. "In the final analysis, it was the willingness of small-scale fishers to resort to violence that prompted decisive action on the part of the Indonesian Government."

A number of management interventions are used to mitigate conflict generated by shrimp fisheries. To reduce the physical impacts of large-scale shrimp fishing on small-scale operations, the most common measure is simply to move the large boats offshore. The measure tends to be ineffective and not complied with when offshore resources are already depleted by chronic overcapacity. Nonetheless, in West Africa, nearly all countries have passed laws giving artisanal fishers exclusive fishing rights to coastal waters within a fixed distance from the shore (1–12 nautical miles, depending on the country), and have prohibited industrial trawlers from operating in these waters (Kura *et al*., 2004). Båge (2003a; 2003b) proposes the installation of artificial reefs that physically hinder trawling in prohibited areas.

Other measures are used to mitigate impacts on small-scale fisheries. Seasonal "time-sharing" of fishing grounds off Florida has been used as a partial solution to the conflict between shrimp trawlers and trappers fishing for stone crab and blue crab: trawl nets bring up traps and entangle trap buoy lines (Cascorbi, 2004b). When conflicts involve competition for resources, they can be reduced by stricter requirements for BRDs and mesh sizes. Schemes that reduce the fishing effort of the larger fishing operations can be an effective mitigation measure.

There is a general feeling among fisheries managers in several regions of the world that the various approaches mentioned above for reducing negative interactions would be effective if enforced. The irony is that, in the developing countries where the conflicts generated by shrimp fishing are the greatest, the required enforcement is the weakest. One of the more extreme examples of weak enforcement comes from Cambodia.

To reduce conflict between trawlers and small-scale fishers in Cambodia, the fishery law bans trawling in the area between the shore and the 20-m isobath. A major difficulty

BOX 23
Origin and outcome of the Indonesian trawl ban

Butcher (2004) indicates that the conflict and even violence generated by shrimp trawlers were greatest along the north coast of Java, because shrimp was concentrated relatively near to shore, and because so many fishers depended on these waters for their livelihood. During the 1960s and 1970s, the government introduced a multitude of regulations to restrict the number of trawlers and to prevent them from operating within various distances from shore, but these proved ineffective for various reasons. In 1977, fishers in seven sailboats attacked a trawler operating off the east coast of Sumatra and killed its captain; there were similar clashes on the south coast of Java.

In July 1980, following many unsuccessful attempts to restrict trawling, President Suharto issued a decree banning trawling from the waters surrounding Java and Bali as of October of that year, and from the waters surrounding Sumatra as of January 1981. As the Director-General of Fisheries explained, the banning was a "political decision", made with the "aim of reaching social peace and stability by providing better protection to poor traditional fishermen masses". The All-Indonesia Fishermen's Association, a functional group within the Golkar, the government's main electoral vehicle, had put considerable pressure on the government to ban trawling. At the same time, many in the government believed that various programmes to help improve the welfare of fishing communities would be in vain unless the resources on which they depended were protected from trawlers. Unlike earlier attempts to restrict trawling, issued as ministerial decrees, the ban carried the full weight of the President and the military. Moreover, it was much easier to enforce a total ban on trawling than to restrict it. Anyone operating a trawl could no longer claim to have been fishing outside areas where trawling was restricted.

Chong *et al.* (1987) and Bailey (1997) summarize the outcome of the trawl ban. The immediate impact of the ban was seen in the reduction of violence, loss of human lives, property destruction and tension in the coastal areas and at sea. This in itself was very positive for a country such as Indonesia, which places a high value on peace and coexistence. However, close to 25 000 trawl fishers (owner, captain and crew) were immediately thrown out of work because of the ban. The aggregate income foregone at the minimum was Rp462.5 million, or US$1.11 million per month (US$13.4 million per year). The government realized the economic hardships confronting the displaced fishers and took the necessary actions to soften the impact of the ban in the form of a large credit programme for trawl crew fishers to purchase new boats and nets; much of the credit was used in already overexploited inshore areas. There was also an immediate interruption in shrimp and fish landings in Indonesia: a 5 percent drop in shrimp landings and a 22-percent drop in shrimp exports.

Bailey (1997) also noted the impact on small-scale fishing. Following the ban, there was a rapid increase in the number of small-scale enterprises. Despite this growth, demersal stocks increased dramatically from 1980 onwards and landings in the Malacca Straits increased by 124 percent over the 1980–93 period. With the elimination of trawlers as a source of supply, shrimp exporters increased their efforts to collect shrimp from scattered rural fishing communities. Prior to 1980, many shrimp exporters had little incentive to seek sources of supply among small coastal villages; it was far easier to take delivery of large volumes of shrimp brought to the exporter's dock by a trawler. After 1980, however, shrimp packers/exporters quickly established marketing channels into rural areas. These efforts by the private sector were complemented by government credit programmes to motorize small-scale fishing boats and to purchase gear specifically designed to exploit demersal resources.

arises because most of the trawlers are relatively small and are unsuitable for use in offshore areas. This results in a situation where most of the trawling is done illegally in areas where there is considerable small-scale fishing activity. This is the major source of conflict between groups of marine fishers in Cambodia. Despite the fact that inshore trawling is clearly illegal, the Department of Fisheries is reluctant to enforce the ban due to various reasons, including the perceived financial difficulties it would cause the operators of trawlers (Gillett, 2004).

In recognition of the difficulties of enforcing spatial separation, a number of countries have opted for the bolder measure of complete trawl bans in order to reduce trawl-generated conflict. The Indonesian example in Box 23 is perhaps the most notable example, but other countries have such bans covering smaller areas.

Another avenue to improve enforcement is given by the Environmental Justice Foundation (EJF, 2003). In Margarita Island, the Bolivarian Republic of Venezuela, local fishers have claimed that their catches have increased significantly since the implementation of a new fishing law, which has raised fines for shrimp trawlers caught illegally within six nautical miles of the coastline. Juvenile fish are now being given the opportunity to reach commercial size and replenish local stocks.

A more fundamental mitigation measure (and one that does not rely on non-existent enforcement) is to strengthen the political power of fishers negatively affected by large-scale shrimp fishing. This was indeed the driving force behind the Indonesia trawl ban (Chong *et al.*,1987; Bailey, 1997). In March 2005, Madagascar cooperative management zones were created with the objective of reducing conflict generated by large trawlers in inshore areas. Although the management zone scheme was an initiative of the trawlers, the catalyst for action was the concern that any open conflict between the different shrimp fishery subsectors would probably be resolved in favour of the traditional fisheries, as a result of the prevailing political and social environment.

12. Management of shrimp fisheries

GENERAL

Most shrimp fisheries throughout the world face similar problems. The stocks are fully exploited, with little opportunity of increasing total catches. Fishing effort continues to increase, giving rise to serious economic or social problems even when the stocks themselves may be in no danger.

This remark was made in 1981 by the keynote speakers at a major international meeting on the management of shrimp fisheries (Gulland and Rothschild, 1984), but the comment is still applicable today. In the last 25 years, much has been learned about the biology of shrimp and its reaction to regulatory interventions, but many problems relating to the management of shrimp resources remain.

In the various shrimp fisheries of the world today, there are considerable differences in the quality of their management. For some shrimp fisheries, management is state of the art and used to demonstrate the benefits of effective conventional fisheries management. Conversely, some important national shrimp fisheries are textbook examples of how unmanaged fisheries can dissipate benefits. Box 24 compares two vastly different management regimes.

The Spencer Gulf-Cambodia comparison is somewhat imbalanced in that it contrasts what is probably the best example of shrimp fishery management in a country that has characteristically strong institutional governance in the fisheries sector with what goes on in an extremely poor nation. Nevertheless, it emphasizes the huge range in outcomes when a shrimp fishery is effectively managed.

MAIN SHRIMP FISHERY MANAGEMENT ISSUES IN THE TEN STUDY COUNTRIES

In this study, a number of countries were chosen to be representative of various geographic regions, as well as the variety of important shrimp fishing conditions: large/small fisheries, tropical/temperate zones, developed/developing countries and good/poor management. The major shrimp fishery management issues of the ten countries examined in Part 2 are summarized in Table 15.

In brief, the issues encountered in the study countries reflect the whole array of issues characterizing fisheries management today: open access; overfishing; effort creep and fishing capacity control; low economic returns; insufficient research and management aggravated by low compliance; unsustainable management costs; bycatch reduction and other multispecies concerns; and conflicts between small- and large-scale fisheries for shrimp. A few more issues existing elsewhere have not clearly emerged from this sample, but could be mentioned: conflict between national and foreign fleets; conflicts with aquaculture; and the impact of pollution and other coastal developments on shrimp production, particularly in heavily urbanized estuaries and deltas.

THE SHRIMP FISHERIES MANAGEMENT FRAMEWORK

Definition

An essential prerequisite for an analysis of shrimp fisheries management is a concise understanding of "fisheries management". Many definitions of this term can be found in the literature. In the *FAO Technical Guidelines for Responsible Fisheries* (FAO, 1997), fisheries management is defined as: *the integrated process of information*

BOX 24

Effective and weak management of shrimp fisheries

Australia. In October 1967, commercial shrimp fishing began in South Australia's Spencer Gulf and, in March 1968, a programme of restricted entry was introduced to prevent overexploitation of the resource and overcapitalization within the fishery. Today, the fishery has a limited entry consisting of 41 licence holders. The fishery is managed jointly by the government and industry through the Prawn Fisheries Management Committee headed by an independent chair. The fishers themselves take an active role in research by participating in stock assessments using their vessels and crew. Industry pays 100 percent of the attributable management and research costs through annual licence fees. Management measures include limited entry, gear restrictions, and temporary and permanent closures. These controls result in Spencer Gulf fishers enjoying a unique and enviable lifestyle – fishing only 55 to 60 nights per year. The fishery provides jobs for some 150 people on board vessels and a significant number of jobs in processing and support industries (Palmer and Miller, 2005).

Cambodia. The number of shrimp trawlers operating in Cambodia increased rapidly from the early 1990s, and today the 1 500 trawlers operating represent about 3.4 vessels per linear kilometre of coastline. For coastal fisheries in general, there are no formal management plans and the objectives of fisheries management must be inferred by the various legal instruments and past government interventions. Although the basic fisheries law prohibits trawling between the shore and the 20-m isobath, most small trawlers operate illegally in shallow inshore areas and cause substantial conflict with smaller-scale fishers. There is at present no legal mechanism in the fisheries law for limiting fish catches or fishing effort. Despite the lack of economic data on shrimp fishing, there are indications that both the profitability of individual shrimp fishing operations and the rent from the various shrimp fisheries are low, including: the open access nature of Cambodian coastal fisheries; poor enforcement of the few legal instruments for management; the rising coastal population; low barriers to participation; lack of non-fishing sources of livelihoods; the rising proportion of trash fish; and falling CPUE.

Source: Gillett, 2004.

gathering, analysis, planning, consultation, decision-making, allocation of resources and formulation and implementation, with enforcement as necessary, of regulations or rules which govern fisheries activities in order to ensure the continued productivity of the resources and accomplishment of other fisheries objectives.

A definition of fisheries management developed specifically from practices in the shrimp fisheries was proposed by Gulland (1984) in his essay on shrimp fisheries management: "Fisheries management can be defined in a broad sense as the manipulation of factors to achieve societal goals from a stock of fish". The important elements of the Gulland definition are goals (or objectives) and associated manipulations (or interventions) in support of these goals. In many cases, the prevention or mitigation of the various problems associated with a particular fishery forms the management objectives for that fishery.

Shrimp fisheries management developed from the 1960s to the 1980s and, in general, needs to be adapted by taking into account the agreed framework offered by the 1995 FAO Code of Conduct for Responsible Fisheries and the FAO Ecosystem Approach to Fisheries (FAO, 2003b).

TABLE 15
Main shrimp fishery management issues in the ten study countries

Country	Main issues
Australia	The management of shrimp fisheries is strongly affected by two general trends in Australian fisheries: a move to a "user pays" system where participants in each fishery are increasingly responsible for funding management, research and compliance costs that support the fishery; and the broadening of management away from a "single-species" approach to include more general ecosystem management issues. In many of the important shrimp fisheries, despite almost continuous management interventions and effort adjustments, overcapacity remains a problem – "effort creep" defeats capacity limits based on numbers of boats.
Cambodia	Considering the paucity of biological information on shrimp resources, the few legal instruments available for management of shrimp fishing, their poor enforcement, and the open access nature of all coastal fisheries in the country, the obstacles to deriving greater benefits from the shrimp fisheries by management interventions are indeed considerable.
Indonesia	The prevention of negative impacts of trawling on small-scale fishers is a dominant objective in the management of shrimp fisheries. The trawl ban to safeguard the interests of small-scale fisheries has been referred to as the boldest fisheries management intervention ever to be implemented in Southeast Asia, but it has been undermined by the renaming of trawl gear and poor enforcement. Protection of shrimp fisheries from overexploitation is a less prominent objective. With regard to the large amount of small-scale shrimp fishing, the open access nature of coastal fisheries in Indonesia makes it very difficult to restrict fishing effort.
Kuwait	The present low catches, high level of effort and low CPUE seem to indicate that shrimp stocks have been overexploited since 1993. Although shrimp fishing overcapacity has been generally recognized for some time and there has been an attempt to halt its increase, the number of industrial fishing vessels was allowed to increase in the mid-1990s.
Madagascar	The main issues are: (i) the protection of the interests of the traditional shrimp fishers from negative interaction of industrial/artisanal shrimp fishing, with appropriate consideration given to the benefits to the national economy from larger-scale operations; (ii) the control of effort increases in the traditional shrimp fishery; and (iii) the importance of reconciling the need to reduce bycatch with the economic benefits of selling bycatch.
Mexico	The main issues are: (i) the declining CPUE and overcapacity in many of the shrimp fleets; (ii) improvement of shrimp fishing profitability, which may require structural adjustment, but whose effort restrictions face strong resistance from fishers; and (iii) management of the interactions between the three different types of shrimp fisheries in Mexico (high seas, bays, estuaries), which often equates to allocation of shrimp resources among very different groups of fishers.
Nigeria	A major issue is the interaction between large- and small-scale shrimp fishing, including the encroachment of industrial shrimp trawlers into areas reserved for small-scale fishing, and the competition for the same fishery resources. Another important issue is the current low profitability of commercial shrimp fishing caused by piracy, falling catch rates and increasing fuel costs.
Norway	Important issues are: (i) the "discard ban" for all commercially important species, which results in the need to avoid cod and other important species; (ii) the need to avoid capture of undersized shrimp; and (iii) the current low profitability of most shrimp fishing operations.
Trinidad and Tobago	There is a high incidental fish catch associated with shrimp trawling, causing considerable conflict between the trawl fishery and other fisheries in the country. Other areas of concern are the full or overexploited condition of shrimp stocks as well as that of bycatch, the high levels of bycatch/discards and the degree of overcapitalization in the trawl fishery. There is a great need to reduce shrimp fishing effort, but a lack of political will and legal tools to do so.
United States of America	There has been increased attention paid to overcapacity in the various United States shrimp fisheries. Many problems facing shrimp fishery managers result from the use of an open access management regime that ignores economic efficiency criteria and implicitly stresses economic impacts in the form of state revenues from licence sales, taxes and low-paying jobs. Other important issues are a decrease in recent profitability in the industry as a result of overcapacity and growing environment concerns.

Source: based on Part 2.

