PART 1
MAJOR ISSUES IN SHRIMP FISHERIES

1. History and development of shrimp fishing

Shrimp has been caught by traditional gear for centuries in many parts of the world. In numerous regions this small-scale fishing continues today, as in China (stow nets), Indonesia (lift nets, push nets, beach seines, gillnets), Mexico (barriers across estuaries), and Madagascar (nets, weirs and traps). Such small-scale fishing is responsible for a surprisingly large proportion of the world's shrimp catch (see Chapter 3, section *Catches by shrimp species*).

The history of modern industrial shrimp fishing is closely related to the development of mechanized trawling. Trawling from sailing vessels in Europe has been carried out for hundreds of years. Two events in the latter part of the nineteenth century caused an increase in trawling activity in Britain: the invention of the otter trawl and the increasing use of steam propulsion in fishing vessels. Until the mid-1800s, most large-scale trawling used beam trawl gear, which relied on a heavy beam to keep the net open. Because all fishing vessels at that time used the wind for their towing power, the weight of this beam was a major constraint on the size of net that could be towed. Boards using the force of passing water to hold open the net were invented in Britain in about 1860. The use of these boards (later called otter boards[1]) did not become widespread until the late 1880s, when Danish fishers used them to spread their plaice seines. Steam propulsion for fishing vessels began in about 1880. In 1893 there were 480 steam trawlers working from English and Welsh ports; in 1899, there were over a thousand (Anon., 2004b).

Much of the European trawling in the late 1800s could be considered large scale and used otter trawl gear, but the target species were groundfish rather than shrimp. Adapting otter trawling to shrimp fishing occurred in several places and followed very different courses, including development led by inspired individuals; expansion of successful national fisheries into the waters of neighbouring countries; promotion by aid projects; and vessels from overexploited fisheries searching for alternatives.

Modern shrimp trawling began in Norway in the 1890s, when the renowned fisheries researcher Johan Hjort collaborated with Danish researchers and introduced trawl technology for shrimp fishing. The fishery started as a coastal fishery in the southern part of Norway and, by the 1930s, had spread all along the Norwegian coast.

On the other side of the Atlantic, the otter trawl was adapted to a subtropical fishery. In 1906, Solicito "Mike" Salvador, who was born in Italy but became a leader in the American shrimp industry, rigged his boats based in Fernandina, Florida, with otter trawl nets modified for shrimp fishing. He was able to increase the daily shrimp catch tenfold. By 1921, the Salvador Fish Company was shipping shrimp as far away as Los Angeles, Canada and Denmark (Anon., 2004b).

By 1930, the new trawls in the United States of America produced about 90 percent of the American shrimp catch, which was mostly canned or air-dried. In subsequent decades, trawling and the use of larger vessels allowed fishing in deeper water further from the shore where bigger catches could be made. Box 2 describes the evolution of

[1] One theory about the origin of the term "otter boards" is that it came from fishing trout and pike in Ireland, where otters hunted in pairs to herd fish to a point where they were easy prey. The doors played the same herding role as the otters and the name stuck (J. Fitzpatrick and the Scottish Fishermen's Museum, personal communication, June 2006).

BOX 2

Evolution of shrimp trawlers in the United States of America

Early shrimp trawlers were open skiffs 5 to 8 m long, powered with gasoline engines. By the 1920s, they were decked over, the engine placed forward, and a pilothouse added forward. This arrangement remains the standard for today's shrimp trawlers in the United States. In the 1930s, the diesel engine was introduced and the average size increased to some extent. During the 1940s and 1950s, the need for larger vessels to exploit offshore grounds resulted in the construction of much larger vessels. Average vessel length increased to about 60 ft (approximately 18 m), with many vessels in the 21–27 m range. Of particular interest during this period was the success of production line model shrimp vessels, built to standard specifications with design emphasis on minimum cost. They had 20 m-hulls, were powered by 150 to 200 HP engines and characterized by a very high freeboard. This, together with the ample sheer fore and aft, provided a very dry working deck. During the 1960s, the trend was towards larger, better equipped and more powerful vessels, capable of long-distance operations. Most vessels are well fitted with electronic equipment.

Source: Kristjonsson, 1968.

American shrimp trawl vessels. By about 1950, most of the potential fishing grounds in waters adjacent to the southeastern states had been discovered. The United States shrimp fleet then expanded operations to the east coast of Mexico and the western Caribbean Sea. From the early 1960s to the early 1970s, between 632 and 860 United States vessels fished off Mexico. In 1976, a treaty between the United States and Mexico resulted in the phasing out of United States shrimping in Mexican waters by the end of 1979. From 1959 to 1979, up to 207 United States shrimp vessels fished off the northeastern coast of South America (Iversen, Allen and Higman, 1993). Vendeville (1990) reports that in the 1960s these industrial shrimp fishing developments in Latin America were extended to Africa and other tropical regions. He concludes that at the end of the 1980s, "shrimp trawlers used in industrial fisheries were relatively homogenous. The American Gulf of Mexico double-rig model has been widely adopted in all regions" (Figure 2).

Many aspects of American shrimp fishing in the Gulf of Mexico have had profound impacts on shrimp fisheries in other regions. Starting in the mid-1960s, experiments were conducted on devices that reduce the bycatch of shrimp trawling. In the early 1980s, substantial gear technology work began to address the issue of reducing the capture of sea turtles in shrimp trawls. The pioneering work of John Watson should be acknowledged. In the mid-1970s, he developed a selective shrimp trawl design for the Gulf of Mexico and, in 1980, the first prototype turtle excluder device (TED). Because the work in bycatch reduction and turtle exclusion eventually led to changed shrimp fishing techniques in many countries, these topics are covered in more depth in Chapter 6. The United States was considered to be the epicentre of biological research on warm-water shrimp in the world until the 1960s, when priorities shifted to research for shrimp farming (Watson and

FIGURE 2

A Gulf of Mexico-style shrimp trawler in the United States

Photograph courtesy of the United States National Marine Fisheries Service

BOX 3
Development of the Thai trawl fishery

When mackerel catches in the Gulf of Thailand declined in 1958 and 1959, perhaps for reasons that had little to do with fishing, the Government became very concerned. Thus, in 1958, when Klaus Tiews – who had been undertaking fisheries research in the Philippines where the otter trawl had been widely adopted in the late 1940s and early 1950s – recommended that trawling might open an untapped source of fish, the Government responded enthusiastically. In 1961, under a bilateral aid agreement between the Federal Republic of Germany and Thailand, Tiews and other German fisheries experts worked with Thai fisheries officers to introduce the otter trawl as part of the Sarit Government's National Economic and Social Development Plan. The project's first task was to design an otter trawl net that would not get stuck in the soft mud that characterizes the bottom of much of the Gulf of Thailand. The German net maker who was part of the team designed a suitable net in just four weeks. At an early stage in the project, it became clear that trawling offered the potential for huge profits. Thai fishers began converting their purse seiners to trawling. From 1960 to 1966, the number of trawlers soared from 99 to 2 700, and the catch by trawlers increased from 59 000 to 360 000 tonnes.

Source: Butcher, 1999.

McVea, 1977; Watson, Mitchell and Shah, 1986; S. Garcia, personal communication, October 2005).

Unlike Latin America and Africa, shrimp trawling appears to have evolved somewhat differently in Southeast and South Asia. Industrial shrimp fishing in Southeast Asia appears to have started from fish trawling. The profitability of steam trawlers in Europe in the late 1800s planted the idea in the minds of a few entrepreneurs and officials that trawling might prove just as successful in Southeast Asia. During the first three decades of the twentieth century, the governments of the United Kingdom, France and the Netherlands individually sponsored exploratory trawling in their Southeast Asian colonies using old steam trawlers from Europe. None of these expeditions was particularly successful. The Japanese began fishing in Manila Bay in about 1900, using trawlers powered by sail. In the 1920s, these vessels adopted diesel engines. Japanese trawlers began basing in Singapore in 1935 and ranged as far as the Arafura Sea. These operations started scaling down in 1937 as a result of pre-war animosity created by Japan's invasion of China and ceased entirely during the Second World War. In the late 1960s, a German-sponsored project led to the establishment of a trawl fishery in the Gulf of Thailand (Box 3). Although not specifically targeting shrimp, it was the buoyant shrimp prices that kept the Thai trawl fleets in business when catch rates for fish fell dramatically. Another way in which the trawling operations survived as catches declined was by moving to new areas. Thai trawlers began fishing in the waters off Burma (now Myanmar) in the late 1960s, and then in Malaysia and other countries in the region (Butcher, 2004).