Ranking objectives

Successful fisheries management is characteristically based on a clear definition of objectives and their ranking. Priorizing management objectives is a central responsibility of fisheries governance. Staples, Satia and Gardiner (2004) stress that: *policy is the starting-point that sets out the broad objectives and framework to guide relevant decisions, actions and institutional arrangements impacting on small-scale fisheries. It should be recognized that policy is required to address many, often competing, objectives that relate to the conservation and sustainable use of resources, and to economic and social (equity) needs. The main issue is that policy is often poorly articulated both within and outside of the fisheries sector.*

In the various shrimp fisheries around the world, a wide variety of management objectives have been explicitly adopted to various extents. Garcia (1989) states that the long-term conservation of the resource is usually given top priority, at least rhetorically. Maximum economic yield is an important objective in the management of many shrimp fisheries. Maximum sustainable yield is also common, with Indonesia being an important example. Reduction of bycatch/discards and physical impacts are becoming increasingly important objectives, especially in developed countries. Chapter 11 stresses the significant role that social peace (through conflict reduction) plays as a management objective in shrimp fisheries, especially in developing countries. Achieving an equitable and sustainable allocation of shrimp resources between the various users is important in the penaeid fisheries because of the movement of shrimp between shallow inshore areas and deep offshore areas. Maximizing employment is sometimes the de facto most significant management objective in some of the poorer countries. Generation of government revenue is often an unstated objective in the management of shrimp fisheries in countries ranging in development from Cambodia to the United States.

Garcia (1989) and Gulland (1984) recognize both the importance of and the difficulty in prioritizing and balancing shrimp fishery management objectives.

- *It is generally recognized that the ranking of shrimp fisheries management objectives are rarely clearly defined in reality and at best expressed as a list of broad and often conflicting goals. Ideally, management in this context must offer mechanisms allowing acceptable compromises on basic objectives* (Garcia, 1989).
- *There is unlikely to be a magic formula to enable balancing objectives. Managers must accept that they are pursuing multiple objectives. Policies must be chosen to achieve some acceptable and balanced degree of progress towards the objectives as a whole. The first step is to identify objectives so that they can at least be borne in mind when making decisions. In the ideal world, it might be possible to express all objectives on some common scale, or at least provide some quantitative weighting between different objectives. This is too much to ask – in practice, the choice must be made by a policy-maker, in light of national objectives and political/social pressure* (Gulland, 1984).

The above comments dating back over two decades on the underlying difficulties of prioritizing shrimp fishery objectives still remain valid today. It is difficult to rank the incongruous and conflicting objectives that are often set for shrimp fisheries. On a practical level, two common situations of objective ranking are especially problematic. One is the maximizing of economic yield in an open access regime. An important objective of open access shrimp fisheries, probably more common in the world than restricted access, is often maximizing employment. This is incompatible with the economic efficiency needed to generate maximum economic yield. The other difficult prioritization issue is the increasingly frequent situation of reconciling maximizing fleet profitability with minimizing bycatch and physical impacts on the seabed.

Issue-based framework

Many different management frameworks can be considered:

- time – e.g. operational versus strategic;
- space – e.g. local, national, regional, integrated;
- resources – e.g. stocks, populations, ecosystems;
- sectoral considerations – e.g. large-scale, small-scale and cross-sectoral); and
- conventional dimensions of sustainable development – ecological, social (including cultural), economic and governance (including institutional).

In this report, it was found convenient to use an issue-oriented conventional framework for analysing the problems of shrimp fisheries, as provided by Poffenberger (1984). He establishes two broad categories of issues to be addressed by shrimp fisheries management: overfishing and issues not relating to overfishing. The latter category includes such considerations as bycatch/discards and physical effects on the seabed. The three types of overfishing problems addressed by Poffenberger are the following.

- *Growth overfishing*. Shrimp is harvested when individuals are small and growth is not yet completed, leading to a loss in total yield-per-recruit or yield. This type of overfishing is common in many of the world's shrimp fisheries.
- *Recruitment overfishing*. Spawning biomass and recruitment to the exploitable stock become significantly reduced because of the level of fishing. This type of overfishing, detected through a stock-recruitment analysis, is particularly difficult to identify in shrimp fisheries where the relation is blurred by significant environmental effects. In general, it seems that shrimp stocks are more driven by environmental oscillations than stock size, although reducing the stock to very low levels could cause recruitment to collapse without notice, particularly in the presence of adverse environmental conditions.
- *Economic overfishing*. The amount of fishing effort increases to the point where the fisheries operate beyond maximum economic yield. Under open access, fisheries can develop to the point that the rent is lost, profitability becomes negative and subsidies are needed to maintain the fisheries. This is a situation that threatens many or most of the world's shrimp fisheries.

Poffenberger (1984) concludes that penaeid shrimp fisheries tend to have more serious problems dealing with economic overfishing than other types of overfishing. The author did not, however, consider *ecosystem overfishing*, a situation widespread in shrimp fisheries, which occurs when the species composition and dominance are significantly modified by fishing, with reductions of large, long-lived, demersal predators and increases of small, short-lived species at lower trophic levels.

The above scheme for classifying shrimp fishery problems can be used to consider the common problems identified in earlier chapters of this report. Overcapacity-related problems include declining shrimp catches and some aspects of deteriorating profitability. Other problems, not related or indirectly related to overcapacity, include excessive bycatch/discards, physical impacts of shrimp fishing, other aspects of declining profitability, impacts on small-scale fisheries and other conflicts. The mitigation or prevention of these difficulties forms the objectives for the management of many shrimp fisheries. It should be noted that many of the "other problems" mentioned above would find at least a substantial solution in the reduction of excessive capacity.

Conventional shrimp fisheries management must be reconsidered in light of the FAO Code of Conduct for Responsible Fisheries and the related approaches, including the progress being made in the management of small-scale fisheries. Many of the issues mentioned above, particularly those of prioritizing objectives, call for more transparent and participative forms of management than those used conventionally for shrimp fisheries in the past. The overriding issue of introducing market incentives in the form of user rights needs to be seriously considered since limited entry and effort controls have demonstrated their limits. The complexity of shrimp fisheries as socio-ecological systems needs to be better taken into account, with a stronger application of social sciences and the adoption of adaptive management processes.

MANAGEMENT INTERVENTIONS

The management issues encountered in the preceding sections relate to three interrelated central issues: capacity control, allocation and conservation. Allocation appears as the overriding issue since it conditions the control of capacity, the incentives for conservation and the level of compliance. All other issues (overfishing, poor selectivity, low economic returns, aggravated environmental issues), with few exceptions, tend to be subsidiary causes or consequences. A central problem of managing by solving recurrent crises, as opposed to planning to avoid them in the first instance, is the general tendency to lump consequences and symptoms together instead of dealing with root causes, resulting in ineffective governance.

Nonetheless, taking an issue-oriented approach – perhaps more familiar to managers, the variety of measures and interventions available for dealing with the most frequently mentioned goals are the following.

- *Economic overfishing*. Improvement of the economic performance of shrimp fisheries has been attempted by using catch limits, controlled access (limiting/reducing participation), restrictions on gear, stock enhancement, monetary measures (taxation of inputs, high licence fees, fractional licensing),[15] reduction/withdrawal of subsidies and buyout programmes. The infrequent use of market incentives (fishing rights) in shrimp fisheries is noteworthy.
- *Growth overfishing.* Improvement in yield and productivity has been attempted by reducing fishing effort and through technical measures such as closed seasons, closed areas, mesh size regulations and minimum landing sizes.
- *Discards/bycatch.* A reduction in the impact on biodiversity and of waste has been addressed by adopting BRDs and TEDs, larger mesh sizes, other net modifications (e.g. square-mesh, codend, fisheye), prohibition of certain gear, no-discards policies, temporary or permanent closed areas, limits on bycatch of particular species, unilateral trade measures, raising fishers' awareness and increased collaboration.
- *Physical impacts and other ecosystem damage*. This has been tentatively controlled by restrictions on the use of certain gear, gear design regulations (benthic-friendly trawl), closed areas (protected areas) and fishing effort reductions. Total bans on trawling have been proposed and adopted (as in the General Fisheries Commission for the Mediterranean), where the banning of all trawling beyond 1 000 m reduces impacts on deep-sea shrimp populations and habitats.
- *Conflicts between large-and small-scale fisheries*. These have been tentatively reduced by zonation schemes, BRDs, reduction of large-scale fishing effort, time-sharing of fishing grounds and, in some cases, total bans on trawling.
- *Resource allocation between groups of fishers*. This has been dealt with by closed areas, closed seasons, gear restrictions and mesh sizes. As noted above, the scarce use of market incentives (fishing rights) for resource allocation in shrimp fisheries is noteworthy.
- *Inshore nursery ground habitat degradation*. This has been attempted through closed areas, artificial reefs, integrated coastal zone development and control of mangrove exploitation and land reclamation, restriction of pollution and watershed management.

These management measures can be broadly grouped into input and output controls. Input controls act on the quantity and quality of the fishing inputs, e.g. restrictions of effort and capacity, gear restrictions and specifications and closed seasons. Output controls act on the quantity and quality of the fishing output, e.g. total allowable catches and quotas, and minimum landing sizes. Input controls are generally more common in shrimp fisheries, but in some of the highly regulated shrimp fisheries (e.g. the NPF in Australia), there is a movement towards complementing effort regulations with output controls, which aims at counterbalancing the effect of "effort creep". Similarly, one of the world's largest shrimp fisheries in terms of volume, Canada's East Coast Northern Shrimp Fishery, is managed by limited entry and a total allowable catch (Box 29).

Input and output controls can be decided upon and implemented top-down, in the conventional and poorly effective manner, or in a participative manner. The latter

[15] A fractional licence programme reduces effort in a fishery by eliminating a portion of each licence and retaining the requirement for a full licence. For example, each licence for a fishery is converted to a half-licence and all fishers are required to buy another half-licence from another fisher in order to fish.

is strengthened if implemented within a decentralized system of decision-making or within a system of formal restricted use rights.

Some general comments should be made on the effectiveness of the above management measures. To be effective, an intervention must be capable of producing the expected result: to be efficient, it must do so at reasonable cost. Compliance with the measure is essential and relates both to the nature of the measure (e.g. its simplicity), how it is perceived by fishers (legitimate or otherwise) and how it is enforced (deterrence). Some measures are not very effective (e.g. mesh sizes to reduce the catch of undersize shrimp), some are inefficient (e.g. poorly implemented buy-back schemes) and others are difficult to enforce (e.g. gear restrictions/requirements for small-scale fishers). On a different level, the capacity of national institutions to manage has a great influence on the effectiveness of the various interventions.

Several of the management interventions mentioned above are discussed in other chapters of this report: interventions dealing with bycatch (Chapter 6), physical impacts (Chapter 10), and interactions with small-scale fishers (Chapter 11). Other measures such as the regulation of mesh sizes and trawl bans deserve particular attention.

Mesh size regulations

Mesh sizes are regulated in most of the world's shrimp fisheries, both trawl and non-trawl. Although stipulating mesh sizes can have considerable value, it is not without problems. The main use of mesh sizes is for regulation of catch-age composition to prevent growth overfishing and optimize yield from a cohort. The principal problems of using mesh sizes are the following.

- *(i) Imperfect selectivity*. A wide range of shrimp sizes and species are often retained by a given mesh.
- *(ii) Difficult enforcement*. Dockside controls are easy in large-scale fisheries but less so in small-scale ones.
- *(iii) Easy to circumvent*. Fishers are clever at reducing the real selectivity of the mesh while apparently complying.
- *(iv) Perceived as illogical.* This occurs when the larger animals purported to be retained by the net do not exist in the fishing area or are extremely rare because of overfishing.

As a result, the use of "too small" mesh sizes is often a consequence and not a root cause of poor fisheries. Mesh size regulations would be more effective in a context of effective capacity control and not, as too often considered, as a replacement for it. An additional complication of mesh regulations is that most shrimp fisheries exploit a mix of shrimp species, and adjusting mesh sizes to the most profitable shrimp species leads to underexploitation of other shrimp species. Furthermore, for the protection of fast-growing juvenile shrimp, closed seasons and closed areas are generally thought to be more appropriate than mesh sizes (Garcia, 1989; Gulland and Rothschild, 1984; Iversen, Allen and Higman, 1993).

Trawl bans

Although complete bans on trawling are not common at present, they are often promoted by environmental groups and have been occasionally implemented in the past. The use of trawls was prohibited in Flanders in 1499; the Dutch banned the use of trawls in 1583; and trawling was made a capital offence in France in 1584. In 1631 in Britain, the use of "traules" was prohibited (Fogarty, 2002). In more recent times, shrimp trawling has been banned on at least two occasions in Southeast Asia. In early 1964, the Malaysian Government banned trawling on the grounds that it would deplete the fish stocks in inshore waters and ruin the livelihoods of traditional fishers. The highly profitable nature of trawling, together with the need to increase landings to meet the growing demand for food, made it impossible to enforce the ban, which was

BOX 25
Lessons learned from the Indonesian trawl ban

An important lesson learned from Indonesia's trawl ban appears to be that regulations that restrict trawlers from certain zones are far more difficult to impose than a complete ban, which can be enforced from shore at a limited number of fishing ports. Imposition of a gear ban is possible, but requires substantial political will. No other country has shown such resolve or ability to reallocate access to an important resource to small-scale fishers. A second important lesson learned is that demersal stocks in the tropics appear to be capable of rebuilding after being overexploited. A third lesson learned is that elimination of trawlers does not necessarily mean a long-term decline in either landings or exports. Small-scale fishers using relatively simple gear appear able to utilize demersal resources as fully as trawlers. This capacity is, of course, a two-edged sword, since eliminating trawlers will not solve problems of resource management. The need for rural and national development to attract labour and capital away from the fishery remains.

Source: Bailey, 1997.

lifted in October 1964 (Talib and Alias, 1997). In 1980, the Indonesian Government imposed a ban on trawling along the Malacca Straits and off the north coast of Java, and extended it nationwide in 1981. The trawl ban has been extensively documented and analysed (Butcher, 2004; Chong *et al*., 1987; Bailey, 1997). The original objective of the ban, reduction of negative impacts of trawling on small-scale fishers, was accomplished (Chapter 11), but its effectiveness has decreased over the years by renaming trawl gear and poor enforcement. Bailey (1997) reviews the ban and extrapolates some lessons learned for other developing countries in the region (Box 25).

OPEN AND LIMITED ACCESS

A fundamental problem of many of the world's shrimp fisheries is open access – the right for the entire public to participate in a fishery. In general, if there are no barriers to entry, fisheries typically end up producing to the point where total revenue equals total costs (profitability shrinks to zero) and beyond if subsidies are provided. The history of shrimp fishery management shows that management interventions (e.g. catch limits, closed seasons) that do not address participation are usually ineffective at preventing overcapacity and economic overfishing in the long term.

Limiting access is often difficult but, if implemented in the early stages of a fishery, the transition can be less expensive and more effective. Two examples illustrate the difference. In 1967, commercial prawn fishing began in South Australia's Gulf of St Vincent. Limited entry was introduced in 1968 and participation in the fishery was further reduced in 1987. Indicators show that the management objectives of "optimizing economic returns to stakeholders" are being achieved (Zacharin, 1997). In Texas, United States, shrimp fishing developed rapidly after 1920 and in the 1930s a closed season and gear restrictions were implemented, but increased participation in the fishery created economic problems for the shrimp fleets. To improve the economic performance of the shrimp fishing, in 1995 the Texas Legislature enacted the first bay and bait shrimp vessel licence limited entry programme. Since the implementation of the licence buy-back programme, the Texas State Government has purchased and retired 815 commercial shrimp boat licences (422 bay and 393 bait) at a cost of approximately US$4.3 million. This represents 25 percent of the 3 231 licences of 1995. Since the buy-back programme was not entirely successful at restoring profitability, additional management measures were implemented in 2002 (TPWD, 2002).

In a comprehensive study of the economic problems experienced by the United States shrimp fleets in the Gulf of Mexico and off the southeastern coast (Ward *et al*,. 2004), a number of options for improving profitability were offered. A notable point is that the study concluded that "none of these options would provide the estimated improvement in present value or profitability for the fishing fleet if some form of limited entry is not adopted".