Priyono and Sumiono (1997) recount the developments that led to the establishment of shrimp trawl fishing in Indonesia. Trawl fisheries started up commercially in 1966 in the Malacca Strait. The development of the trawl fisheries may have been influenced by earlier trawling in western Peninsular Malaysia. The ancestors of many Chinese fishers in Riau Province, Indonesia, had migrated from there and contact was still maintained with relatives in Malaysia. The original fishery was characterized by wooden sampan-like motorized vessels of 5–20 gross tonnage (GT). The fishery developed rapidly and, by the end of 1971, over 800 vessels were being used. In the 1970s, with the oil production boom in the country, fuel subsidies were lavished on almost all sectors of the country's economy, including fisheries. In subsequent years, the trawl fishery spread throughout western Indonesia, via southeastern Sumatra to the north and south coasts of Java and to southern Sulawesi.

Chen (1999) gives a short history of shrimp trawling in China. Before 1970, shrimp was caught mainly by stow nets (see Chapter 2, section *Main fishing gear*). Exploited species were mainly coastal ones, particularly *Acetes chinensis* (70–80 percent of landings). There was some coastal trawling for finfish by mainland Chinese and Taiwanese trawlers, but catch rates were low. By the mid-1970s, the stock size of coastal demersal fish species had declined. Fishers started exploratory shrimp fishing using beam trawls. Subsequently, shrimp fisheries expanded rapidly and extended further seawards; beam trawls were the main gears used, typically 24–26 m in length, although some exceeded 30 m. Before 1984, prawn fishing activity was concentrated in the northern waters of Zhejiang Province and the coastal waters near the mouth of the Yangtze River. After 1984, the fishery rapidly extended to the southern and offshore waters. Catches increased in the Province, reaching 40 000 tonnes in 1986, 100 000 by 1990 and 530 000 in 1995. Vessels from other provinces also fished in these waters. Shrimp production from all vessels in the East China Sea increased to 780 000 tonnes in 1995.

In India, small-boat shrimp trawling started on the west coast in the early 1970s. The fleet grew very rapidly and catch rates declined within a short period. Although the penaeid species were many, their stocks were small. With the decline on the west coast, shrimp trawling on the southeast coast began out of Chennai Port. However, this fishery did not stay in operation for long and quickly shifted its emphasis to finfish and cephalopods. Towards the end of the 1970s, shrimp trawler operators became interested in the Sand Head area of the upper Bay of Bengal. In this area there was a serious problem in operating small-sized trawlers, which were commonly used on the west or southeast coast, because there were no suitable harbours close to the fishing grounds for unloading and processing shrimp catches. The nearest harbour with basic facilities was in Vizakhapatnam, where cold storage facilities were established for processing and exporting frozen shrimp. To operate from Vizakhapatnam, the shrimp trawling companies requested authorization from the Indian Government to import industrial-scale vessels. The Government readily provided foreign currency loans for the import of larger trawlers with outriggers for twin-trawling. These vessels were able to stay at sea for long periods and bring in the preserved shrimp to Vizakhapatnam for processing and exporting (K. Sivasubramaniam, personal communication, March 2006).

In Pakistan, the development of the shrimp fishery appears to have preceded that of India. According to officials of the Pakistan Marine Fisheries Department (M.M. Khan, Marine Fisheries Department, personal communication, April 2006), in 1951, an American-sponsored project conducted experimental trawling with an 11–m vessel. Van Zalinge, Kaliluddin and Khan (1987) state that "commercial shrimp trawling began in 1958 after FAO recommended to the Central Fisheries Department that some of the larger fishing craft be mechanized". There were three commercial trawlers in 1958, 450 vessels in 1970, 897 in 1980 and 1 070 in 1985. FAO (2003e) indicated 2 564 trawlers in 2002, and that the rapid development of the shrimp trawl fishery was a result of tax concessions, credit schemes and export incentives.

In examining the development of shrimp trawl fisheries in several countries, several patterns emerge. One is the influence on the development process of innovative individuals such as J. Hjort in Norway, M. Salvador in Florida and K. Tiews in Thailand. Another is that many of the present-day trawl fisheries that target shrimp were originally oriented towards finfish and only switched to targeting shrimp when finfish became depleted. Declining catch rates of shrimp and finfish have played an important role in expanding trawl fisheries into neighbouring countries. Government industry promotion through tax concessions, credit schemes and export incentives has been a major factor in the development of shrimp fishing in many countries. In many places around the world, such as in West Africa, shrimp resources were discovered and mapped by scientific surveys before the development of a fleet. A final point is that, although much has been written about the sustainability (or lack of sustainability) of shrimp trawling, a review of the history of shrimp trawling in regions around the world does not uncover many examples where a shrimp trawl fishery has been abandoned as a result of the exhaustion of shrimp resources.

2. Structure of shrimp fisheries

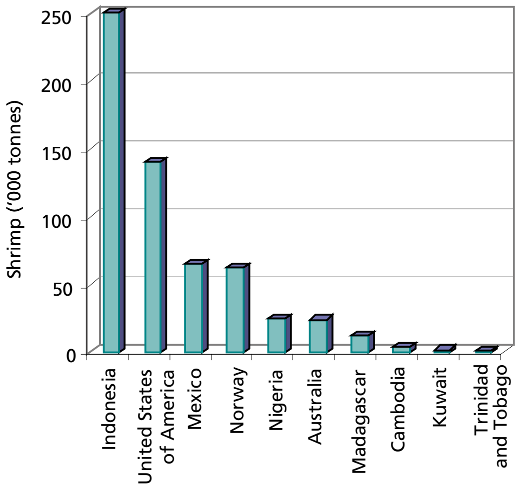
MAIN FEATURES AT THE NATIONAL AND GLOBAL LEVELS

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 structure of the fishing industry and related issues in these countries are given in Part 2. The major features are summarized in Table 1.

Figure 3 places the recent annual shrimp catches of the ten study countries in perspective with each other. From Figure 4 it can be seen that combined catches of the study countries form about 17 percent of the global shrimp catch in recent years.

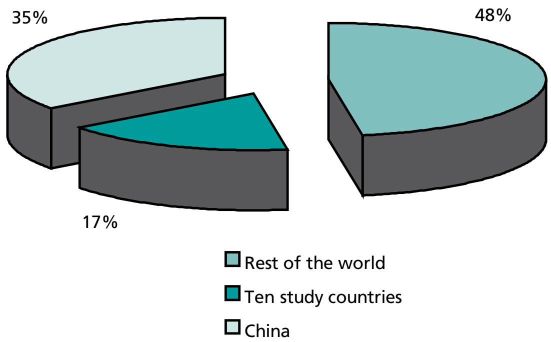
Although there are large differences among countries in the structure of shrimp fisheries, some generalizations can be made. Major distinctions occur between warm- and cold-water shrimp fisheries regarding species, scale of fishing operations, fishing gear/strategies and management measures. In most countries where shrimp fishing occurs, there are both large- and small-scale segments of the industry. While most shrimp fisheries focus on producing food, shrimp fisheries also exist in both tropical and temperate region for bait. Moreover, recreational shrimping is a significant activity in some developed countries. In addition, the capture of broodstock and postlarval shrimp for shrimp farming is important in several countries.

FIGURE 3
Annual shrimp catches in the ten study countries



Source: based on Table 1.

FIGURE 4
Relative importance of the shrimp catches in the ten study countries



Source: based on Chapter 3.

MAIN FISHING GEAR

A major characteristic of most large-scale shrimp fishing is the use of trawl gear. FAO (2005f) has estimated that in the late 1990s there were about 140 000 trawlers of all types in the world's fisheries, but the number of shrimp trawlers is not known.

Otter trawl

Many types of trawls are used to catch shrimp, but because the otter trawl is the most important commercial gear in many countries, it deserves special mention. Figure 5 shows the major parts of a shrimp otter trawl and Figure 6 shows the gear used.

FAO (2005f) describes some important characteristics of the otter trawl gear, which is also used in many fisheries apart from shrimp fisheries.

TABLE 1
Main characteristics of the shrimp fisheries in the study

Country and annual catch[1]	Shrimp fishery characteristics
Australia 24 000 tonnes	Australia has a significant involvement with shrimp fishing and its associated activities. Shrimp fishing produces about 24 000 tonnes of shrimp, occurs in the tropical, subtropical and temperate waters of the country, and ranges in scale from recreational fisheries to large-scale operations using vessels up to 40 m in length. Australia also produces shrimp from aquaculture and is involved in both the export and import of shrimp in various forms. Some Australian shrimp fisheries are considered to be very well managed and a model for other countries to emulate. The availability of recent information on Australian shrimp fishing and management issues is excellent.
Cambodia 3 500 tonnes	Although marine fisheries in Cambodia are of minor importance compared with freshwater fisheries, shrimp fishing is important along its short coast. Trawling, and to a lesser extent other gears, take from 3 000 to 4 000 tonnes of shrimp annually. Shrimp is important for domestic consumption and is the most important fishery export of the country. Its shrimp fisheries management faces major challenges, including: the paucity of biological information on shrimp resources; the few legal instruments available for the management of shrimp fishing; their poor enforcement; and the open access nature of all coastal fisheries in the country.
Indonesia 250 000 tonnes	After China and India, Indonesia's shrimp catch is the largest in the world. Shrimp farming is also of great significance in the country, with over 65 000 participating households. Shrimp production, from both fishing and aquaculture, has reached over 400 000 tonnes per year, and shrimp is by far the country's most valuable fishery export. Shrimp fishing in Indonesia is not without its problems, however. A multitude of conflicts have been generated, most of which involve small-scale fisheries. The 1980s trawl ban is cited as the most significant fisheries management measures ever to have taken place in the country, but its effectiveness has been eroded over the years. As in many parts of the world, industrial-scale shrimp trawling operations are having major problems coping with the recent rise in fuel prices. The structure of the shrimp industry is complex. There are countless boats that catch shrimp and many types of fishing gear, as well as their being illegal activity and poor statistical information.
Kuwait 1 500 tonnes	The shrimp fleet of Kuwait has two components: 35 steel-hulled double-rigged Gulf of Mexico-type trawlers and 34 dhow trawlers. Only three species of shrimp are economically important: green tiger prawn (*Penaeus semisulcatus)* (60 percent of catches), Jinga shrimp *(Metapenaeus affinis)* (30 percent of catches) and Kiddi shrimp (*Parapenaeopsis stylifera)* (10 percent of catches). The landed value of shrimp is at present about 39 percent of that of all marine capture fisheries in the country. Total shrimp catches for the 2003/04 and 2004/05 seasons were low, at 1 577 and 1 420 tonnes respectively. In the previous decade, the average annual catch was about 1 900 and shrimp catches fluctuated between 1 012 tonnes and 5 125 tonnes from the 1960s through the 1980s. The present low catches, high level of effort and low CPUE seem to indicate that the stock has been overexploited since 1993.
Madagascar 12 000 tonnes	In recent years, industrial, artisanal and traditional fishers in Madagascar have captured from 10 000 to 13 000 tonnes of shrimp. Employment associated with shrimp fishing is vital to the country, and shrimp (both captured and farmed) is the most valuable fishery export. In past years, about 5 000 tonnes of shrimp were produced by farming operations. Shrimp from Madagascar has a special identity in Europe and commands a higher price than similar products from Asia or Latin America. About two-thirds of the shrimp landings come from the export-oriented industrial trawl fleet comprised of 70 trawlers. About 8 000 to 10 000 people are involved in traditional shrimp fishing, which is aimed primarily at domestic markets. The relationship between these two sectors is important in the management of shrimp fishing in Madagascar. A substantial amount of biological, economic and social research associated with shrimp fishing is carried out in the country. The major fall in shrimp catches in 2005 is likely to be the subject of much future research.
Mexico 65 000 tonnes	Shrimp fishing in Mexico takes place in the Pacific, Gulf of Mexico and Caribbean, by both artisanal and industrial fleets. A vast number of small fishing vessels use many types of gear to catch shrimp. The larger offshore shrimp vessels, numbering about 2 212, trawl using either two nets (Pacific side) or four nets (Atlantic side). In 2003, shrimp production in Mexico of 123 905 tonnes came from three sources: 21.26 percent from artisanal fisheries, 28.41 percent from industrial fisheries and 50.33 percent from aquaculture activities. Shrimp is the basis of the most important fishery commodity in Mexico in terms of value, exports and employment. Catches of Mexican Pacific shrimp appear to have reached their maximum. It is generally recognized that overcapacity is a problem in the various shrimp fleets.
Nigeria 25 000 tonnes	Nigeria has an annual shrimp catch of between 15 000 and 30 000 tonnes. Shrimp fishing is carried out by about 225 industrial shrimp trawlers and a very large number of fishers inshore using small trawls, beach seines and stow nets. As the most important agricultural export of Nigeria, shrimp is responsible for a substantial amount of employment and is a significant source of food in coastal areas. Major difficulties associated with shrimp fishing are the damage that industrial operations cause to small-scale fishers and overcapacity of the trawl fleet. Good data on shrimp catches, shrimp fishing effort and shrimp exports are not readily accessible and, when available, are often conflicting.

Country and annual catch[1]	Shrimp fishery characteristics
Norway 62 000 tonnes	Between 60 000 and 70 000 tonnes of shrimp are caught annually in Norway, which is the 14th largest producer of shrimp in the world. Fishing for shrimp, however, is not nearly as important as for other species such as herring, blue whiting, cod and saithe. In 2003, shrimp represented about 4 percent of the value of all Norwegian fishery product exports. The main shrimp stocks exploited by fishers from Norway are in the Barents Sea, Skagerrak and the North Sea. In addition, many Norwegian fjords have small local stocks. The poor profitability of many types of shrimp vessels in Norway is at present a major problem. This has probably arisen from a combination of factors, including excess capacity, increasing fuel costs and falling market prices for shrimp. Much of the management of Norwegian shrimp fishing, both domestically and internationally, is driven by the need to avoid both overfishing and bycatch of cod and other important species.
Trinidad and Tobago 800 tonnes	Shrimp fishing is currently carried out in Trinidad and Tobago by about 102 artisanal trawlers, ten semi-industrial trawlers and 20 to 25 industrial trawlers. From 1999 to 2004, annual shrimp catches averaged about 825 tonnes. In 2004, there was an estimated 785 tonnes of shrimp landed, valued at US$2.72 million, and 703 tonnes of groundfish bycatch valued at US$0.65 million. At present, 96 percent of exports go to the states of the Caribbean Community (CARICOM). There is a high incidental fish catch associated with shrimp trawling, which is one of the most important sources of 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.
United States of America 140 000 tonnes	Two main types of shrimp fisheries operate in the United States of America: those that target warm-water shrimp off the southeast Atlantic coast and the Gulf of Mexico, and those for cold-water shrimp in the northeast and northwest of the country. In terms of value, shrimp is the second most important fishery in the United States after crab. The combined landings for United States domestic shrimp fisheries have been about 140 000 tonnes annually in recent years, with the warm-water fisheries responsible for over 90 percent in 2004. United States domestic production is dwarfed by shrimp imports of 500 000 tonnes per year, over 80 percent of which are from aquaculture. The domestic shrimp market has greatly expanded in recent years. Shrimp is the most important seafood item for United States consumers – currently 1.9 kg edible weight per year. The United States market is now the largest in the world for shrimp, followed by the European Union. Despite record demand for shrimp in the United States, real and nominal prices for shrimp have declined, primarily as a result of cheaper imported shrimp. This downward pressure on dockside prices and increasing operational costs of domestic shrimp vessels have resulted in severe financial difficulties in many United States shrimp fisheries.