Garcia (1989) reviews other considerations of limiting access. He stresses the advantages of limited entry in shrimp fisheries, but notes some complications. One of the most controversial features of limited access is, ironically, that it may generate large rents. If these rents accrue to fishery participants, social tension can be created. Another difficulty with limited entry is that it tends to transfer excess effort into neighbouring fisheries or stocks, creating a need to restrict access at those locations (a domino effect). Limited entry management is considered more challenging and dependent on community- or territory-based strategies for small-scale fisheries, especially in developing countries where identification of eligible fishers and exclusion of others are difficult and where numerous practical problems arise in enforcement.

One mechanism for limiting entry into a fishery consists of the government granting a long-term right to participate in a fishery to a restricted number of fishers, allowing them to transfer the right to fish to others. This effectively creates a property right that assumes tradable value. Since this value can increase, should the profitability of the fishery increase, the participants have an interest in the effective management of the fishery. The use of such property rights is becoming increasingly common in the management of shrimp fisheries.

MANAGEMENT OF SMALL-SCALE SHRIMP FISHERIES

The vast majority of success stories in the management of shrimp fisheries come from medium- and large-scale fishing operations in developed countries. In the literature, cases of successful management[16] of small-scale shrimp fisheries in developing countries are not common in modern times. An important issue is whether, under the present management systems, small-scale fisheries can indeed be managed to prevent overfishing, reduce discards and avoid environmental damage while achieving other livelihood objectives.

There are several perspectives on the small-scale shrimp fisheries management challenge, most of which are conditioned by the various national circumstances. Some of the ideas are the following.

- *"Laisser-faire" strategy*. Because the management of small-scale shrimp fisheries is considered extremely difficult or unrealistic, it has been suggested that management attention should be focused on the larger scales of fishing. As one fishery manager put it: "Don't attempt to manage the unmanageable". The implication of this strategy is that it is hoped that the worse will not happen but that, if it does, small-scale fisheries will have enough resilience to adapt.
- *Transfer of benefits*. An alternative view is that in cases where large-scale shrimp fisheries take most of the shrimp catch, they should be managed for the benefit of the mainly disadvantaged small-scale fishers.
- *Alternative employment*. There is also the opinion that development of other sectors, not necessarily limited to those in coastal areas, should be undertaken to reduce fishing pressure in these areas, offering alternative employment to fishers. An example is the development of the oil-palm plantation industry in Malaysia, which has been able to absorb an appreciable number of fishers in coastal areas, thus reducing fishing pressure (P. Martosubroto, personal communication, May 2007).

[16] "Management success" is taken to mean that objectives have been set and to some degree achieved through interventions.

- *Participatory management*. Much of the current discussion on shrimp fisheries management concerns interventions by centralized government agencies. Some fisheries specialists argue that the management of small-scale fisheries is more successful if undertaken through participative processes (e.g. comanagement, community-based management), with local communities and government agencies contributing where they have strength. It follows that, if their use can be shown to fulfil the needs of the fishery, protected areas where no shrimp fishing (or fishing of any kind) is allowed may simplify the chronic compliance problems if they have been established in a participatory process.
- *Awareness and education*. It is contended that if small-scale fishers know the implications of some of their fishing practices, then they may tend to refrain from those that have negative effects.

ECOSYSTEM APPROACH TO FISHERIES

In the management of shrimp fisheries, increasing attention is being focused on the ecosystem approach to fisheries (EAF). In general terms, the fisheries management policies in several countries are widening away from a "single-species"' approach to include more general ecosystem issues. Specifically with respect to shrimp management, there is increasing recognition of the range of impacts outside the shrimp fishery in question, hence more emphasis on managing the effects of the fishery on the ecosystem and vice versa. Box 26 describes some important aspects of the ecosystem approach.

The principles of EAF are the following. It is science-based and uses both qualitative and quantitative information and traditional knowledge. Within pragmatically defined ecosystem boundaries, EAF aims at human and ecosystem well-being, maintaining the potential for maximum biological production as well as ecological relations, and

BOX 26

Some important aspects of the ecosystem approach

An ecosystem approach entails taking careful account of the condition of ecosystems that may affect fish stocks and their productivity. It also means taking equally careful account of the ways that fishing activities may affect marine ecosystems. This means, where necessary (e.g. within agreed levels of impact), changing the way in which the fishery operates, adjusting the type of gear used, or imposing closed areas to protect biodiversity or habitats critical to the whole fishery or to the biodiversity of the region. Furthermore, it means taking an inclusive approach to setting goals and objectives for harvested fish and the fish ecosystem, recognizing ecosystem interactions, possibly integrating activities across a range of other users and resource sectors, and respecting the broad range of society's values for the marine environment.

The ecosystem approach aims at environmental and human well-being by:

- maintaining the natural structure, function, biodiversity and productivity of natural systems;
- accounting for human needs and values of ecosystems when establishing objectives;
- recognizing that ecosystems are dynamic with attributes and boundaries constantly changing and that consequently, interactions with human uses are also dynamic;
- accepting that natural resources are best managed within a management system based on a shared vision and a set of objectives developed among stakeholders;
- adopting adaptive management procedures, based on scientific knowledge, continual social learning and recurrent audit and evaluation of the management performance.

Source: based on Ward *et al.*, 2006.

minimizing the impacts of use. It also aims at equity, transparency and participation as a means to ensure them. Furthermore, it acknowledges uncertainty and develops precaution and foresight. It integrates information building, assessment and management within the ecosystem area. Finally, it addresses transboundary impacts and ensures compatibility of management measures across the entire ecosystem (Garcia *et al*., 2003).

EAF cannot be developed in a vacuum. It can only be sustainably implemented within supporting national economic, policy, institutional and juridical frameworks operating as an enabling environment. This requires the existence or establishment of local democratic institutions, a pragmatic decentralization of equitably distributed rights and duties, the adoption of a system of indicators and a set of minimal environmental norms. It also requires good coordination among ministries.

Garcia *et al*. (2003) and FAO (2005f) state that the ecosystem approach to fisheries, blending ecosystem and fisheries management, requires: (i) a definition and scientific description of the ecosystem in terms of scale, extent, structure and functioning; (ii) assessment of its state in terms of health or integrity as defined by what is acceptable to society; (iii) assessment of threats; and (iv) maintenance, protection, mitigation, rehabilitation, etc., using (v) adaptive management strategies. An especially useful comparison between conventional fisheries management and ecosystem management is given in Table 16.

An ecosystem approach is perhaps particularly appropriate for the management of shrimp because of its important role as prey in most ecosystems; its sensitivity to climatic factors as drivers of its life cycle and recruitment success; its sensitivity to the quality of coastal habitat; its impact on other fisheries through bycatch; and the potential impact of trawling on the bottom and bottom fauna.

TABLE 16
Comparison between fisheries and ecosystem management

Criteria	Fisheries management	Ecosystem management
Paradigm	Sector-based. Vertically integrated. Focusing on target resource and people.	Area-based. Holistic. Loosely cross-sectoral. Focusing on habitats and ecosystem integrity.
Objectives	Not always coherent or transparent. "Optimal" system output. Social peace.	A desired state of the ecosystem (health, integrity).
Scientific input	Formalized (particularly in regional commissions). Variable impact.	Less formalized. Less operational. Often insufficient. Stronger role of advocacy science.
Decision-making	Most often top-down. Strongly influenced by industry lobbying. Growing role of environmental NGOs and fishing communities.	Highly variable. Often more participative. Strongly influenced by environmental lobbies. Stronger use of tribunals
Role of the media	Historically limited.	Stronger use of the media.
Regional and global institutions	Central role of FAO and regional fishery bodies.	Central role of United Nations Environment Programme (UNEP) and the Regional Seas Conventions.
Geographic basis	A process of overlapping and cascading subdivision of the oceans for allocation of resources and responsibilities.	A progressive consideration of larger-scale ecosystems for more comprehensive management, e.g. from specific areas to entire coastal zones and large marine ecosystems.
Stakeholder and political base	Narrow. Essentially fishery stakeholders. Progressively opening to other interests.	Much broader. Society-wide. Often with support from recreational and small-scale fisheries.
Global instruments	1982 UN Convention on the Law of the Sea, UN Fish Stocks Agreement and the FAO Code of Conduct.	Ramsar Convention, 1992 United Nations Conference on Environment and Development Agenda 21, Convention on Biological Diversity, and the Jakarta Mandate.
Measures	Regulation of human activity inputs (gear, effort, capacity) or output (removals, quotas) and trade.	Protection of specified areas and habitats, including limitation or exclusion of extractive human activities. Total or partial ban of some human activities.

Source: Garcia *et al*., 2003.

In moving towards an ecosystem approach to shrimp fisheries a number of steps should be taken to:

- delineate the practical boundaries of the shrimp fishery ecosystem inland and at sea;
- identify critical habitats (e.g. lagoons, mangroves, seagrass beds, mudflats, spawning grounds), their state and existing threats (agriculture, urbanization, etc.);
- identify the species assemblage and information available on it, predators and preys;
- identify all stakeholders and catalogue the different values of the ecosystem for them;
- identify potential partners, e.g. in the Ministry of the Environment, Non-governmental Organizations (NGOs), etc.;
- assess, at least qualitatively, the bycatch issue, looking for threats to protected/endangered species;
- identify institutional zones such as reserves and exclusion zones for industrial fishing;
- identify potential external drivers such as climate oscillations, rainfall and market forces, etc.;
- identify potential sources of threats such as pollution sources, competing sectors, urban development, and oil industry and dumping activities;
- identify patterns of variability and change; and
- identify explicit and implicit objectives.

To be particularly effective, the steps towards improved management will need to be participatory and include a risk assessment analysis (Fletcher, 2005). Any management plan might also benefit from establishing recurrent audit and evaluation processes to guarantee adaptive improvements; and programmes of stakeholder awareness raising and education to ensure a common platform of understanding.

The task may sound daunting for the shrimp fisheries of most developing countries (and perhaps also for some developed ones), but can be implemented stepwise, with a direction and speed to be jointly decided by stakeholders and with the collaboration of international institutions, NGOs and institutions with converging interests, etc., sharing the burden and pooling competencies and resources. For example, guidance is available in Garcia *et al.* (2003); FAO (2003b) and Cochrane, Augustyn and Cockcroft (2004).

To a certain extent, the progression to an ecosystem approach to the management of shrimp fisheries is well under way in some countries. This is evidenced by increased management attention to bycatch reduction; the introduction of estuarine and watershed aspects into shrimp fishery management plans; efforts to mitigate negative effects on the seabed; and the use of marine protected areas in shrimp fisheries management. The incorporation of the principles of an ecosystem approach into shrimp management appears considerably more advanced in developed countries, such as Australia and Norway (Part 2).

LEGISLATION FOR SHRIMP FISHERIES MANAGEMENT

Globally, legislation for fisheries management reflects the variety of legal systems in the world. For shrimp fisheries, a key aspect of national fisheries legislation is whether or not there is a legal mandate to restrict participation in fisheries. Other features of legislation that are important for effective shrimp fisheries management include the authority to reduce participation, limit catches, restrict gear, establish closed seasons/areas and collect data.

In countries with effectively managed shrimp fisheries, legislation often requires or encourages certain positive features. These include fisheries management plans, bycatch management plans, collaboration among the various stakeholders, provision for keeping management interventions at arms' length from the political process, an ecosystem approach to management and the flexibility to intervene quickly, based on

BOX 27

Modernizing fisheries legislation in Trinidad and Tobago

The Fisheries Act of 1916 does not provide a legal basis for controlling access by nationals of Trinidad and Tobago to fisheries resources under the national jurisdiction. Efforts to limit fishing effort in the trawl fishery have subsequently been attempted through a 1988 Cabinet decision to restrict entry of new vessels, both artisanal and industrial. This measure is effective to a greater extent for the semi-industrial and industrial fleet, where permission for the importation of any new fishing vessel must be obtained from the Minister with responsibility for fisheries. The Fisheries Management Bill prepared in 1995, to be known on finalization as the Marine Fisheries Management Act, will repeal the Fisheries Act of 1916. The new Act will provide for the preparation of fishery management plans and, in accordance with these plans, will control and limit access to fish resources through the establishment of a licensing system for both local and foreign fishing vessels. Currently, however, there appears to be insufficient political will to enact the proposed legislation.

Source: based on Part 2.

research findings or changing fishery conditions. Many of these features are, however, important for fisheries management in general and not strictly specific to shrimp fishery management.

There are numerous complications and difficulties in the legislation for shrimp fisheries management. Problems associated with revising antiquated legislation are common. The case of Trinidad and Tobago is similar to that of many countries (Box 27). Jurisdictional issues whereby a shrimp fishery occurs in the geographic area of more than one management authority plague many countries. In the United States, multiple jurisdictions result in the inability even to determine the number of operational shrimp vessels in the major shrimp fishery of the country, making implementation of effective management difficult. The prevention of inshore nursery ground habitat degradation is important for shrimp fisheries, but does not usually fall within the legal mandate of the government agency responsible for fisheries management.

The greatest difficulty with legislation for shrimp fisheries management often involves enforcement, especially in developing countries. The situation of “relying on non-existent enforcement” is covered in Chapter 13.

MANAGEMENT COSTS

An important consideration is the cost-effectiveness of fisheries management. Management costs are not, however, readily available for most of the world’s shrimp fisheries. The typical situation is when the budget of a government fishery agency is known but is partitioned by administrative section, rather than by function, such as research or management. It is even more uncommon to disaggregate government fishery budgets to the level of the management of a specific fishery. In some countries, however, industry is responsible for at least a portion of management costs associated with the fisheries in which they participate, and consequently management expenditure is carefully accounted for on a fisheries basis (Box 28). Since industry is paying for a service, cost efficiency is encouraged.

DIFFICULTY IN MANAGING SHRIMP FISHERIES

It should be emphasized that shrimp fishery management is *not that difficult.* Compared with other fisheries, warm-water shrimp fishery management is relatively easy because of several factors: growth and mortality have been determined for many

BOX 28
Management costs in Australia's Northern Prawn Fishery

Current government policies for fisheries managed by the National Government are that the fishing industry pays for management costs directly attributed to fishing activity on a full cost-recovery basis, with the government paying for, or contributing to, activities that may benefit the broader community as well as industry. Recoverable management costs include the running costs of management committees, the fisheries management agency's day-to-day fisheries management activities, costs of developing and maintaining management plans, and logbooks and surveillance, but do not include enforcement costs (Cartwright, 2003). From 1995 to 2002, annual management costs attributed to the Northern Prawn Fishery ranged from $A1 million to $A2.2 million.[1]

Source: Galeano *et al.*, 2004.

[1] In 2002, the average exchange rate was US$1 = $A1.84.

of the important species; shrimp is highly fecund; and abundance is largely climate-driven. Furthermore, since most warm-water shrimp fisheries utilize more than one shrimp species, it is unlikely that bad year classes will occur in all species in one year. Because of the short life cycle of shrimp, overfishing is immediately apparent and, if management mistakes are made, they can often be rectified in one year (S. Garcia, FAO, personal communication, 2007).

On the other hand, the management of a shrimp fishery can be more complex if it involves small-scale fishers (Chapter 11), is open access or occurs in a poor country with weak institutional arrangements for management. Overall, some of the best-managed fisheries of any type (invertebrate, finfish or other) are the commercial-scale shrimp fisheries in the countries that limit fisheries access. Even in these cases, there is considerable room for improvement.

COLD-WATER SHRIMP FISHERY MANAGEMENT

The discussion of shrimp management issues in the sections above is focused to some extent on the warm-water or penaeid shrimp fisheries. To a certain degree, this reflects the greater international attention currently given to the management of warm-water shrimp fisheries rather than to that of cold-water ones.

In general, the management of cold-water shrimp fisheries is more simple. Cold-water fisheries are most often limited entry, industrial-scale operations carried out by fleets from developed countries. They do not characteristically have the management difficulties associated with small-scale fisheries and the generally larger vessels involved allow more options to deal with bycatch issues. In relative terms, the fisheries are closely regulated and there is better compliance. Much of the cold-water shrimp fishing occurs in countries whose fisheries policies stress the importance of an ecosystem approach to fisheries management. On the other hand, the international nature of many of the cold-water shrimp fisheries requires bilateral and multilateral arrangements that introduce considerable management complexity.

Nevertheless, the management of cold-water shrimp fisheries is usually less complex and consequently more successful than that of warm-water fisheries in terms of achieving common management objectives, such as maximizing rent or reducing bycatch. As an indication of the easier management situation, most of the shrimp fisheries in consideration for certification by the MSC (Chapter 5, section *Important issues in the shrimp trade*) are cold-water fisheries (Leadbitter and Oloruntuyi, 2002).

BOX 29

Canada's management interventions for northern shrimp

Access to northern shrimp stocks is regulated through fishing licences, shrimp fishing areas, seasons, quotas, enterprise allocations and gear specifications.

- For 2007, a total northern shrimp quota of 164 244 tonnes was established for the eight shrimp fishing areas. This quota is partitioned among the eight areas and then allocated to participants.
- Nordmøre grids continue to be mandatory in shrimp trawls to reduce bycatches of other species including Atlantic cod, Greenland halibut, wolffish, skates, seals and snow crab.
- The fishery is monitored by extensive at-sea observer coverage paid for by licence holders. Vessels over 100 ft (30.5 m) carry 100 percent observer coverage. This is based on 10 percent coverage on inshore vessels. At-sea observers monitor for compliance with management measures, including bycatches, dumping and high-grading, gear restrictions, area and closed time provisions. Observers also collect valuable scientific information including size composition, temperature data and bycatch composition.
- Dockside monitoring by a certified dockside monitoring company is conducted on all landings from vessels less than 100 ft in length. Dockside monitoring of shrimp landed from vessels of over 100 ft in length is not currently required.
- Completion and submission of accurate fishing and production logbooks as well as fish purchase slips are required.

All vessels fishing shrimp must be equipped with a government-approved electronic vessel monitoring system. Offshore vessels fishing northern shrimp must report to the government their position and catch on a daily basis in the prescribed format. Fishery officers conduct surveillance of fishing activities through periodic aerial and dockside surveillance and by conducting at-sea boarding of fishing vessels. From time to time, vessels may be subject to audit of reported landings and catch information.

Source: DFO, 2007.

Management objectives in the main cold-water shrimp fisheries reflect the characteristically high quality of governance in the fisheries sectors of the important countries involved (Canada, Greenland, Iceland and Norway). Objectives are often the maximization of economic efficiency and reduction of environmental costs, using a variety of management interventions to achieve these goals. For example, Box 29 describes the management interventions used in 2007 in Canada's Northern Shrimp Fishery off northeast Newfoundland, the Labrador Coast and in the Davis Strait.

13. Enforcement

Enforcement is defined as ensuring the observance of laws. Fisheries enforcement includes not only the process of recording violations of fisheries laws, but also the legal processes and penalties applied (Kelleher, 2002).

ENFORCEMENT ISSUES IN SHRIMP FISHERIES

Enforcement is an important aspect of any fisheries management regime. For the purpose of the present study, it is important to identify the issues and elements of enforcement that are specific to shrimp fisheries or are of particular significance.

Because of the variety of life cycles, fishing gear and practices, and the communities involved, the management of shrimp fisheries is associated with a complex enforcement environment within a large range of national conditions. The complicating factors for shrimp fisheries include: the use of many types of management measures, many of which require enforcement activities at sea; substantial incentives to circumvent restrictions on inshore trawling (i.e. productive near-shore fishing grounds); the fact that many restrictions are counter to the short-term economic interests of fishers (some measures dealing with bycatch/discards); the management measures that infuriate fishers (unilateral TED requirements imposed on developing country fishers by the United States); and the huge problems, or even futility, of enforcing requirements in small-scale shrimp fisheries.

Although there are a multitude of measures employed in the management of the world's shrimp fisheries (Chapter 12), the main areas of concern regarding fisheries enforcement and its associated considerations are the following.

- *Gear measures*. These include mesh sizes, other net specifications, TEDs and BRDs. Although some form of gear control is in force in most of the world's shrimp fisheries, it is relatively difficult to enforce in port and often requires observers or boarding at sea to ensure compliance.
- *Restricted areas*. These include both permanent and temporary closures for protecting juvenile shrimp, sensitive areas and small-scale fishers. Enforcement is generally easier than for gear measures and the use of electronic vessel monitoring further facilitates enforcement.
- *Catch restrictions*. These include requirements (quantities, sizes of individuals) on retaining and discarding target species and bycatch. Some aspects can be monitored in port, but others require on-board observers at sea.
- *Participation*. In restricted access fisheries, fishers that are legitimate participants often effectively contribute to the enforcement process. Even in open access fisheries, domestic fishers have incentives to report illegal foreign fishers.

In the ten country studies of Part 2, a number of issues related to enforcement of regulations emerge. As expected, enforcement matters differ greatly between developed and developing countries, but there are also major differences in enforcement between warm- and cold-water shrimp fisheries, with the latter more involved in compliance with shrimp size regulations and quotas. Enforcement of turtle excluder requirements is confined to warm-water fisheries, which also have greater involvement in the complexities of enforcement in small-scale fisheries.

Other enforcement issues that became apparent in the national studies are given below.

BOX 30
Enforcement in Madagascar

Fisheries surveillance and enforcement are carried out by the Centre de surveillance des pêches, which was created by the Minister in charge of fisheries by Decree No. 4113/99 of 23 April 1999. The objective of the Centre is to oversee compliance with regulations, at sea as well as on land. Twenty provincial agents are deployed along the coast to inspect boats and to verify fishing gear, which for shrimp fishing involves the following criteria: the length of the backrope, the mesh size of the trawl and installation of TEDs and BRDs. Thirty-five observers dedicated to the shrimp fisheries allow for observation of fishing operations at sea. A vessel monitoring system has been used since the beginning of the 2001 fishing season to regulate the fishing areas of industrial shrimp trawlers. All vessels are equipped with ARGOS or INMARSAT transmitters. The Centre has several funding sources, both national and international. The annual budget is about US$1.4 million.

Source: based on Part 2.

- Poor enforcement appears to stem from a number of factors: insufficient operational budgets, inadequate enforcement infrastructure, weak institutions, political considerations affecting enforcement priorities and official corruption.
- Much or most of the corruption associated with shrimp fisheries seems to involve payments to circumvent enforcement of regulations.
- In many cases where efficient enforcement exists, the fishing industry itself has at least some enforcement responsibilities; this applies to both developed and developing countries.
- If penalties for non-compliance are harsh enough, then the actual detection efforts do not need to be as great to be a deterrent.
- A reasonable degree of compliance with some of the technical measures (mesh sizes, BRDs) requires at least some on-board observer coverage.
- Enforcement of regulations in small-scale shrimp fisheries is often considered to be too hard a prospect.
- Not all cases of good enforcement of shrimp fisheries management requirements occur in wealthy developed nations (Box 30). The significance of a fishery for the national economy and effective national institutions appear to be at least as important as national wealth in whether adequate resources are dedicated to enforcement.

Another aspect of enforcement that emerges from Part 2 concerns unilateral attempts of a single country, the United States, to extend its shrimp fishery management requirements overseas. This is an issue whereby the United States requires an equivalent monitoring and enforcement programme for the use of TEDs in countries wishing to export shrimp to the United States. In effect, the harvesting country must document its enforcement of the laws of another country. Currently, this is only a TEDs/United States issue, but the concept could conceivably be adopted by other major shrimp markets in relation to turtle conservation or other matters.

ENFORCEMENT ISSUES IN SMALL-SCALE SHRIMP FISHERIES

Enforcement of regulations in small-scale shrimp fisheries deserves additional attention. In Chapter 12, section *Difficulty in managing shrimp fisheries*, it is noted than in many countries, even modest regulatory interventions dealing with small-scale shrimp fisheries do not succeed as a result of enforcement problems: the large numbers of vessels, the impracticality of placing observers, the many landing sites and reluctance to place demands on poor people.

As discussed in Chapter 12, section *Management of small-scale shrimp fisheries*, there appear to be three main types of small-scale fishery management strategies, each of which has its enforcement problems: (i) the *laisser-faire* strategy, which gives low priority to imposing or enforcing regulations; (ii) bans and protected areas, which are expected to require less enforcement (a less than obvious assumption in many situations); and (iii) participative management involving the communities and the government in the management process, including enforcement.

Funge-Smith, Lindebo and Staples (2005) refer to enforcement restrictions on small-scale trawling in Southeast Asia and observe that such regulations are unfortunately difficult to enforce and success has been rather limited, unless supported by local communities and administrations. Increasingly, small-scale fishers are the main endorsers of responsible fishing practices in small-scale fisheries, through community-based and comanagement programmes, often with strong support from the local government.

ELECTRONIC VESSEL MONITORING

The introduction of electronic vessel monitoring has a very positive effect on some aspects of shrimp fishery enforcement. A vessel monitoring system (VMS) provides accurate geographic information on participating fishing vessels to the monitoring agency. VMS alone does not provide evidence of a standard likely to satisfy most criminal courts of an offence that involves fishing activity. VMS can, however, indicate probable fishing activity and provides a good and sufficient basis for further investigation by one or more of the conventional enforcement measures (FAO, 1998).

There are now requirements in most countries that large-scale shrimp trawlers be equipped with VMS. This mitigates one of the most serious problems of shrimp fishing – large trawlers encroaching on banned inshore areas and creating conflicts with small-scale fishers. As in many other fisheries, the introduction of VMS for shrimp fishing was initially resisted by industry. After VMS use became mandatory and part of normal shrimp fishing operations, the fishing industry became aware of some peripheral benefits: companies can more accurately track the movements of their fleets and legitimate companies can more easily demonstrate compliance of their vessels with geographic restrictions.

In many countries, there is a general perception that VMS reduces overall enforcement costs. Yet VMS places additional demands on monitoring agencies to deal with a substantial amount of information from vessels equipped with VMS transponders, and fishers usually pay at least the cost of the on-board transmitting unit.

Experience has shown that VMS can make a valuable contribution to fishery enforcement effectiveness when:

- states do not have adequate monitoring of the fishery or when the do, they require access to data that are close to real time, which other monitoring tools cannot provide. VMS allows some measure of fishing effort and can rapidly and precisely allow a fishery manager to see spatial and temporal distribution of effort;
- there are industrial-type foreign fishery agreements;
- there are conflicts between fishery sectors or between neighbouring countries, in which case VMS can provide a mechanism for dispute resolution;
- there are limited human and financial resources in the country and fisheries are remotely located;
- it is combined with other control activities, such as dockside monitoring;
- improved efficiency is desired since it reduces the surface/aerial patrol costs without sacrificing part of the evidence of a violation; and

- a state's infrastructure can accommodate VMS demands: operational, legal, etc.

The use of VMS information is not confined to enforcement. In some shrimp fisheries, VMS provides valuable information for researching aspects of the fishery, such as the fine-scale distribution of effort and logbook validation.

ENFORCEMENT COSTS

Kelleher (2002) discusses enforcement costs and places them into two categories: capital costs (buildings, infrastructure, communications systems, patrol platforms, etc.) and recurrent costs (personnel, administration, patrolling, etc.). The reality is, however, that enforcement costs are not readily available for most of the world's shrimp fisheries. This is partly because of the way that budgets for fisheries administrations are organized and partly because external enforcement agencies (e.g. military, police, coast guard) do not usually partition their budgets or expenses by fishery or even by category (e.g. smuggling, sea safety, fisheries).

By contrast, the enforcement costs of some shrimp fisheries are well known. The annual compliance budget for the relatively small Gulf St Vincent Prawn Fishery in Australia is currently about US$25 000 and accounts for costs incurred for checking on bycatch, maximum trawl headline length and the landed prawn catch. This equates to enforcement costs of about 1 percent of the value of the fishery. In 2005, in Kuwait, the total annual cost for all fisheries enforcement was KD1 091 532 (US$3 714 600), of which an estimated 40 percent related to shrimp fishery management. This equates to enforcement costs of about 21 percent of the value of the shrimp fishery.

Government policies vary considerably as to who bears the burden of enforcement expenses. Generally, for fisheries management, many countries are moving towards a policy of "user pays", but this is not always extended to enforcement costs. Participants in nationally managed shrimp fisheries in Australia pay for most management costs, but not those related to enforcing regulations. In Canada's east coast Northern Shrimp Fishery, harvesters pay only the costs of observer coverage and dockside monitoring.

14. Shrimp fishery research issues

PAST AND CURRENT RESEARCH

The purpose of fishery research is to provide a basis for management decisions. An important point concerning shrimp research is that past efforts have resulted in major advances in knowledge. As mentioned in Chapter 13, researchers have made considerable progress in gaining an understanding of the life histories and other aspects of the biology of the important species of shrimp. In the early days of shrimp fishing, biologists had poor knowledge of shrimp biology, including shrimp's complex larval life, growth and mortality rates, life span, migration and habitat requirements. *After two decades of research, most of the big unknowns regarding population dynamics and interactions between small- and large-scale fisheries were reduced by the end of the 1980s* (S. Garcia, personal communication, 2006). This provided a strong foundation for conventional management strategies fisheries that were tested for four decades and are still evolving.

Much of the past research associated with shrimp fisheries has involved biological and economic research on shrimp in support of stock assessment. Another research area that has received considerable attention is bycatch: quantities, species, resilience to fishing pressure and reduction. Several decades ago, the most advanced research on tropical shrimp was carried out in the United States. Policy decisions resulted in transferring much research effort to shrimp culture by the end of the 1960s. During the 1970s, with substantial support from FAO, tropical shrimp research developed on shrimping grounds in West Africa, Latin America, the gulfs between the Islamic Republic of Iran and the Arabian Peninsula, and Southeast Asia. Since the end of the 1970s, Australia has, in many respects, led the world in research on warm-water shrimp. From the 1990s onwards, there seems to have been a slump in this type of research as the world has shifted from single-species to ecosystem perspectives for fisheries.

Substantial research work on cold-water shrimp fisheries is currently being carried out in Canada and northern Europe. One of the most effective national shrimp research programmes in a developing country is the National Shrimp Research Programme of Madagascar (Box 31).

At present, much of the shrimp research in the various shrimp fisheries around the world can be placed into several categories:

- ongoing monitoring and stock assessment of existing fisheries;
- socio-economic research, including for reduction of conflicts and improving economic efficiency;
- research that encompasses both socio-economics and biology, such as the development of bioeconomic models and determining optimal exploitation strategies;
- gear technology, especially for reducing bycatch and impacts on the benthic environment; and
- topics of special concern: impacts on non-target species and effects of trawling on the sea bottom.

The specific research needed to bring shrimp fisheries management into an ecosystem approach framework is still limited, except in Australia, as shown in the discussions on discards and the biological impact of shrimp trawling.

BOX 31

Madagascar's National Shrimp Research Programme

Madagascar's National Shrimp Research Programme (PNRC) began in September 1997. The programme has taken over the objectives of some previous shrimp research projects, including that of FAO, to become the focal point of Madagascar shrimp research. PNRC was initially focused on shrimp research in three areas.