[1] These are the average annual catches from 2000 to 2005, rounded to the nearest thousand tonnes.

General description. A bottom otter trawl (Figures 5 and 6) is a cone-shaped net consisting of a body, normally made from two, four and sometimes more panels, closed by a codend and with lateral wings extending forwards from the opening. A bottom trawl is kept open horizontally by two otter boards. Bottom trawls usually have an extended top panel (square) to prevent fish from escaping upwards over the top of the net. The mouth of the trawl is framed by a headline with floats to open the trawl vertically, and a ground gear, which is designed according to bottom conditions at the fishing ground, so as to maximize the capture of targets living close to the bottom while protecting the gear from damage and facilitating movements across an uneven bottom.

FIGURE 5
An otter trawl

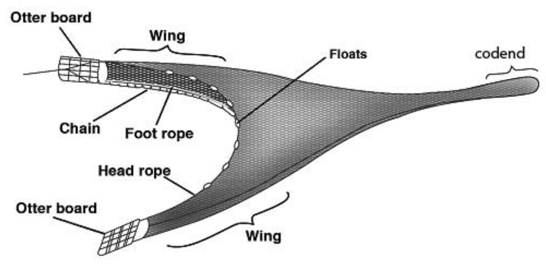
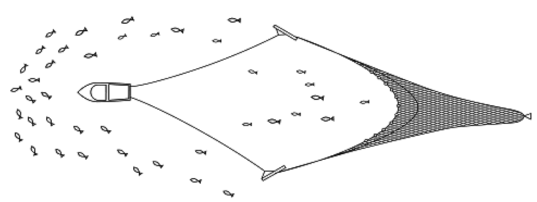


FIGURE 6
Bird's eye view of an otter trawl in action



Specific equipment. The horizontal opening of the net is obtained by two otter boards. The vertical opening is obtained with floats and/or hydrodynamic devices (kites) on the upper edge (floatline) and weights on the groundrope. The groundrope may be chain or weighted rope, or equipped with rubber discs, bobbins or spacers, etc. to shield the lower leading margin of the trawl from ground damage while maintaining ground contact. The horizontal opening of the trawl is obtained by two otter boards. There are many models of otter board: relatively heavy, made of wood, aluminium and steel or a combination of the three. Otter boards may be rectangular or oval-shaped, and equipped with a steel sole designed for good contact with the ground. Instruments to monitor gear performance are common in modern bottom otter trawling using large vessels. Such instruments monitor geometry (door distance, vertical opening, bottom contact, trawl symmetry), water temperature in trawling depth, catch and trawl speed with selective grid devices such as angle and speed of water flow through the device.

Specific handling equipment. The main handling equipment of a trawler is a powerful winch with two drums (or two or more split winches, each consisting of one drum) for shooting, hauling and storing the trawl warps. The trawlers operating otter trawls have gallows, gantries or derricks to handle the heavy otter boards. The net hauling system varies greatly, depending on the size of the vessel and the type of trawl used. A large net drum can be used for shooting, hauling and storing the trawl (including spare ones for additional trawls). Light wing trawls may be hauled in by power blocks. Heavy bobbin trawls may be lifted aboard with gilson winches or quarter ropes. Larger trawlers are arranged with a horseshoe deck layout for handling the trawl.

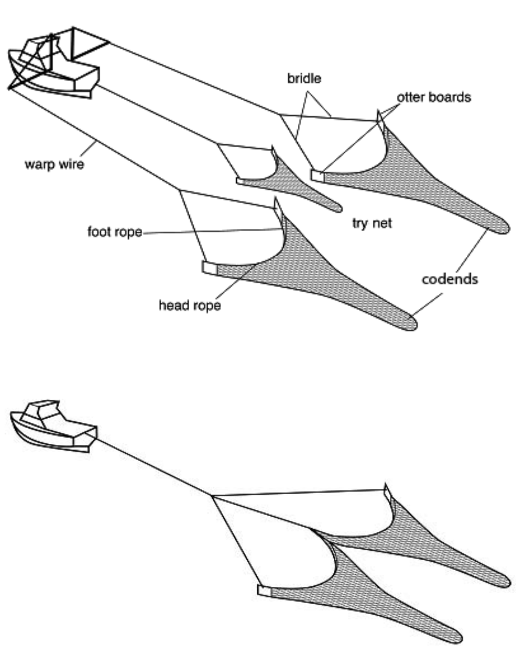
Fishing vessels using the gear. Otter bottom trawls can be used by side trawlers (being gradually phased out), stern trawlers and outrigger trawlers. Vessels range from small open boats to large factory trawlers.

Fishing operations. The trawl is designed and rigged to have bottom contact during fishing and, depending on the bottom substrate, is equipped with different kinds of groundrope for shielding the lower leading margin of the trawl from ground damage while maintaining ground contact.

In general, trawlers tow a single otter trawl. However, the use of more than one otter trawl per vessel is common (Figures 7 and 8) in shrimp fisheries. Where two nets are towed from a single warp wire, a sledge is used between them to preserve net geometry and maintain bottom contact. Two single nets, each with a set of otter boards, may be towed from outriggers, which are characteristic of larger prawn trawlers in tropical shrimp fisheries. Some fisheries use three or four nets per boat, two from each outrigger.

Multiple nets are more usually used by larger fishing operations in relatively shallow water and where the bottom is relatively smooth. Single or double nets (towed over the stern from one warp) are more easily manoeuvred around topographical obstructions and are also more suitable than quad gear for use in deep water. In recent years, there has been considerable interest in

FIGURES 7 AND 8
Two types of double otter trawls



using multiple nets for improved catches and fuel conservation (see Chapter 7, section *Mitigation of fuel cost increases*).

Vendeville (1990) reviews the technical aspects of tropical shrimp fishing gear and recognizes eight variations of the general Florida-type otter trawl. One is an arrangement with two trawls towed at the ends of two outriggers. Each net is towed by a single warp and the outrigger booms are at an angle of 20 to 30 degrees from the horizontal.

The otter trawl has also been used for large-scale shrimp fishing operations. In the North Atlantic, nets can have a footrope of 70 m in length and a vertical opening of 20 m. These trawls, which can cost over US$100 000, are used in water up to 400 m in depth. Some of the technical improvements made on these sophisticated nets have been applied to much smaller-scale trawls for use in other regions.

Over the years, in various regions, the otter trawl has been modified for increased selectivity, total catch maximization, improved ease of handling, improved swept area, increased fuel efficiency, greater durability in rough terrain, reduction of effects on the sea bottom, and other purposes. One of the major modifications from the original Florida-type otter trawl design is a considerable reduction in size to enable use by small outboard open boats. Iversen, Allen and Higman (1993) state that shrimp trawls and the method of rigging have been undergoing change since the original shrimp trawl was developed.

Recent innovations in otter trawling in Australia and Norway are indicative of the evolution of this gear in warm- and cold-water shrimp fisheries, respectively.

- In Australia, the most obvious innovations in shrimp otter trawling in recent years relate to the imperative to introduce TEDs and BRDs. The use of both these devices is now mandatory in all Australian shrimp fisheries and has led to innovations by fishers to make things "practical" or, in other words, not causing hassles or loss of shrimp catch. Included in this category are downward TEDs with split flaps and near-vertical grids, and "fisheye" BRDS (see Chapter 6, *Effectiveness of bycatch reduction efforts*) (D. Sterling and I. Cartwright, personal communication, June 2007).

In Norway, a recent trend in otter trawling for shrimp is increased fishing width by individual trawlers. This is either achieved by increasing the length of the footrope and thus the horizontal wing spread of the trawl, or by using two or three parallel trawls. Over the last ten years, nearly all large shrimp trawlers have converted to twin trawling, whereas triple trawling was introduced in 2002 and is increasingly common (J. Valdemarsen, personal communication, June 2007).