- *Socio-economic research:* the importance of traditional shrimp fishing, the economics of the industrial/artisanal shrimp fisheries and analysis of the types of management.
- *Biological research*: sound justification for the period of closure of shrimp fishing; considerations related to the proposed trawl ban within two miles of the coast; the relationship between fishing and the environment; sites and importance of nursery grounds; determination of migration/growth/mortality from shrimp tagging; comparisons of biological cycles for the different fishing areas; stock identification; and evaluation of resource potential in the various fishing areas.
- *Research that encompasses both socio-economics and biology*: the study of economic and biological interactions between the three shrimp fishing subsectors – industrial, artisanal, traditional; and bioeconomic modelling to simulate the various management schemes.

The PNRC is now in a transitional phase. Following the workshop on the results of scientific studies in October 2004, several proposals for future shrimp research were made, including: extending the work carried out at Baie d'Ambaro and other important areas on the traditional shrimp fishery; pursuing shrimp stock assessment in the various fishing areas using cohort analysis and yield per recruit analysis; integrating the catch data of the three shrimp fishing subsectors; bioeconomic modelling of the fisheries by fishing area; and undertaking simulations to determine optimal exploitation strategies.

Source: based on Part 2.

IMPORTANT NATIONAL ISSUES IN SHRIMP RESEARCH

In the ten study countries, a number of issues related to shrimp research were identified. One of the most prominent features is the lack of research, or even basic data collection, in many countries where the shrimp resource is important. In Bangladesh, for instance, there has not been much research so far on shrimp fisheries in general and on shrimp trawling in particular. Valid scientific information in this regard is still lacking. The Cambodian fisheries statistical system is oriented towards collection of production information, while even the most basic indicators useful for stock assessment (e.g. CPUE) are not included (Gillett, 2004). ICES/FAO (2005) state that, in Cameroon, no proper research has been carried out so far regarding stock assessment and the actual level of exploitation.

Several other important matters related to research emerge from the national studies. One persistent issue concerns the identification of shrimp stock assessment models that are appropriate for use in developing tropical countries. As expressed by an Asian shrimp fishery manager: "The next step up from using trends in CPUE is unclear". An African fisheries specialist expressed a similar sentiment: "*With respect to shrimp stock assessment, there is a general lack of knowledge in moving from the theoretic/experimental to the recipe book*". The statements could indicate a decrease in assessment capacity from the 1980s when FAO, in collaboration with the Danish International Development Agency (DANIDA) trained more than 1 500 scientists in techniques adapted to various situations.

Other prevalent research issues and concerns are given below.

- Non-penaeid tropical shrimp (e.g. sergestoid shrimp of the genus *Acetes*) is important in the global shrimp catch (Chapter 3, section *Catches by shrimp species*) but little, if any, stock assessment information is readily available for fishery managers on these species.
- Some countries that carry out little research on shrimp are adjacent to those where substantial research has been undertaken. The high degree of applicability of shrimp research conclusions across areas offers considerable opportunities for knowledge transfer.
- With respect to research priorities related to shrimp fisheries, there is some debate in several countries on the amount of attention to give to biological research with respect to other types of research, such as socio-economics or gear technology. The latter should be a priority since it is an area in which differences across countries are more likely.
- Most research on shrimp is oriented towards large commercially important fisheries, with much less work on the shrimp resources that are exclusively targets of small-scale fishing. Although the latter is often responsible for large quantities of shrimp, there is uncertainty as to whether such research is cost-effective, considering the difficulties of data collection (on multiple-gear fisheries with a large number of fishing units in isolated areas) and management.
- In many developing tropical countries, some sophisticated stock assessment has been carried out on shrimp resources by externally funded projects, using expatriate expertise. The lack of continuity after the departure of project staff is an issue in many of these countries.

GEF/UNEP/FAO PROJECT RESEARCH

Some form of research on shrimp bycatch reduction is carried out in most countries that have shrimp fisheries. Bycatch reduction research is also promoted on a global basis by a GEF/UNEP/FAO project, "Reduction of the Environmental Impact from Tropical Shrimp Trawling Fisheries, through the Introduction of By-catch Technologies and Change of Management".

Research is a major component of the project, justification for which is given in the project document (FAO, 1999).

With the problem of fish bycatch, particularly of juvenile food-fish, identified as a priority area for mitigation, research aimed at developing efficient and practical solutions has been started in several countries (including the United States, Australia, Mexico and Thailand), and is likely to continue in these countries, but because research and development require substantial financial and human resources they will tend to be restricted to those countries with a strong economy. The intervention of GEF is therefore required to support efforts by a number of less fortunate developing countries in all four major regions of the world in order to resolve a common problem.

In addition to supporting national research efforts, the project is striving to increase cooperation in shrimp bycatch research among countries, the success of which will be demonstrated by the number of agreements made by governments on fishery research.

RESEARCH ON SMALL-SCALE SHRIMP FISHERIES

Small-scale fisheries, including those for shrimp, have special research needs. In recognition of both the unique research requirements and the lack of sufficient attention in the past, FAO convened a meeting on small-scale fisheries research in November 2003. This meeting was charged with examining the role and importance of small-scale fisheries, elaborating a research agenda for the sector, and reviewing strategies and mechanisms to bridge the gap between research and action. An important finding of the meeting concerned the placement of emphasis in small-scale fisheries research.

In order for research to have more impact on small-scale fisheries, the more traditional biotechnical approaches of many fisheries agencies must be augmented by substantial contributions from socio-economic research. In many cases, government fishery agencies are structured and staffed with an emphasis on northern hemisphere approaches to stock assessment. While resource assessment and monitoring remain key functions, the emphasis of a research agenda more appropriate for small-scale fisheries should be on policy formulation and socio-economic research (Staples, Satia and Gardiner, 2004).

This general statement above is especially applicable to small-scale shrimp fishery research in developing countries. Currently, many aspects of conducting shrimp fisheries research in these countries were either learned in, or borrowed from, developed countries where large-scale shrimp fishing and associated stock assessment dominate the agenda. In the fisheries research agencies of some countries, research on issues of critical importance to small-scale shrimp fisheries, such as conflict with other scales of fishing, is dismissed as not being "scientific" and thus being inappropriate as a subject.

Overall, it seems that socio-economic research on issues of importance to small-scale fisheries should receive greater attention in the fisheries research agendas of many countries. Furthermore, it appears that the results of past socio-economic research have often been inadequately considered in the fisheries management process. This suggests the importance of developing mechanisms for incorporating the findings of socio-economic research in management plans, perhaps similar to what routinely occurs in many countries to obtain the results of stock assessment.

RESEARCH COSTS

Research costs are not readily available for most of the world's shrimp fisheries. Research budgets of fisheries agencies are known, but costs are not often disaggregated to the level of research on a particular fishery. In the countries where little or no research on shrimp fisheries is carried out, the budgets are obviously small or zero. In countries where one agency/programme is responsible for all shrimp research, the associated costs are well known.

As an example of the latter case, Madagascar's National Shrimp Research Programme (PNRC) is a multidonor initiative with the participation of Agence française de développement, the Madagascar Government (the Aquaculture and Fisheries Development Fund and the Fisheries Agreement with the EU), the Institut de recherche pour le développement, and the Madagascar Shrimp Fishers and Farmers' Cooperative. The original budget was about €2.0 million and about €1.8 million for the second phase.

The Madagascar situation also highlights another issue dealing with shrimp research funding in developing countries: reliance on donor support. It can be risky using the sometimes volatile aid funds to finance an ongoing activity. There can also be difficulties should the donors wish to exert influence over research priorities.

Comparison of funding levels among countries is complicated by several factors, including: definitions of "research"; apportioning agency administrative costs; and dealing with donor funding and purely academic research. Nevertheless, some indication of the magnitude of funding for research on shrimp fisheries can be obtained from the country studies in Part 2.

- The cost of shrimp-related research in *Indonesia* is not readily available. Estimating the cost of such research is rendered difficult by the large number of government, academic and donor agencies involved, and the difficulties associated with partitioning budgets by species groups. Nevertheless, some understanding of the financing available can be gained by considering the Research Institute for Marine Fisheries. Much of the government biological research on shrimp is undertaken at the Institute, which has an annual budget of approximately US$350 000. About 20 percent of its work could be considered to be focused on shrimp.

- In *Kuwait,* in recent years, it is estimated that the annual cost of research projects on the shrimp fishery averages US$340 000.
- In *Norway*, the cost of shrimp research is not easily quantified, but a leading shrimp researcher estimated it at about US$1 million for 2004.
- The average annual budget for research in the Fisheries Division of *Trinidad and Tobago* is estimated at US$170 000. The budget supports the ongoing catch and effort, biological sampling programmes, participation in regional scientific working groups and counterpart funding for the GEF trawl project. It is estimated that 35 percent of the annual research budget is focused on the demersal trawl fishery (shrimp and groundfish resources), and another 35 percent on the pelagic fisheries. The remaining 30 percent covers information services shared equally between pelagic and demersal fisheries.

In some countries there has been a move to the concept of "user pays" for shrimp fishery research. This can be positive in terms of encouraging cost-efficiency. In South Australia's Spencer Gulf Prawn Fishery, industry pays 100 percent of the attributable research costs through an annual research levy per licence holder, based on the production value of the fishery.

15. Data reporting

Most countries collect information on the total catch of industrial shrimp fisheries. Developed countries with effectively managed shrimp fisheries typically and routinely collect data on catch, effort and size of the important shrimp species. These data are verified by a number of means, including observers, boarding at sea and port sampling. Developing countries often collect information on shrimp catches as simply a component of an overall national fisheries statistical system, in which case, features that are important for shrimp assessments, such as shrimp size and species, may not always be included. In some developing countries, shrimp research projects (often established and initially operated with donor funds) collect information that is important for shrimp to augment the catch information of the overall fisheries statistical systems. In some developing countries where shrimp fishing is relatively important in the national economy, a specialized national statistical system for shrimp fishing has been established.

Given the considerable diversity of the various systems around the world for reporting data on shrimp fishing, only a few overall generalizations can be made on their functioning. In many of the better systems, industry is involved with collecting and reporting data. In Norway, all shrimp is sold through fishers' sales organizations. Catch information is obtained from the sales agreements between buyer and vessel. The fishers' organizations report the sales documents to the Directorate of Fisheries, which compiles the Norwegian catch statistics. In Australia's NPF, logbook design has involved continuous industry involvement and input, since the accuracy of the data is a function of industry satisfaction and commitment to the process (Cartwright, 2003).

Many of the poorer systems for collecting information on shrimp fisheries are in a situation similar to what Coates (2002) described for fisheries data in one region.

The countries of Southeast Asia in general struggle with limited resources to compile information that, in many cases, they do not themselves trust, need or use. At the same time, most of those countries are aware of what information it would be more logical to collect, but lack the methods and support to obtain it.

In general, the data systems that have input by industry and multiple verification mechanisms seem to be the most accurate. Box 32 gives examples of two very different situations.

Previous chapters of this report have stressed the importance of small-scale shrimp fishing in many countries. The large number of special problems of these fisheries has also been noted, including difficulties in management, enforcement and bycatch reduction. Data reporting is also problematic – most countries have considerable trouble collecting information on small-scale shrimp fisheries. In countries where such fishing is significant, there are often questions about the costs and utility of collecting information on potentially a huge number of types of shrimp fishing units, and also about the accuracy of such information once collected. In some countries, information collected outside the fishing sector (i.e. from national nutrition surveys or household income/expenditure surveys) is the best or only data available on small-scale shrimp fisheries.

Gulland (1984) reports on a global meeting of shrimp specialists held in the early 1980s and discusses many features related to the management of shrimp fisheries, including the importance of catch and effort statistics. The conclusions of the meeting in this regard are still applicable today – and suggest that many aspects of reporting data on shrimp fisheries did not change in the last quarter century.

BOX 32

Data from Indonesia and Shark Bay, Australia

Venema (1996) indicates that over the previous decade in Indonesia, shrimp stock assessments were undertaken with data from various sources, including: (i) survey data from research vessels; (ii) data collected by scientists on commercial fishing boats; (iii) logbook data; (iv) data collected at landing places; (v) data collected by interviewing captains and crews of commercial fishing vessels at fishing harbours; and (vi) government fishery statistics at the provincial and regency level. After a thorough scrutiny of the data, it was concluded that all assessments need to be redone with independent data, including data on catch rates by different types of gear. Even rudimentary shrimp assessments were only possible in three areas and were based on focused research results, rather than the official statistics.

In the Shark Bay Prawn Fishery of Western Australia, data are obtained through compulsory monthly logbooks, which all operators voluntarily complete on a daily basis. Commercial logbooks are validated against processor records and against VMS data. The logbooks contain information on daily and shot-by-shot target and by-product catch, hours trawled and areas of operation. Data on protected species interactions have been collected through the observer surveys operating in the fishery since 1998.

Source: Environment Australia, 2002.

- Adequate data collection is crucially important, comprising at least comprehensive statistics on catch and fishing effort, distinguishing catches of different species of shrimp and some data on the sizes of shrimp caught.
- Although statistics on total catch are readily available for most of the main industrial shrimp fisheries, if not all, there is concern that information has not been collected on significant catches in sport, subsistence and artisanal fisheries.
- Since complete catch data are basic to many analytical approaches, omissions of potentially large components of the total catch can be a serious problem. Because the size of these unreported components may vary radically over time, the inability to address or even detect such changes could create a very biased picture of the condition of the stock.
- The practice of discarding fish in the shrimp fisheries is well known, but it has been pointed out that in several fisheries, small shrimp is also discarded but the amounts are not often recorded; this may seriously affect the results of stock assessments.
- Since otter trawls are not the only gear in many shrimp fisheries, a broad consideration of shrimp fishing effort would need to take various other gears into account.

A recent technological innovation is improved data reporting in some shrimp fisheries. The use of electronic logbooks is being contemplated or introduced in some of the more advanced countries. In the last few years, many of the vessels participating in Australia's NPF reported using electronic notebooks. Studies related to modifying the Gulf of Mexico Shrimp Fishery Management Plan suggest that the use of 100 percent coverage with electronic logbooks is one option to enforce a trip/days quota system.

16. Impacts of shrimp farming on shrimp fishing activities

GENERAL INFORMATION ON SHRIMP FARMING

Briggs *et al*. (2004) review the history of shrimp aquaculture.[17] Modern shrimp farming began in the late 1960s and early 1970s when French researchers in Tahiti developed techniques for intensive breeding and rearing of various penaeid shrimp species, including *Penaeus japonicus, P. monodon* and later *P. vannamei* and *P. stylostris.* At the same time, in China, *P. chinensis* was produced in semi-intensive ponds, while *P. monodon* was produced in small intensive ponds in Taiwan Province of China. In North America, the NMFS began funding research on shrimp farming.

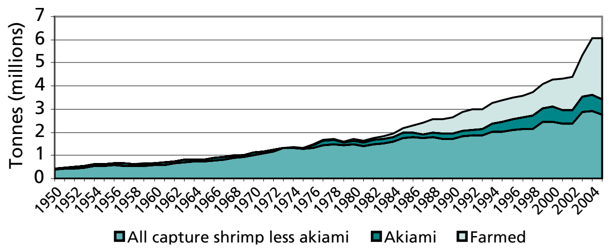
Until the early 1980s, world shrimp harvests were comprised almost exclusively of catches in oceans and bays. In 1982, cultured harvests accounted for only 5 percent of total shrimp production. By 1990, shrimp aquaculture was credited with 25 percent of world shrimp harvests and about half of all shrimp exports. In 2000 and 2001, new shrimp farming projects came on line all over the world, particularly in Viet Nam, Brazil and China. Brazil quickly became the low-cost producer in the Western Hemisphere, while shrimp farmers in Asia learned to produce large yields of shrimp at very low prices. Governments throughout Asia encouraged the development of shrimp farming with land concessions, tax breaks, easy loans and technical assistance. Consequently, from 1999 through 2004, production of farmed shrimp doubled, from approximately 1 million to an estimated 2 million tonnes (Shrimp News International, 2004). Clay (2004) estimates that 1 to 1.5 million people are directly employed in shrimp farming, with another million dependent on the industry for a major portion of their livelihoods.

Figure 30 gives the evolution of shrimp harvesting in the world and the proportion of capture[18] and culture shrimp production.

Today, world annual production of shrimp, both capture and farmed, is about 6 million tonnes. Currently, just over 40 percent of world shrimp production is from farming, or about 2.6 million tonnes per year. With respect to exports, the precise composition is not known with certainty (capture and farmed shrimp is combined in export statistics), but it appears that about 60 percent of internationally traded shrimp comes from aquaculture.

The leading shrimp farming countries are shown in Table 17. It can be seen that the five largest Asian producers are responsible for about 80 percent of world cultured shrimp.

FIGURE 30
World shrimp production, 1950–2004



Source: FAO, 2007.

[17] Shrimp aquaculture in this report is confined to marine and brackish-water operations.

[18] Since it can be argued that the capture of akiami paste shrimp is distinct from most other species (magnitude of production, fishing technique, product form, end market), the world catches of akiami paste shrimp are given separately.

TABLE 17
Leading producers of farmed shrimp

Country	2000	2001	2002	2003	2004	2005
China	217 994	304 182	384 141	789 373	935 944	1 024 949
Thailand	309 862	280 007	264 924	330 725	360 292	375 320
Viet Nam	89 989	149 979	180 662	231 717	275 569	327 200
Indonesia	138 023	149 168	159 597	191 148	238 567	279 539
India	96 715	102 930	114 970	113 240	117 589	130 805
Mexico	33 480	48 014	45 853	45 857	62 361	72 279
Brazil	25 388	40 000	60 000	90 190	75 904	63 134
Bangladesh	59 143	55 499	56 020	56 503	58 044	63 052
Ecuador	50 110	45 269	46 735	55 500	56 300	56 300
Myanmar	4 964	5 473	6 550	19 181	30 000	48 640
Philippines	41 812	42 390	37 479	37 033	37 947	39 909
Malaysia	15 894	27 014	25 582	26 180	30 838	33 364
Colombia	11 390	12 000	14 000	16 503	18 040	18 040
Venezuela (Bolivarian Republic of)	8 500	10 512	12 000	14 259	16 500	16 500
Saudi Arabia	1 961	4 150	4 650	9 160	8 705	11 259
Belize	3 630	4 460	4 400	10 160	11 042	10 433

Source: FAO, 2007.

Currently, all significant commercial shrimp farming operations are based on the penaeid species. Table 18 shows the important cultured shrimp species.

The increasing popularity of farmed shrimp is attributable to several factors:

- the farm-raised product has greater consistent quality than the wild product;
- the farmed product is less seasonal in nature and production is more reliable than its wild counterpart;
- the species and sizes can be controlled better in a farm-based system than in a wild-based one; and
- the current trend towards vertical integration in the farming system lends itself to better adaptation to consumer needs (Ward *et al*., 2004).

On the other hand, aquaculture operations are unable to produce larger sizes of shrimp economically, which are especially valuable. In some markets, there is a preference for the taste of captured shrimp.

Shrimp farming is not without major problems; FAO *et al.* (2006) review some of them. Rapid expansion of shrimp farming has generated substantial income for many developing countries, as well as developed ones, but has been accompanied by rising concerns over the environmental and social impacts of development. Major issues raised include the ecological consequences of conversion of natural ecosystems, particularly mangroves, for the construction of shrimp ponds; effects such as salination of groundwater and agricultural land; the use of fishmeal in shrimp diets; pollution of coastal waters through pond effluents; biodiversity issues arising from the collection of wild brood and seed; and social conflicts in some coastal areas. The sustainability of shrimp aquaculture has been questioned by some in view of self-pollution in shrimp-growing areas, combined with the introduction of pathogens, leading

TABLE 18
Production of farmed shrimp

English name	Scientific name	Farmed production in 2005 (tonnes)
Whiteleg shrimp	*Penaeus vannamei*	1 594 039
Giant tiger prawn	*Penaeus monodon*	710 806
Penaeus shrimp – nei	*Penaeus* spp.	125 025
Banana prawn	*Penaeus merguiensis*	81 105
Fleshy prawn	*Penaeus chinensis*	51 300
Kuruma prawn	*Penaeus japonicus*	43 181
Indian white prawn	*Penaeus indicus*	31 875
Metapenaeus shrimp - nei	*Metapenaeus* spp.	14 600
Blue shrimp	*Penaeus stylirostris*	3 170

nei – not elsewhere included
Source: FAO, 2007.

FIGURE 31
A shrimp farm in New Caledonia

Courtesy of B. Ponia, Secretariat of the Pacific Community.

to major shrimp disease outbreaks and significant economic losses in producing countries. Béné (2005) indicates that the social impacts of shrimp farming include: loss of access to mangrove resources and services; marginalization and increased vulnerability of local communities; social unrest, conflicts and harassment leading, in some extreme cases, to loss of life and ultimately, a widening gap between the poorest and the more affluent.

Rising concerns over the environmental and social impacts of shrimp farming led to the formation in 1999 of the Consortium on Shrimp Farming and the Environment, whose purpose is to analyse and share experiences on these impacts, and on the management of sustainable shrimp farming. The Consortium consists of representatives of FAO, the Network of Aquaculture Centres in Asia-Pacific, the Coordination Office of the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities of UNEP, the World Bank and WWF. The Consortium formulated the International Principles for Responsible Shrimp Farming from studies and consultations involving a wide range of stakeholders, from government, private and non-governmental organizations. These principles provide the basis upon which stakeholders can collaborate for a more sustainable development of shrimp farming. The eight principles cover farm siting, farm design, water use, broodstock and PL, feed management, health management, food safety and social responsibility (FAO *et al*., 2006).

GENERAL IMPACTS

Shrimp farming affects shrimp fishing in several ways, giving rise to some controversy as a result. In a review of shrimp farming and shrimp fishing, Iversen, Allen and Higman (1993) indicate that the competition between the two sectors is both real and imagined. Aquaculture industry representatives refute many of the accusations against shrimp farming, including some that impact unfavourably on shrimp fishing. Overall, most stakeholders would agree that interactions between shrimp farming and shrimp fishing are fluid, not well established or understood, and therefore open to considerable speculation.

The impacts of shrimp farming on shrimp fishing are different in the various regions. Interaction appears to be most intense in Southeast Asia, with many elements apparent in Indonesia (Box 33).

The economic effects that aquaculture in general has on fishing have been well studied. Ye and Beddington (1996) in their study of bioeconomic interactions between capture and culture fisheries found that the entry of aquaculture lowers market price, increases total supply, reduces fishing effort and raises natural fish stocks. When culture costs are reduced, the fish price will decrease and fishing effort will decline. Willmann (2005) states that capture fisheries and aquaculture produce fish and supply the same processing industries, markets and consumers. Capture fisheries and aquaculture therefore compete in these markets, and the supply of cultured fish will influence the price of wild fish and vice versa.

The main effects that shrimp aquaculture has on shrimp fishing can be classified in several categories:

- economic impacts in the marketplace;
- destruction of mangrove forests for shrimp aquaculture operations; and

BOX 33

Impacts of shrimp aquaculture on shrimp fishing in Indonesia

Shrimp aquaculture in Indonesia affects shrimp fishing in several ways.

- Many shrimp farms in Indonesia are situated in former mangrove forests. In Sumatra, large sections of mangrove forests have been transformed into shrimp ponds from Aceh to Lampung, where the world's largest shrimp farm (18 000 ponds) was constructed in the 1990s.
- Although there is considerable hatchery production of fry for shrimp farming, there is still some collection of fry in the wild. Official fishery agency data indicate that 27.5 million tiger prawn fry (valued at US$275 000) were collected in 2003, mostly from Sulawesi.
- The large increase in farmed shrimp production has led globally to a decline in prices for all shrimp, including captured shrimp. The shrimp price fall and the rise in fuel prices are the main components of the present financial problems. This is having a major effect on commercial shrimp fishing in Indonesia and is likely to result in fewer Indonesian shrimp fishing operations and a lower shrimp catch.

Source: based on Part 2.

- capture of shrimp PL and broodstock for farming;
- escapes of cultured shrimp into the wild;
- other impacts, including "trash fish" and symbiosis.

These aspects are dealt with in more detail below.

ECONOMIC IMPACTS IN THE MARKETPLACE

The best studied example of economic interaction between shrimp fishing and shrimp farming occurred a few years ago, when large amounts of cheap imported farmed shrimp came on the market in the United States. In simplistic terms, the supply of shrimp on the world market soared mainly as a result of farming operations; prices decreased; imports into the United States increased; and prices paid to domestic fishers fell, causing a demise of warm-water shrimp fishing in the country. According to Ward *et al*. (2004), major impacts are the following.

- Since 1980, much of the growth in world shrimp production has been the result of successful farming activities throughout the world, particularly in Asia and, to a lesser extent, in South and Central America. World production of farmed shrimp in 1980 was about 160 million pounds[19] (live weight), which accounted for approximately 5 percent of total world production at the time. By 2001, farmed production had advanced to 2.8 billion live-weight pounds, or more than 35 percent of total world warm-water shrimp output.
- There was an 11 percent increase in world farmed shrimp production from 2000 to 2001, representing an additional 280 million pounds of shrimp (live weight) on the world market.
- From 1997 to 2001, import prices (in constant United States dollars) declined from US$5.20 to US$4.25; shrimp imports into the United States increased by about 50 percent; and prices paid to domestic fishers declined from US$2.13 to US$1.73.
- Analysis shows that the ex-vessel shrimp price should decline 84 cents per pound for every hundred million pounds of shrimp imported into the United States.

[19] Seafood weights in the United States are expressed in pounds; 1 pound = 0.453 kg.

- Although farmed shrimp imports were responsible for much of the price decrease, other factors could have contributed, including the varying conditions of national economies, tariff structures and tolerance levels for banned chemical substances.[20]

Shrimp price declines, at least partially a result of the increased availability of low-cost farmed shrimp, were not confined to the United States. From the mid-1990s to 2005, a major feature in the shrimp markets was that prices were generally falling. In Japan, there has been a general downward trend in prices from the mid-1990s. In the EU, combined penaeid import prices mostly declined from 2000 to 2005.

Since late 2005, the shrimp price situation has changed, with farmed shrimp once again responsible to some degree. Lower than expected aquaculture production, especially in Thailand, together with increased Asian domestic consumption, have been causing shrimp prices to increase.

Globally, the effects of cheap farmed shrimp are felt in most shrimp fishing fleets, especially those that target the major international markets. The resultant income declines are a major component of the current worldwide shrimp fishing "profit squeeze". The typical current situation for shrimp vessels is rising costs (mainly fuel) and falling revenue from shrimp sales (competition with lower-cost farmed shrimp being a major component) in an environment where there is overcapacity.

Several measures are being discussed or implemented to mitigate the adverse economic effects of shrimp farming on shrimp fishing. At the level of the individual vessel, low shrimp prices (from whatever cause) reduce profitability and, consequently, the means to increase revenue (e.g. higher catch rates) or lower expenses (e.g. fuel efficiencies) are pursued. At the fleet level, capacity reduction is often attempted in restricted access fisheries. At the national level, subsidies, trade promotion and trade restrictions are used.

The boldest example of such a trade restriction was the initiative in the United States to restrict the import of farmed shrimp, on the basis that it had been dumped on the market (Chapter 5, section *Important issues in the shrimp trade*). In December 2003, the Southern Shrimp Alliance, a lobbying organization formed by shrimp fishers and processors in eight southern states, filed an anti-dumping petition with the United States Department of Commerce against shrimp farms in Brazil, China, Ecuador, India, Thailand and Viet Nam. In July 2004, the Department imposed duties varying up to 113 percent on farmed shrimp from these countries.

DESTRUCTION OF MANGROVE FORESTS

The destruction of mangrove forests for shrimp farming operations is well known and acknowledged even by aquaculture industry representatives. There is considerable disagreement, however, over the amount of this destruction in the past caused directly by shrimp farming. For the present discussion, the important issue is the degree to which mangrove destruction caused by shrimp farming affects shrimp fishing.

Clay (1996) cites various sources to summarize the mangrove/shrimp issue. Mangroves are estimated to have once lined as much as 75 percent of the world's tropical coasts, but perhaps half of the mangrove areas have been destroyed for various reasons, including urbanization, commercial logging, unrestricted firewood collection, charcoal making, river impoundment and shrimp pond collection. Globally, shrimp farming is not responsible for even a quarter of the mangrove clearings that have taken place since 1960 but, in the last ten to 20 years, mangrove destruction has been accelerated by shrimp farming. Much of the information on mangrove destruction is vague, general and contradictory. Specific data from one region are generalized for a whole country and the

[20] These chemicals are mainly chloramphenicol and nitrofuran in shrimp imported from Thailand. The EU had a lower tolerance level, resulting in shrimp being redirected to the United States.

FIGURE 32
Shrimp pond in a former mangrove area

Courtesy of B. Ponia, Secretariat of the Pacific Community.

relative importance of multiple causes is not identified. Current use of areas that were once mangroves is often assumed to be the cause of the destruction, when in many cases, this was not so. Examples of original causes are milkfish and rice cultivation in many places of the Philippines and India, respectively. In assessing the overall situation, it appears that mangrove destruction is a complex subject. There is no useful purpose in hiding this fact, but there is little doubt that shrimp aquaculture poses the most serious threat to mangroves in regions that are considered suitable for shrimp ponds.

There are contrasting views on the amount of mangrove destruction caused by shrimp farming. An environmental group states:

We can reasonably estimate that more than one-third of total mangrove loss has been due to shrimp farming, which appears to be clearly the greatest single threat to mangroves worldwide (Greenpeace, 2004).

A paper by a representative of the Global Aquaculture Alliance states that less than 3 percent of the loss of world's mangrove resource is a result of shrimp farm development, and indicates that this figure puts shrimp farming impacts into perspective as a minor cause of global mangrove losses (Chamberlain, 2001). Boyd and Clay (1998) estimate that shrimp farming is responsible for some 5 to 10 percent of the global loss of mangrove habitat. FAO (2006c) reviews various studies and concludes that "aquaculture globally accounts for less than 10 percent of the loss of this important habitat".

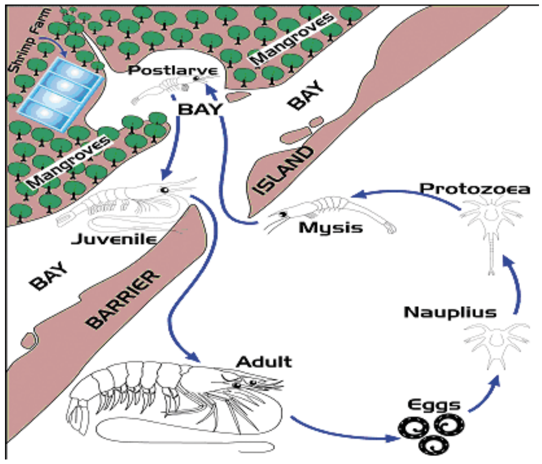
Despite the controversy over the amount of past mangrove destruction by shrimp farming, there now appears to be a consensus among stakeholders that there is a declining trend. Factors contributing to less mangrove destruction include government action banning mangrove removal and the realization that the acidic soil found in mangrove areas is unfavourable for shrimp farming. In addition, the movement towards intensive shrimp farming has limited the clearance of large areas that took place in previous years (S. Funge-Smith, personal communication, April 2007).