Box 4 describes the markedly different behaviour of shrimp and fish to trawls. These differences are well known to prawn fishers and net makers, who have designed their gear accordingly. Since prawns tend to be found close to the seabed, nets generally have low openings, with the wings of the trawl attached directly to the top and bottom of the otter board. This also reduces catches of fish. Otter boards are connected directly to the "wing" of the trawl, since prawns, unlike fish, cannot be herded by using a wire between the otter board and the net. Nets tend to be short since prawns do not actively swim in the direction of the tow and are washed quickly down into the codend. The different behaviour of fish and prawns is also exploited in the design of devices to reduce unwanted fish bycatch (see Chapter 6, *Bycatch reduction devices*).

Other trawl gear

Although the otter trawl is the most common form of shrimp trawl, several other similar types of gear are used to catch shrimp on a large scale; two common types are the beam trawl and the pair trawl.

The *beam trawl* (Figure 9) consists of a cone-shaped body ending in a bag or codend, which retains the catch. In these trawls, the horizontal opening of the net is provided by a beam, made of wood or metal, up to 12 m in length. The vertical opening

BOX 4

Behaviour of shrimp and fish in a trawl

Shrimp. As the trawl approaches, shrimp is located either on the seabed or swimming in the water column. Shrimp on the seabed generally responds to the approaching trawl by remaining motionless. This behaviour is thought be used to avoid detection by predators. Shrimp that is swimming does not respond to the trawl until contact is made or imminent. Shrimp escape response is rapid swimming or contraction of the abdomen and rapid propulsion (tail flicks) away from the trawl. Since this response is not sustained, the animals are eventually overrun by the trawl and enter the codend. There is no herding of shrimp into the trawl. Shrimp on the seabed responds to ground chain contact with rapid tail flicks backwards and upwards. This response may be repeated several times to a height of several metres. The combined influence of the towing speed and the height of the net ensures that many of the shrimp are unable to escape from the trawl. Shrimp that does escape the approaching trawl may swim within the water column for several minutes before returning to the seabed. Shrimp that enters the trawl mouth have limited swimming capability, particularly if it has responded several times to trawl contact. It usually enters the codend passively, although some shrimp may first be impinged on the netting for a period of time. If shrimp is then contacted by other animals, the trawl or bycatch reduction device (BRD), it may take evasive action and tail flick several times. There is no evidence that shrimp is capable of deliberately swimming through openings designed for fish escape. Shrimp enter sthe codend at any height, but is usually exhausted and unable to swim with the trawl.

Fish: Fish in the water column may escape over or around the approaching trawl or enter the trawl mouth. These fish in the trawl mouth may attempt to swim with the trawl for a period of time. This is linked to a desire to swim with an object that has a strong visual contrast with the background. If the towing speed is higher than the sustained swimming speed of the fish (cruising), they attempt to maintain their position with the trawl by repeatedly using short bursts of acceleration followed by a gliding movement. This is the "kick-and-glide" response, which is used by fish to conserve energy and avoid predation. The fish in the trawl mouth eventually tire and either attempt escape around or through the meshes of the trawl, or they enter the trawl. Many small fish will also swim with the trawl in the same direction. Since they are weak swimmers, they do not have the luxury of using a kick-and-glide response. To keep up with the trawl, they must swim at a speed that rapidly leads to exhaustion, and they are soon overrun by the trawl. Other fish do not respond by swimming with the trawl. Instead, they enter the trawl mouth either passively or with burst-speed swimming manoeuvres in random directions. Those that enter the trawl passively are quickly overrun and are collected in the codend. Fish that are burst-speed swimming typically contact the trawl netting at high speed. Some become gilled in the netting and some may escape through the meshes. Others will rebound off the netting and swim in another direction. This may continue until they make their way into the codend. Many schooling pelagic fish may attempt an upward escape by swimming through the meshes in the top panel of the trawl as they become tired. Fish on the seabed usually remain motionless until contact is made or imminent. They may react with a kick-and-glide response to keep ahead of the approaching trawl, or may even settle back on the seabed before being contacted by the trawl. This may be repeated several times before they either escape (usually over the lower sweep or under the footrope) or enter the trawl.

Source: Eayrs, 2005.

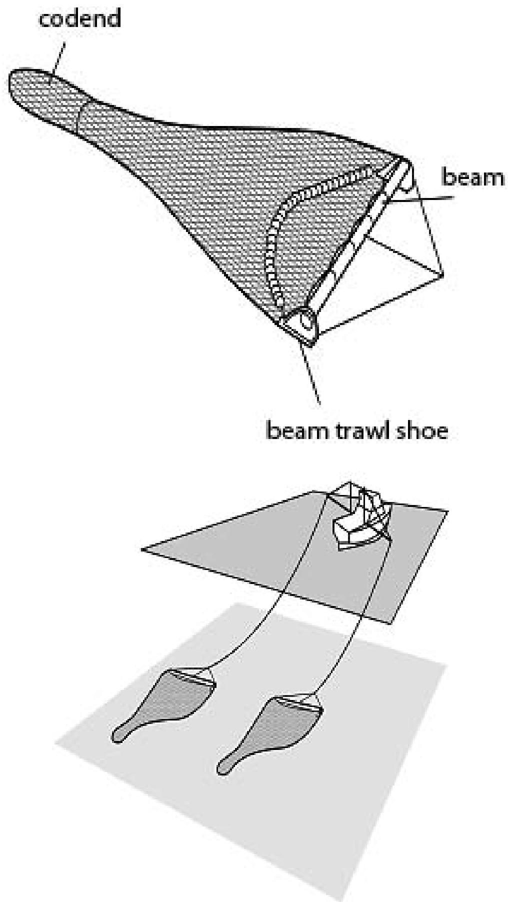
is provided by two hoop-like trawl heads mostly made from steel and equipped with weighted shoes designed to maintain seabed contact. No hydrodynamic forces are needed to keep a beam trawl net open. Beam trawls are the primary gear used to catch northern shrimp in Alaska and banana prawns in estuaries off the east coast of Australia. They are also the predominant gear used by the 650 vessels in the fishery for

Crangon in the shallow coastal waters of the southern North Sea (Figure 10).

The *pair trawl* consists of a cone-shaped body, normally made of two or four (and sometimes more) panels, closed by a codend and with lateral wings extending forwards from the opening. The bottom pair trawl is operated by two vessels, each towing a trawl warp attached to the bridles in front of the two trawl wings.

A pair trawler may be an open boat with an outboard engine or a vessel up to 60 m in length. The pair trawlers are normally of similar power and sizes. This fishing practice is often used by non-powered vessels. Pair trawling for shrimp takes place in Southeast Asia, but is prohibited in Cambodia and Indonesia's Arafura Sea. Owing to the ability of pair trawl gear to "sweep" large areas of the seabed (relative to the width of the trawl mouth) and thereby herd demersal species of fish, its use is more common in fisheries targeting finfish.

FIGURE 9
The beam trawl



Source: Graham, Polet and Revill, 2005.

FIGURE 10
Beam trawl gear in the North Sea

Source: Graham, Polet and Revill, 2005.

Non-trawl gear in large-scale fisheries

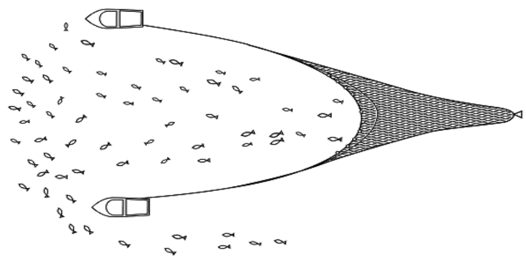
Most of the industrial shrimp fishing in the world is done by trawling (primarily otter trawling but, to a lesser degree, also beam trawling), yet there are some large-scale shrimp fisheries that use other gear. Vessels that participate in the spot prawn fishery off the coast of California use up to 500 pots and those that fish from southeast Alaska use traps (Roberts, 2005). Some of the shrimp gillnets used in Asia could be considered industrial in scale. Sun and Yin (no date) indicate that in China, 135 horsepower (HP) vessels use shrimp gillnets of 2 500 m in length. In Indonesia, there are almost 28 000 fishing units in the gear categories "shrimp nets and fishnets" and "demersal Danish/lampara seines", some of which are industrial in scale.

Iversen, Allen and Higman (1993) state that one of the reasons for using non-trawl gear in large-scale fishing operations is bottom topography; rocky bottoms are mostly unsuitable for trawling.

Small-scale fisheries: trawl and non-trawl gear

Many other types of gear are used to capture shrimp. The diversity of shrimp fishing gear in some of the Asian countries is remarkable. In Indonesia, shrimp is caught by some 137 000 units of shrimp nets, fishnets, demersal Danish seines, lampara seines, beach seines, shrimp gillnets, drift nets, trammel nets, stow nets and guiding

FIGURE 11
A pair trawl



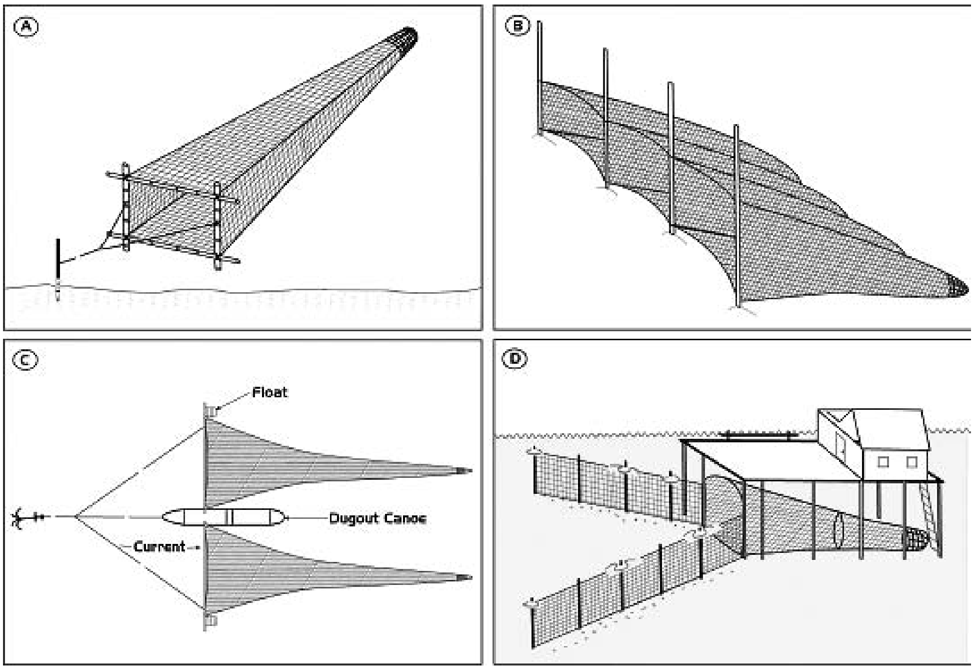
barrier nets. As mentioned above, almost 28 000 fishing units make up the categories "shrimp nets and fishnets" and "demersal Danish/lampara seines". This represents an interesting collection of gear types, many of which function as trawls. The vessels that use the small trawls are sometimes referred to as "mini-trawlers".

Small-scale gear used to catch tropical penaeids is generally operated in estuarine waters and lagoons to catch larvae, juveniles and migrating subadults. This fishing often affects large-scale shrimp fisheries that target more mature shrimp.

In terms of tonnage, it is likely that the most important non-trawl gear in the world for catching shrimp is the stow net. This gear, sometimes known as a stake net, set net or filter net, is configured in various forms (Figure 12), but all rely on the current to carry the shrimp into the nets. Liu-Xiong (1995) indicates that there are 350 000 units of this gear in just four coastal provinces of China and the main targets are five species of shrimp, of which *Acetes* is the most important. In European waters, substantial quantities of crangonid shrimp are caught by stow nets.

Non-trawl gear is also used in the shrimp fisheries of developed countries. For example, the largest pandalid shrimp, the spot prawn, is captured on the west coast of the United States entirely by traps, and there is a substantial shrimp pot fishery in southeast Alaska (Roberts, 2005). Iverson, Allen and Higman (1993) describe the use in the United States of channel nets (gear similar to stow nets), push nets, dip nets, cast nets and seines for catching shrimp for bait.

FIGURE 12
Types of stow nets



Note. (A) a simple stow net; (B) multiple stow nets; (C) aerial view of two stow nets set from an anchored canoe; and (D) an Indonesian-style shrimp stow net.

FIGURE 13
A motorized push net on the coast of the Gulf of Thailand

Figure 13 shows a motorized push net, a type of gear used in several Asian countries to catch shrimp in inshore areas. Box 5 gives an example of the variety of small-scale fishing gear used within the relatively small geographic area of Negombo Lagoon, Sri Lanka. Postlarval shrimp for shrimp farming is caught with small-scale gear in Bangladesh and a few other Asian countries.

Vendeville (1990) gives other types of small-scale shrimp fishing gear.

- *Beach seines* (with and without bags). These are used in many areas of the world, including West Africa, Madagascar, the northeastern coast of South America, Central America, India, Bangladesh, Sri Lanka and Indonesia. In most cases, they are used in shallow waters and hauled on to the shore.
- *Lift nets*. These are used either from small craft or from a platform built on stilts in shallow protected areas. They are common in India and several countries of Southeast Asia.
- *Cast nets*. These are used from small craft or from the shore. They are common in South and Southeast Asia, Central America and Brazil.
- *Traps.* Large traps, 12–13 m in length and of various shapes, are used in the intertidal zones of many countries in South and Southeast Asia,

The use of small trawl-like gears is common in small-scale fisheries of developing countries, but these gears often go by different names. Because there is even debate over whether some of these gears should be considered as trawls or are small-scale, the following definitions are used.

- *Trawlers*. Vessels that tow a net consisting of a cone-shaped body, closed by a bag or codend, and extended at the opening by wings.
- *Small-scale fisheries*. Labour-intensive fisheries using relatively small craft, little capital and equipment per person on board, mostly family-owned, and with low fuel consumption.

Small-scale trawlers thus defined are very common in Asia (Figure 14). Many of them make a substantial amount of non-shrimp catches and cannot therefore be considered strictly shrimp fishing gear. In Latin America, the use of small trawls to

BOX 5
Shrimp fishing in Negombo Lagoon, Sri Lanka

The most common gears are trammel nets. These, together with cast nets, are operated across the central portion of the lagoon. Stake nets are operated immediately inside the entrance at the northern end; they are set at night during the outgoing tide and target species aggregated at the entrance and migrating to sea. The gears used in the shallower waters are lagoon seines and brush pile. Brush piles are dead tree branches, each encompassing an area of 5–10 m in diameter. The fish and shrimp aggregate within the branches and are periodically removed with surrounding nets. The other gears used in the lagoon for catching shrimp are fyke nets. These are set at the southern end adjacent to the marsh. Outside the lagoon, there are non-mechanized shrimp trawlers operating north of the entrance and mechanized shrimp trawlers operating 5–10 km to the south.

Source: Sanders, Jayawardena and Ediriweera, 2000.

FIGURE 14
Small trawlers in Southeast Asia

catch shrimp is also very common, often with outboard-powered open boats. In West Africa, 8–12 m wooden canoes propelled by 15–40 HP outboard engines are often used with tow nets in inshore waters to catch mainly subadult shrimp.

ALTERNATIVES TO TRAWL GEAR

There has been considerable interest in developing alternative gears that could replace existing shrimp trawling operations. Despite this attention, 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. Chapter 10 explores this subject further.

Because of a lack of promising industrial-scale alternatives to shrimp trawling, most shrimp gear technology efforts in recent decades have been channelled into improving trawl gear and trawl techniques, rather than developing new industrial shrimp fishing technologies. It is important to note that some of the shrimp trawl gear innovations, especially those concerning bycatch reduction, have also been adopted by other trawl fisheries.