How does mangrove destruction affect shrimp fishing? Clay (1996) states that postlarval and juvenile stages of shrimp depend on mangroves for survival. Primavera (1995) studied mangroves as shrimp nurseries in one area of the Philippines. The author's report concluded that the nursery use of mangroves by shrimp is well defined and year-round in a riverine mangrove area; limited to peak recruitment periods in an island mangrove area; and absent in a non-vegetated tidal flat. The report also cites a variety of other studies that show a positive correlation between mangrove area and near-shore fish and shrimp catches in the Philippines, Malaysia, Indonesia and Australia. EJF (2003) indicates that in Malaysia, a study estimated that from each hectare of mangrove, 600 kg each of finfish and shrimp are produced annually. Naylor *et al.* (2001) estimate that in areas of Thailand where shrimp farms have been carved out of mangrove forests, a total of 400 g of wild fish and shrimp are lost from near-shore catches for every kg of shrimp farmed. On the other hand, many shrimp farming experts feel that the relationship between mangrove destruction and shrimp fishing has not been well researched and many of the quantitative findings would not stand up under close scrutiny (R. Subasinghe, FAO, personal communication, 2007).

Figure 33 shows schematically the life cycle of penaeid shrimp and its association with mangroves. A possible location for a shrimp farm in the mangrove area is also given.

In recognition of the need to address mangrove destruction by shrimp farming, the Consortium on Shrimp Farming and the Environment (this chapter, section *General information on shrimp farming* above) included mangrove issues in its International Principles for Responsible Shrimp Farming. It stipulated that there should be no net loss of mangroves or other sensitive wetland habitats; and that existing farms should be improved in intertidal and mangrove areas through mangrove restoration, retiring unproductive ponds and increasing the productivity of remaining farm areas above the intertidal zone.

FIGURE 33
The penaeid life cycle and mangroves



POSTLARVAE AND BROODSTOCK

The capture of shrimp PL and broodstock for shrimp farming is likely to have had negative effects on shrimp fishing. Although there are diverse impacts from these capture practices, the main problems for shrimp fishing appear to be that the capture of PL may result in considerable bycatch (including juvenile shrimp) and the capture of adult broodstock may result in overfishing of shrimp.

Garcia (1989) indicates that the collection of PL from natural sources is a major source of conflict between shrimp culture and capture. Clay (1996; 2004) reviews the collection of PL for shrimp culture. Traditionally, shrimp farmers relied on wild shrimp for the production of seedstock. Currently, they either capture wild juveniles, which are stocked directly in a nursery or growout pond, or they spawn egg-laden or gravid females at a hatchery. Unfortunately, there is good evidence that the bycatch from capturing wild PL is even higher than from the shrimp trawling industry. Two studies are cited in support of the statement, “for every single shrimp grown in a pond, almost a hundred other fish or shrimp are killed”.

The situation is changing. Most of the shrimp seed used in the world today no longer relies on wild-caught larvae, but comes from hatcheries. Clay (2004) indicates that globally, some 98 percent or more of PL used by farming operations are produced in hatcheries. Wild-caught PL are most common in Bangladesh, India and Ecuador, where hatcheries are not required by law. Kura *et al.* (2004) state that even farmers in countries such as Ecuador, who favoured the use of wild seed for shrimp farms, are now shifting to hatchery-reared seed because it is perceived to harbour fewer diseases. Because of hatcheries, the capture of wild PL has become much less of an issue in many countries, but continues to be problematic in some places. Shrimp farmers in Bangladesh are currently partly dependent on wild fry and its collection contributes to the livelihood of several hundred thousand poor people (Nautilus Consultants and IIED, 2003). In Indonesia, there is considerable hatchery production of fry for shrimp farming, but a significant amount of fry in the wild is still collected (Box 33). Cascorbi (2004a) points out a dilemma: while the capture of larvae is still a cottage industry in some economically disadvantaged coastal communities, larva fishing takes a heavy toll on bycatch of the youngest stages of many fish and invertebrates.

Some facilities now specialize in breeding shrimp in captivity to raise broodstock. While this takes some of the pressure off wild shrimp populations, there is not enough broodstock cultivated to supply worldwide demand (Cascorbi, 2004a). The shrimp farming industry, especially in Asia, remains highly dependent on the capture of wild broodstock for hatchery spawning. Although substantial progress has been made in

Latin America with regard to captive breeding programmes for *Penaeus vannamei* and *P. stylirostris*, similar success has not occurred in Asia for *P. monodon (*Nautilus Consultants and IIED, 2003).

The high value of wild shrimp broodstock for farmers can cause fishers to target it. There is the contention that prices received may enable fishing effort to increase to a level above that of normal (non-broodstock) shrimp fishing, thereby increasing the possibility of overfishing. Alternatively, some shrimp farming specialists feel that there is a lack of evidence about this and such interaction is largely speculation.

The Consortium on Shrimp Farming and the Environment included this issue in its International Principles for Responsible Shrimp Farming in recognition of the need to address the wild capture of PL and broodstock for shrimp farming, It stipulated that, where possible, domesticated selected stocks of disease-free and/or disease-resistant shrimp broodstock and PL should be used to enhance biosecurity, reduce disease incidence and increase production, while reducing the demand for wild stocks.

In general, there appears to be a consensus that that there is a decreasing trend for PL and broodstock collection in the world. The controversy seems to be whether the much diminished quantities are still a problem or are "next to nothing", as currently stated by some shrimp farming specialists. Of relevance to the present study is whether what is taken has a significant effect on shrimp fishing.

ESCAPES OF CULTURED SHRIMP

Escapes of cultured shrimp into the wild affect shrimp fishing in both positive and negative ways. Shrimp has been introduced (transported and released outside the present species range) and transferred (transported and released within the present species range) for shrimp farming purposes (Clay, 1996). This has raised two issues for shrimp fishing: the establishment of non-native shrimp populations and the dissemination of pathogens.

Chemonics (2002) states that an important and interesting feature of recent shrimp fishing in Nigeria has been the arrival of wild *Penaeus monodon* specimens in trawler catches. *P. monodon* (tiger shrimp) appeared four years ago, mainly in the Calabar/eastern delta zone of Nigeria, where it comprises as much as 10 percent of trawler catches. It is an Asiatic exotic that could only have arrived through human agency (African current patterns preclude natural introduction), and presumably escaped from a West African (Gambian, Senegalese or Cameroonian) shrimp farm. This occurrence is important for shrimp farming for two reasons. First, it forestalls the question of introducing an exotic farm species to an existing economically important shrimp ecosystem – obviously, *P. monodon* already exists in Nigerian waters. Second, hatcheries that are essential for commercial shrimp culture still mostly depend on wild-caught gravid (egg-bearing) females for a source of eggs. This is particularly true for *P. monodon*, so that the presence of a viable population in Nigerian waters ensures a local supply of these gravid females for farming purposes. What remains unclear is which species, if any, has been displaced by the invasion of *P. monodon*.

Cascorbi (2004) indicates that as a result of escapes from shrimp farms, Pacific white shrimp (native to the west coast of the Americas) is now found in the Gulf of Mexico. Briggs *et al.* (2004) state that a total of nine penaeid species has been introduced for farming purposes into the Pacific Islands (mainly Tahiti and New Caledonia) but, of these, only the banana prawn (*Penaeus merguiensis*) has become established in the wild (in Fiji).

These species introductions could have complex ecosystem and genetic implications. Their effects on shrimp fishing appear to be mixed. At least in the short term, the arrival of a new and valuable shrimp species in Nigeria is appreciated by the country's shrimp fishers. In Fiji, where there is no commercial shrimp fishing, the new species goes virtually unnoticed by coastal residents or even fishery researchers.

There is considerable uncertainty over the possibility that shrimp pathogens may be disseminated through shrimp that has escaped from farms. Clay (2004) states that the impact of disease pathogens on wild stocks is not documented, but anecdotal information suggests that it may be serious. In 1992–93, for example, when diseases reduced shrimp farming production by 60 to 70 percent, the production of wild-caught shrimp in China also declined by 90 percent. Briggs *et al*. (2004) review various studies on wild shrimp populations affected by viruses from shrimp farming.

- Overstreet *et al.* (1997) and JSA (1997) report that pathological viruses could be transmitted to native wild penaeid shrimp populations; thus, introduced alien shrimp viruses may be capable of infecting these shrimp populations.
- Taura syndrome virus (TSV) has been detected in wild *P. vannamei* escapees in the United States, but appears to have had minimal impact on wild shrimp populations (Brock, 1997; Global Monitoring for Food Security [GMFS] Web site; World Organisation for Animal Health [OIE] Web site). TSV appears to occur largely as a subclinical infection in populations of wild shrimp (Brock *et al.*, 1997).
- There is also some evidence of TSV in the wild populations of *P. monodon* around the southwest coast of Taiwan Province of China during 2000, although pathological effects on its new host were not noted and they appear largely unaffected (IQ2000 Web site, cited in Briggs *et al*., 2004).
- There are speculations that another virus, infectious hypodermal and haematopoietic necrosis virus (IHHNV), originating from United States culture facilities, may have caused the closure of the Mexican shrimp fishery from 1987 to 1994 and the loss of millions of dollars, since wild *P. stylirostris* (and other less prevalent native species) proved highly susceptible to IHHNV (Lightner, 1996; JSA, 1997). The virus is commonly found in wild shrimp on the Pacific coast of Latin America and throughout Asia, from where it probably originated (OIE Web site; Lightner, 2002).

An alternative view of the situation is provided by some shrimp farming specialists. They feel that because good data on any wild population declines and subsequent catch reduction are mostly absent, the relationship of escapes of cultured shrimp to shrimp fishing is largely conjecture.

OTHER IMPACTS OF SHRIMP FARMING ON SHRIMP FISHING

"Trash fish" has been defined as "fish that have a low commercial value by virtue of their low quality, small size or low consumer preference. They are either used for human consumption (often processed or preserved) or used to feed livestock/fish, either directly or through reduction to fishmeal/oil" (Funge-Smith, Lindebo and Staples, 2005). The composition of trash fish is highly diverse, with over 97 fish families represented in the trash fish of Southeast Asia and China. This is because of the numerous types of fisheries that contribute to trash fish and the fact that most comes from trawl fisheries (WorldFish, 2005). Funge-Smith, Lindebo and Staples (2005) review trash fish issues in the Asia-Pacific region. The continued expansion of aquaculture in the region has resulted in dependency on capture fisheries for trash fish. There is general concern that the rapid expansion of aquaculture may ultimately be constrained by dependence on trash fish and fishmeal, popularly referred to as the "fishmeal trap". A dangerous spiral has evolved where the demand for trash fish has supported increased fishing pressure on already degraded resources.

There is some debate as to the amount of trash fish from shrimp trawling used in shrimp farming operations. FAO (2006c) cites an example of up to 140 000 tonnes of trash fish being used annually in the mid-1990s for farming *Penaeus monodon* in Viet Nam. However, some shrimp specialists feel that trash fish use in shrimp farming is not important. If it is indeed significant or increasing, it may be an important issue because: (i) increasing demand for trash fish may create economic incentives for bycatch increases by shrimp trawling and other fishing techniques, rather than bycatch reduction; and (ii) in some developing countries, trash fish previously used for human consumption is now being used to feed farmed shrimp exported to affluent countries.

Shrimp farming and shrimp fishing each have public relations problems. In the minds of consumers, some of the stigmas of farming can affect the image of fishing and vice versa. One of these is that the use of chemicals in shrimp aquaculture can negatively affect the perception of captured shrimp in the marketplace. Two references, which may be only applicable to the United States situation, illustrate a negative attitude towards farmed shrimp that has caused concern in the shrimp capture industry.

- *Nearly 80 percent of the shrimp that American consumers eat in restaurants or buy at the grocery store are imported and farm-raised. Chances are, the delicious shrimp cocktail you're splurging on is loaded with antibiotics and chemicals because that's what goes into the cramped, dirty ponds made to mass-produce shrimp. Doesn't sound yummy, does it?* (www.foodandwaterwatch.org/fish/shrimp)
- *Consumer health risks associated with eating imported farmed shrimp have been given little attention in the United States. While shrimp tops the list of popular seafood choices, consumers are usually unaware of the health impacts. By the time shrimp arrive in grocery stores or are served in a restaurant, it has been injected with antibiotics, doused in pesticides and fed chemical-laden food. Imagine what this chemical cocktail does to your health* (Public Citizen, 2004).

Nevertheless, shrimp farming and shrimp fishing can form a favourable symbiosis in marketing, as shown by an example from Madagascar. There, the limited shrimp farming specializes in the production of *Penaeus monodon* and is almost all owned by industrial and artisanal shrimp vessels. This situation illustrates the potential for combining resources for effective monitoring of international markets and associated exporting. By combining marketing for both wild and farmed shrimp, clients can be offered a large range of shrimp: different species, different sizes and wild/farmed options.

There seems to be an additional, yet more subtle impact of shrimp farming on shrimp fishing. Both sectors have their difficulties: for example, farming has problems with mangrove destruction and fishing with bycatch and other issues. Generalization is difficult but, in many fishery agencies, it appears to be felt that the problems of shrimp farming are more manageable than those of shrimp fishing. Although this difference in perception may not be great, the implications could be significant in terms of government support. In some places, this could result in shrimp farming receiving relatively more subsidies, development attention, research allocation and favourable treatment in management schemes. For example, in the 1970s in the United States, there was a remarkable shift in research priorities by the Federal Government from shrimp fishing to shrimp farming.

OTHER CONSIDERATIONS

It can be seen from the above discussion that shrimp farming has had a substantial impact on shrimp fishing activities, with some quite definite forms of interaction and others more open to debate. Interaction in the marketplace seems to be the most certain, with the most effect, at least during the present period of low profitability.

There is frequent debate as to whether past trends will continue in the future and whether farmed shrimp will largely displace capture shrimp. Despite the considerable uncertainty, this seems unlikely to happen.

Farmed shrimp is likely to acquire a larger market share of global shrimp production, especially in view of rising fuel costs for the energy-intensive capture sector and limited opportunities for expansion of catches; however, a complete displacement is improbable for various reasons. Historically, production trends (Figure 30) show that shrimp production from both capture and farming increased over the last 20 years; hence, farming increases have not been at the expense of capture declines (i.e. the market is growing). Without increasing demand, conditions for captured shrimp would be more difficult, but several authors have commented that, in such a competitive environment, shrimp fishing fleets will probably become more profitable as the less efficient operators drop out. In addition, the various subsidies enjoyed by shrimp fishers (including for fuel) are likely to continue. It should also be remembered that aquaculture operations have great difficulty in producing economically the large-size shrimp so valued in many markets.

Finally, a great deal of shrimp farming (and its expansion) is largely related to international markets while, domestically, the captured product has certain advantages, including the low production costs of small-scale fishers and important markets not suitable for aquaculture, such as the large domestic demand in Asian countries for condiments made of paste shrimp.

17. Conclusions

Since the observations on the main shrimp fishery issues made in the preceding chapters are actually summaries of those subjects, they do not require further repetition. However, some other findings of the present study could be considered cross-cutting since they emerge in discussions of several different topics. A few deserve additional attention in this chapter: whether or not shrimp fishing is manageable; difficulties in small-scale shrimp fisheries; and benefits/costs of shrimp fishing. Some general suggestions for improvement are also given here.

IS SHRIMP FISHING MANAGEABLE?

In the course of collecting information for the present study, the question of whether or not shrimp fishing is manageable arose on several occasions, both in the literature and in discussions. On reflection, the prospect of "manageability" seems to depend on perceptions of the management process and of its outcomes.

The recent history of shrimp fishing, especially that of warm-water shrimp trawling where many difficulties lie, shows that much of associated management activity is aimed at mitigating perceived problems. This characteristically involves reducing negative interactions with small-scale fishers, alleviating overfishing of target and non-target species, decreasing bycatch and/or discards, and lessening impacts on the seabed and ecosystem.