3. Shrimp species, catches and fishing effort

CATCHES BY SHRIMP SPECIES

Shrimp, known taxonomically as Natantian decapods, comprises about 3 000 species. Figure 15 shows the features often used by taxonomists to differentiate among the various species; the development of the legs (pereiopods) and whether the plates on the abdomen overlap are particularly important for distinguishing the main groups.

Shrimp is subdivided into several groups, three of which have major fisheries importance (Chan, 1998).

- Penaeoidea (about 376 species in total) or the penaeid shrimp, which include the genera *Penaeus, Metapenaeus, Parapenaeopsis* and *Trachypenaeus.*
- Caridea (at least 2 517 species), which include the genera *Pandalus* and *Heterocarpus.*
- Sergestoidea (about 94 species); the only group of significant economic importance is the genus *Acetes* – the paste shrimp.

The above taxonomic classifications correspond roughly to the three major categories of shrimp fisheries: warm-water, cold-water and paste shrimp. As mentioned in the earlier chapter on *Development of the study*, the three major groups of shrimp differ greatly with respect to their biology, the fisheries that catch them, and other factors. The biological differences are elaborated upon in Chapter 9, section *Basic biology and life histories*. Despite the rationale for including all three groups in this global study, the differences should be borne in mind when comparing the various shrimp fisheries.

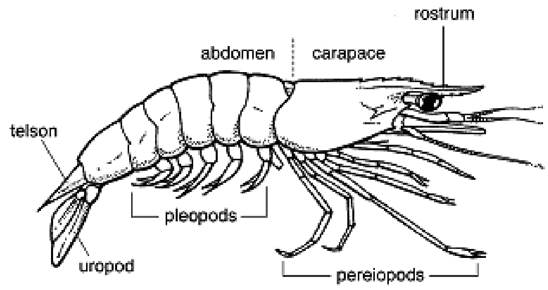
About ten species of shrimp have been commercially raised in captivity. All current commercial shrimp farming involves penaeid shrimp.

Slightly fewer than 300 species of shrimp are of economic interest worldwide, out of which 100 species provide the bulk of the annual world catch. FAO statistics on marine shrimp catches cover 66 "species items", which represent a taxonomic group, most often at the species level, but sometimes at the level of genus, family or suborder. Table 2 gives annual landings for several years for the 25 most important shrimp species items.

It can be seen from Table 2 that in 2005 six shrimp species items (four species and two aggregated groups) accounted for 82 percent of the global shrimp catch. The most important single species in the world by weight (19 percent of global total shrimp catch in 2005) is the akiami paste shrimp, which belongs to the genus *Acetes* (Box 6). The "all other species items" category in the Table (37 species items in 2005) accounts for less than 1 percent of the global shrimp catch.

The species item "Natantian decapods nei" represents about a quarter of the word's shrimp catch and is therefore highly significant. If this category is excluded, the remaining six most important species items in the Table account for 80 percent of the

FIGURE 15
Important features for shrimp taxonomy



Source: King, 2007.

TABLE 2
Catches of shrimp

FAO Name	Scientific Name	1965	1975	1985	1995	2005
Natantian decapods nei	Natantia	239 028	524 096	629 327	542 552	887 688
Akiami paste shrimp	*Acetes japonicus*	104 000	13 524	222 608	406 495	664 716
Southern rough shrimp	*Trachypenaeus curvirostris*		5 278	93 028	154 623	429 605
Northern prawn	*Pandalus borealis*	25 503	63 557	235 587	275 601	376 908
Penaeus shrimp nei	*Penaeus* spp.	194 009	261 450	277 565	296 483	230 297
Giant tiger prawn	*Penaeus monodon*	9 981	12 940	12 195	207 097	218 027
Fleshy prawn	*Penaeus chinensis*		34 297	33 191	44 449	106 329
Banana prawn	*Penaeus merguiensis*	22 400	39 269	39 023	71 150	83 392
Metapenaeus shrimp nei	*Metapenaeus spp*	10 927	30 410	36 690	51 536	63 211
Atlantic seabob	*Xiphopenaeus kroyeri*	8 000	13 093	17 900	18 802	52 411
Northern white shrimp	*Penaeus setiferus*	32 141	26 802	44 573	39 959	50 253
Common shrimp	*Crangon crangon*	52 200	35 902	27 328	30 761	44 852
Northern brown shrimp	*Penaeus aztecus*	57 250	44 736	70 852	57 126	44 692
Sergestid shrimp nei	Sergestidae		26 229	52 602	60 377	23 259
Deep-water rose shrimp	*Parapenaeus longirostris*	12 700	18 099	39 896	15 833	19 938
Southern pink shrimp	*Penaeus notialis*	1 900	6 744	6 896	21 484	14 648
Pacific shrimp nei	*Xiphopenaeus, Trachypenaeus spp.*	9 113	63 564	15 222	15 130	12 125
West African estuarine prawn	*Nematopalaemon hastatus*					11 700
Parapenaeopsis shrimp nei	*Pandalus* spp. *Pandalopsis* spp.	7 927	6 085	8 486	12 919	10 412
Redspotted shrimp	*Penaeus brasiliensis*	100	774	8 006	6 565	9 390
Northern pink shrimp	*Penaeus duorarum*	11 048	18 955	15 512	11 121	7 720
Argentine red shrimp	*Pleoticus muelleri*	300	190	9 835	6 705	7 510
Caramote prawn	*Penaeus kerathurus*	1 000	3 505	2 879	4 880	6 655
Chilean nylon shrimp	*Heterocarpus reedii*	5 900	7 934	2 949	10 620	3 880
Aristeid shrimp nei	Aristeidae				2 551	3 174
All other species items		24 395	54 111	71 933	83 023	33 741
Total		**829 822**	**1 311 544**	**1 974 083**	**2 447 842**	**3 416 533**

nei – not elsewhere included.
Source: FAO, 2007.
Note: units: tonnes.

global shrimp catch. "Natantian decapods nei" has an unknown species composition, but the countries that contribute to this species item can be determined from the FAO FISHSTAT database. Five countries (China, India, Viet Nam, Indonesia and India) contribute 68 percent of this category, while no contribution from a major cold-water shrimp fishing nation is more than 1 percent. It can also be concluded from the Table that the category comprises almost exclusively penaeid and sergestid shrimp.

FAO English names[2] for some of the species are often different from regional usage, which can lead to confusion. For example, in the United States three different species are known as pink shrimp and two species as northern shrimp. Cascorbi (2004b) indicates that the species *Pandalus borealis* may be marketed as pink shrimp, northern shrimp, Alaska pink shrimp, northern pink shrimp, Pacific pink shrimp or salad shrimp. It is therefore understandable why scientific names for shrimp (rather than common names) are used so often in the literature.

After the akiami paste shrimp (*Acetes japonicus*), the five most important single shrimp species are northern prawn (*Pandalus borealis*), southern rough shrimp (*Trachypenaeus curvirostris*), giant tiger prawn (*Penaeus monodon*), fleshy prawn (*Penaeus chinensis*) and banana prawn (*Penaeus merguiensis*). The distribution of catches of these species by country is listed in Table 3.

Table 3 could be misleading because the large size of the several unspecified "nei" categories in Table 2 (over a million tonnes in 2005, 35 percent of total shrimp catches)

[2] This is based on the ASFIS list of species for fishery statistics purposes. (Available at http://www.fao.org/fi/statist/fisoft/asfis/asfis.asp)

BOX 6

The small but important *Acetes* shrimp

Acetes shrimp is not well known in many regions outside Asia but is actually important in terms of global catches – and the basis for the largest shrimp fishery in the world.

The genus *Acetes* contains several species of shrimp which, although small in size (adult body length varies from 1 to 4 cm), support substantial fisheries, especially in Asia. Most shrimp is caught with very small-scale fishing gear such as stow nets, triangular nets, lift nets, scoop nets, push nets, bag nets and seines and is marketed mainly dried, boiled, salted, fermented with salt or processed into paste or sauce (Chan, 1998).