Sufficient technology and management experience now exist to mitigate these major problems. Substantial advances have been made in understanding the biology of the main shrimp species and their resilience to fishing pressure, and indeed such work has been commendable in showing the benefits of biological fisheries research in general. Spatial separation methods, enhanced by new technologies (e.g. VMS), can be used to reduce or eliminate industrial shrimp trawlers from interfering with inshore fishers. A great deal of work has been done on bycatch reduction, which has shown the way to successful interventions, by gear modifications and restrictions on fishing. Although the study of impacts on the seabed and the wider ecosystem is challenging, our understanding of these disturbances is increasing and several effective mechanisms to reduce physical impacts have been developed.

Fisheries management institutions in some countries are able to take advantage of these mechanisms and knowledge and alleviate many of the identified difficulties in shrimp fishing. Some of the best managed fisheries in the world of any type (invertebrate, finfish or otherwise) are shrimp trawl fisheries. Australia's Northern Prawn Fishery and Spencer Gulf Prawn Fishery are global models for many aspects of fisheries management, including stakeholder participation, flexibility/responsiveness of interventions, verifiable achievement of objectives and the use of rights-based approaches. Some of the cold-water shrimp trawl fisheries are also exemplary for similar reasons.

It is therefore apparent that there are tools and models that can effectively mitigate the difficulties associated with shrimp fishing. The inference is that shrimp fishing, including shrimp trawling, is certainly manageable. This does not mean that shrimp fishery management practices are problem-free; in many countries, weak agencies dealing with fisheries, lack of political will and inadequate legal foundations cause failures in management. It is these factors that are largely responsible for lack of success, rather than any inherent unmanageable qualities of shrimp fishing gear or shrimp fishing practices. Statements such as "shrimp fishing in this country is far more damaging than all other fishing put together" reveal more about the quality of the management regimes in that country than about shrimp fishing.

The above has implications for the improvement of the management of shrimp fisheries. It suggests that, in many countries, initiatives to enhance management should focus on these institutional aspects. Formerly, the agenda for improving the management of shrimp fisheries in many countries was oriented towards biology and technology, which in many cases was successful. At present, the weakest link – at least in many developing tropical countries where much of the shrimp management difficulty occurs – relates to institutional problems and in understanding the need for and benefits of management intervention. This suggests that efforts to improve shrimp fishery management in these countries should include more attention to such factors as agency effectiveness, awareness raising and the adequacy of legislation to support rights-based and dedicated access systems. For developed countries, much of the challenge lies in improving economic conditions within shrimp fisheries to deal with competition from aquaculture and rising fuel prices.

Another aspect of the question concerns management objectives. Many of the misunderstandings among the various concerned stakeholders are not fundamentally about shrimp fishing gear or fishing activities, or whether they can be controlled or not. Rather, they relate to differing ideas on acceptable costs transferred (externalized) by the gear/activities to non-target species, other fisheries, the environment and society. After all, management tools and experience are currently available to attain almost any level of costs. Perceived lack of success at achieving management objectives (i.e. the inability to manage shrimp fishing) often results from a lack of consensus over these objectives. This suggests that another key aspect for the enhancement of shrimp fishery management is an improvement in the participatory processes needed to generate greater stakeholder agreement on acceptable costs.

The conclusion here is that shrimp trawling is indeed an activity that can be managed to achieve objectives. In contrast, the management of many small-scale shrimp fisheries in developing countries appears to be extremely difficult.

MANAGEMENT OF SMALL-SCALE SHRIMP FISHERIES IN DEVELOPING COUNTRIES

Small-scale shrimp fishing is very important in many regions and is responsible for a large portion of the total shrimp catch, especially in Asia. The number of small-scale shrimp fishers in the world is not known, but is likely to exceed by far those working on industrial shrimp vessels.

Various chapters of this report cite difficulties dealing with small-scale shrimp fisheries. In Chapter 6, it is argued that the objective of reducing bycatch in many small-scale shrimp fisheries of developing countries is challenging and perhaps even impossible. In Chapter 12, it is suggested that access restriction is necessary to prevent economic overfishing, but this is not practical in many small-scale shrimp fishery situations for several reasons. Other chapters mention the additional difficulties of small-scale shrimp fisheries: concerns over the cost/benefits of research; carrying out stock assessment; and obtaining reasonable catch data. It is also cited that management of these fisheries often "relies on non-existent enforcement". In many countries, even modest top-down regulatory interventions dealing with small-scale shrimp fisheries do not succeed because of enforcement practicalities: large numbers of vessels; the impracticality of placing observers on board; many landing sites; and reluctance to place demands on poor people. A further complication is that many of the concerned small-scale fisheries are not really "shrimp fisheries", but multispecies fisheries in which shrimp is caught.

The net result of the above is an extremely challenging situation which, in many cases, may approach what Pauly (1993) refers to as "Malthusian overfishing", i.e. the inability of fishery resources to support large and rising numbers of fishers who have few non-fishing alternatives.

An important issue in these circumstances is whether management interventions can be effective and worthwhile. Chapter 12 gives the many views on this topic, some of which are only applicable to specific national conditions. Most of these opinions on how best to deal with the challenges of small-scale shrimp fisheries and improve their management seem to fall into three categories: a *laissez faire* approach – to recognize the difficult realities and give low or no priority to management; a strategy to favour management measures that are easy to enforce to some degree, such as marine protected areas or total bans; and participatory management, in which communities and government are jointly involved in the management process.

Despite these differences in dealing with the complexities of small-scale shrimp fisheries, many shrimp specialists agree that much more attention should be focused on the issue of what is desirable, possible and practical in their management.

BENEFITS AND COSTS

Shrimp fishing has numerous benefits, but also considerable costs. In Chapter 4, the economic benefits of shrimp fishing are discussed. As regards costs, since there are so many associated with shrimp fishing, they are dealt with in several chapters.

Table 19 gives the benefits and costs of shrimp fishing. The list is not intended to be exhaustive and nor do all benefits/costs apply to every shrimp fishery.

As regards the benefits of shrimp fishing, Chapter 4 provides information for ten representative shrimp fishing countries on simplistic indicators of benefits: contribution to GDP, shrimp consumption, employment, gross value of the catch and value of exports. This information is summarized in Table 6, followed by a number of observations on the availability and reliability of the indicator data. Particularly relevant comments are the following.

- Employment associated with shrimp fishing is often thought to be one of the main benefits. In the ten countries studied, data on employment seem to be the least reliable and least comparable across countries. Where reasonable employment data are available, they are usually confined to formal jobs on board industrial trawlers but, in many cases, employment in small-scale shrimp fisheries is probably much greater than it is on board large vessels.
- Resource rent for a fishery represents the net benefits available to the private and/or public sectors in various forms. Unfortunately, estimates of resource rent appear to have been made for only a few of the world's shrimp fisheries.
- With a view to exploiting the information gleaned, it should be noted that the available benefits information for the ten countries studied represents a heterogeneous assemblage of facts, collected in different ways, with varying

TABLE 19
Some of the benefits and costs of shrimp fishing

Benefits	Costs
Income from direct employment	Physical impacts on sea bottom
Company profits	Overexploitation of target resources
Spin-off benefits (profits/income indirectly generated)	Ecosystem impacts
Nutrition	Conflicts with other fisheries
Export earnings	Cost of subsidies
Government revenue	Management costs (including research, enforcement and costs of exclusion)
Social stability	

degrees of rigour. As such, summations or comparisons of most types of benefit are difficult.

There is often less information available on shrimp fishing costs than benefits and, in many cases, it is considerably less precise. In some well-studied fisheries, several types of shrimp fishing costs are known and readily available to fishery managers. Examples are the financial impact of bycatch in the *Crangon* Beam Trawl fishery of the southern North Sea, and the cost of fisheries management in Australia's Spencer Gulf Prawn Fishery. However, these examples appear to be exceptions – costs in most shrimp fisheries are elusive. For some collateral costs (e.g. physical and ecosystem impacts), neither the methodology for determining impact has been developed, nor that for valuing detected impacts. With respect to costs in developing countries, government fishery agency officials are typically fairly aware of the many types of costs associated with shrimp fishing, but focus, to some degree, only on those that affect the agency's budget (often subsidies and management costs) and involve conflict. Some important observations on shrimp fishing costs are the following.

- A large proportion of shrimp fishing costs appears to be associated with trawling, or at least there is far less information on the costs of other types of shrimp fishing.
- Discards are substantial in many shrimp trawl fisheries, yet Kelleher (2005) states that few comprehensive studies have been carried out on the cost of discards to society and on who bears these costs.
- Costs associated with shrimp fishing, as for most fisheries, occur mainly out of sight and are not visible to the general public.
- Many costs are external to shrimp fishing operations and are borne by society. These externalities represent indirect, and in most cases unconscious, incentives to pursue an irresponsible and altogether uneconomic use of goods.
- There are often significant political costs involved in implementing management.

Both benefits and costs are difficult subjects to quantify and compare, but somehow costs appear more suited to colourful metaphors, such as: "*clear-cutting a forest in order to catch songbirds*" and "*using a bulldozer to harvest corn*". Benefit information, such as income, seems more mundane in proclamations and brochures. Many of the benefits cited in Table 19 are promoted by strong economic forces; some appear transitory. Several costs appear more enduring and some may even be irreversible, such as the eradication of three-dimensional biological structures.

Based on the information in this report, some conclusions can be drawn as to the benefits and costs of shrimp fishing. In the process of managing shrimp fisheries, some form of balancing the benefits of the fishing with the various costs incurred is required. Considering the scarcity and limitations of data on shrimp fishing benefits/costs, it does not seem that there is enough information on benefits in most countries to determine whether costs incurred are justified, at least not in a quantitative sense. Although it is recognized that it is difficult to compare benefits and costs for most shrimp fisheries, in effect they are being compared and trade-offs made in the fisheries development and management processes. The controversy that often results appears to be partially a result of lack of stakeholder consensus over the mechanisms for making the trade-offs, and the adequacy of the information used.

In fisheries where this is indeed the case, information from resource rent studies may improve the process. Estimates of resource rent can be formulated to include both monetary and non-monetary benefits and costs. Considering the advantages, it is ironic that rent information is unavailable for many of the world's shrimp fisheries, just as for most fisheries in the world.

AUSTRALIA

Throughout this report, constant reference to Australia has been unavoidable. The country is a convenient source of positive shrimp fishery examples, including quantity and relevance of research on shrimp/bycatch, bycatch reduction, mitigation of the physical effects of trawling, stakeholder participation in management, "user pays" and management cost-recovery arrangements, data reporting and the use of property rights in management. While a few other shrimp fishing countries can also provide good experience and models, Australia's knowledge is especially valuable for two reasons. First, it concerns warm-water shrimp fisheries, where the interests of developing countries lie and which have the greatest management challenges. Second, Australia's shrimp-related information is internationally available.

In one sense, Australia is a wealthy developed country with well-developed fishery institutions and processes that cannot simply be replicated by a developing country. In addition, Australia does not have a poor and growing population of fishers, and limited access is the norm. Nonetheless, the experience and lessons learned from Australia's large industry and government investment in shrimp fishing research and management could be used as a model to strive towards and could save fishery managers in other countries much expenditure and time, and from having to "reinvent the wheel".

SOME SUGGESTIONS

Many important issues related to the world's shrimp fisheries are highlighted in this report. The findings show that there are many opportunities for improving the sustainable benefits from shrimp fisheries and considerable potential for reducing their negative impacts.

Deficiencies and possible solutions at the fishery and national levels are far better known by individuals and agencies at these levels. Because the present study has some advantage in looking at issues globally, it is appropriate that attention be focused on those subjects that are generally applicable and where there is potential for international cooperation. Another factor in favour of generalizations is that, because shrimp is one of the few real fishery "commodities", the improvement of shrimp fishery management is simply often not compatible with local solutions, because of global demand and prices.

Shrimp fisheries in developing countries

Of all shrimp fisheries, those in developing countries present the greatest challenges. They typically have the major problems of overcapacity, overexploitation, conflict with small-scale fishers and high discard rates for industrial-scale trawl vessels. In addition, these countries characteristically have weak fisheries institutions for researching and managing such difficulties. In short, there are many problems and few affordable solutions. Ironically, many of the countries in this unfortunate category are highly dependent on the economic benefits of shrimp fishing.

More could, and should be done to improve this bleak situation, by both national governments and the international community. In general, means to improve shrimp fisheries should be oriented towards the institutional aspects of fisheries management, such as agency effectiveness, awareness raising and adequacy of legislation. On the technical side, priority should be given to:

- ensuring minimal administrative capacity (in data collection, staff with management capacity, minimal scientific support, extension officers), including at the decentralized level;
- recognizing the limitations of single-species management and, where possible, and appropriate, moving towards an ecosystem approach to management;

- promoting fisheries management regimes that grant secure resource rights to the stakeholders in these fisheries, focusing on the usefulness of collective rights and responsibilities as an alternative to centralized fisheries institutions and processes;
- "democratizing" important types of analysis that are often not carried out because of their complexity. This includes establishing processes for simplified resource and fisheries integrated assessment to the level where they are suitable for less sophisticated users; and
- promoting fisheries management tools appropriate for difficult environments, specifically marine protected areas, because of their potential enforcement, bycatch and ecosystem advantages.

Some suggestions for improvement in management of shrimp fisheries in developing countries depend on the scales of fishing. With respect to small-scale shrimp fisheries, a major recommendation is that greater attention be paid to socio-economic aspects.

- Research on socio-economic issues should receive greater attention in the fisheries research agendas of fisheries agencies.
- Mechanisms should be developed to incorporate the findings of socio-economic research in the management process.
- Special emphasis should be placed on the fundamental question of whether additional net benefits can be produced by management intervention ("What kinds of management attempts will be worthwhile?") and the practicalities of small-scale shrimp fishery capacity reduction.

For large- and some small-scale shrimp fisheries where there is open access (the right for the public to participate in a fishery), an overriding recommendation of this study is that serious consideration be given to introducing a regime to restrict access effectively and subsequently provide secure tenure, either collectively or individually, to participating stakeholders.

Capacity reduction

Many or most of the world's shrimp fisheries are overexploited, at least in an economic sense. Reduction of effort, or the more fundamental reduction of capacity, is likely to have positive effects on the profitability of fishing operations and on the wider net benefits from these fisheries. Such reductions would also serve to moderate some of the major negative impacts of trawling, such as bycatch and physical disturbances to the seabed.

In view of these benefits, shrimp fishing capacity reduction efforts need to be reinvigorated, by publicizing the benefits of capacity reduction, highlighting the various schemes in shrimp fisheries that have been successful, drawing attention to innovative mechanisms for capacity reduction (e.g. fractional licensing) and addressing the issue of open access.

Open access

Following on from the last section, a key observation of this study is that open access management regimes plague shrimp fisheries in both developing and developed countries – from Cambodia to the Gulf Coast of the United States. Conversely, in restricted access regimes where participants have secure tenure, there is a long-term relationship between fishers and the fishery resource, hence a powerful incentive for conserving the resource for the future.

The history of shrimp fishery management shows the futility of attempts to maximize economic yield over the long term in an open access environment. Considering that many, or even most, of the world's shrimp fisheries are open access, it appears that economic overfishing will continue to plague the global shrimp fishing industry for a long time.

Reduction of bycatch and mitigation of impacts on the seabed are also important objectives in the management of shrimp fisheries in an EAF framework. Reducing capacity is important to do this, but to do so efficiently necessitates the ability to restrict effort.

One of the most important overall recommendations of a global study of shrimp fisheries is that the open access nature of a large number of shrimp fisheries around the world should be addressed. This would include raising public awareness of the benefits of a change to restricted access, generating the political will to transform, establishing mechanisms for a transition process and accommodating any windfall in benefits.