Huge quantities of *Acetes* shrimp are captured. The most recent FAO statistics indicate that more *Acetes* is captured than any other shrimp in the world;[2] in 2005, it amounted to 664 716 tonnes. Furthermore, the North Pacific Marine Science Organization (PICES, 2001) indicates that world landings of paste shrimps are likely to be grossly underestimated. Almost all the reported *Acetes* catches are from China (673 485 tonnes in 2003), but other important fisheries occur in the Republic of Korea, Japan and throughout Southeast Asia. *Acetes* is the most important shrimp caught in China, where the fishery has been of major significance for over 300 years. Acetes is largely responsible for the Chinese landings of shrimp being close to the combined total of all of the rest of the world. In terms of relative importance of fisheries production, Sugiyama, Staples and Funge-Smith (2004) report that a type of *Acetes* (akiami paste shrimp[3]) is the fourth most important species group by weight in the entire Asia-Pacific region fisheries after hairtails, anchovies and scads.

[2] The exception is the miscellaneous category “Natantian decapods, nei”.

[3] PICES (2001) indicates that the akiami paste shrimps (*Acetes chinensis* and *Acetes japonicus*) overlap in their geographic ranges and are generally not distinguished in landing statistics. Carpenter and Niem (1998) report seven species of *Acetes* in the Indo-Pacific area: *Acetes erythraeus, A. indicus, A. intermedius, A. japonicus, A. serrulatus, A. sibogae* and *A. vulgaris.*

could affect the absolute quantities and relative importance of the various species. Several countries, from both developed and developing areas, report over half of their shrimp catches not identified by species, but at higher taxonomic levels or under the “nei” category.

For example, FAO statistics for Australia show half of the 2005 catches as “Penaeus shrimp nei”. Nevertheless, some observations can be made on the significance of the various shrimp species. The northern prawn is the most important cold-water shrimp, with Canada and Greenland taking almost 70 percent of the catch in recent years. China dominates the catch of many of the most important shrimp species: akiami paste shrimp, southern rough shrimp and fleshy prawns.

Although fishing for the northern prawn could be considered a single shrimp species fishery, almost all the important tropical shrimp fisheries produce significant amounts of more than one species of shrimp (Box 7). This has important fisheries management implications. The factors that cause fluctuations in the abundance of each species are usually different, and it is therefore unlikely that all important shrimp species in a fishery will be in low abundance at the same time.

Garcia (1989) points out a sequential progression in species targeting during the development of shrimp trawl fisheries. In the early stages, fishing tends to begin on more coastal and valuable white shrimp of the genus *Penaeus* caught during the day. As effort increases and abundance decreases, additional night fishing develops on deeper brown and tiger shrimp. As overall profitability decreases further and the useful fishing season shortens, fisheries tend to develop on more coastal and smaller and less valued shrimp of the genus *Xyphopenaeus, Trachypenaeus, Lithopenaeus, Metapenaeus,* etc. At this stage, in

TABLE 3
Catches of important shrimp by country

Species	Country	2005 landings
Akiami paste shrimp	China	657 364
	Republic of Korea	7 352
Southern rough shrimp	China	425 643
	Republic of Korea	3 364
	Taiwan Province of China	598
Northern prawn	Canada	136 209
	Greenland	134 895
	Norway	48 310
	Iceland	12 381
	Estonia	8 659
	Russian Federation	8 658
	Faeroe Islands	7 432
	Denmark	7 183
	Lithuania	5 860
	Latvia	2 356
	Sweden	2 145
	United States	1 884
Giant tiger prawn	India	178 146
	Indonesia	32 910
	Australia	4 337
	Thailand	1 678
	Philippines	654
	Pakistan	147
	Papua New Guinea	117
	Taiwan Province of China	38
Fleshy prawn	China	105 340
	Republic of Korea	989
Banana prawn	Indonesia	65 710
	Thailand	13 352
	Australia	3 320
	Papua New Guinea	1 000
	Solomon Islands	10

Source: FAO, 2007.

many countries, shrimpers start keeping more and more of the fish bycatch on board. In the process, the progressive depletion of offshore adult shrimp tends to attract shrimp trawlers inshore, where they enter into serious conflict with coastal and small-scale fisheries.

CATCHES BY COUNTRY

Table 4 gives shrimp catches from 2000 to 2005 for the 35 most important producing countries. Figure 16 shows the relative importance of the ten most important producers.

Figure 17 gives world shrimp catches for the past half-century. Since it could be argued that akiami paste shrimp is distinct from most other species (magnitude of production, fishing technique, product form, end market), world catches of shrimp less akiami paste shrimp are given. For comparison purposes, the production of farmed shrimp is also shown.

A number of observations can be made on the production information given in Table 5.

- Sixty percent of shrimp production in the world is from fishing; 40 percent is from farming. The relative proportion by fishing has been decreasing since the mid-1980s, and sharply so in the last decade.
- Even allowing for the fact that fisheries production statistics for China may be too high (FAO, 2004), China has a dominant role in shrimp fishing; about one-third of the world shrimp catch is taken by this country.

BOX 7
The shrimp species of the fisheries of Negombo Lagoon, Sri Lanka

Fourteen species of shrimp are identified in the catch from Negombo Lagoon, six of which are major contributors to the catches. *Penaeus indicus* and, to a lesser extent, *P. semisulcatus*, were the most important in the trammel net and cast net catches. *P. indicus* was also the main species from brush piles. The stake nets set at the entrance caught mainly *Metapenaeus dobsoni* and *M. moyebi*. The latter were the major component of the catches with lagoon seines. The other important species caught in the lagoon was *M. elegans*. The main species in the trawl catches were *M. dobsoni* and *Parapenaeopsis coromandelica*. The former was the only major contributor to both the lagoon and outside catches. *P. indicus* and *P. semisulcatus* were relatively scarce in the trawl catches.

Source: Sanders, Jayawardena and Ediriweera, 2000.

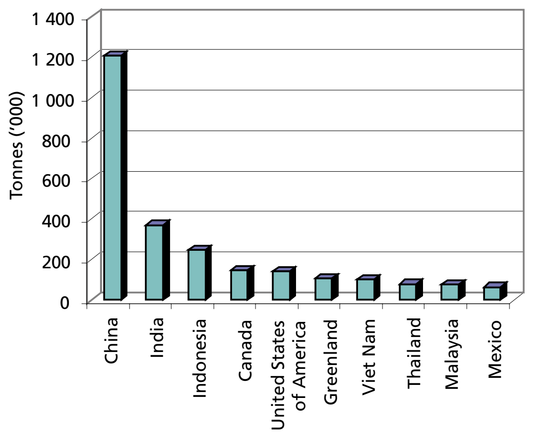
TABLE 4
Shrimp catches by country, 2000–05

	2000	2001	2002	2003	2004	2005	Av. 2000–05
China	1 023 877	909 083	911 838	1 451 990	1 481 431	1 471 575	1 208 299
India	343 860	328 941	400 778	417 039	369 153	366 464	371 039
Indonesia	252 914	266 268	242 338	240 743	246 014	235 050	247 221
Canada	139 494	129 774	139 061	144 495	178 743	139 829	145 233
United States of America	150 812	147 133	143 694	142 261	139 830	118 446	140 363
Greenland	86 099	86 451	105 946	84 764	137 009	137 009	106 213
Viet Nam	96 700	94 282	94 977	102 839	107 069	107 900	100 628
Thailand	84 625	85 115	80 996	79 082	71 889	67 903	78 268
Malaysia	95 976	77 468	76 020	73 197	78 703	52 788	75 692
Mexico	61 597	57 509	54 633	78 048	62 976	66 968	63 622
Norway	66 501	65 225	69 148	65 564	58 960	48 310	62 285
Philippines	41 308	48 398	43 386	46 373	46 132	45 101	45 116
Argentina	37 188	79 126	51 708	53 310	27 293	7 654	42 713
Brazil	39 185	28 025	29 100	34 013	32 504	38 497	33 554
Republic of Korea	36 035	30 800	29 634	31 117	19 345	21 116	28 008
Iceland	33 539	30 790	36 157	28 787	20 048	8 659	26 330
Nigeria	20 446	19 714	30 489	28 205	22 915	28 549	25 053
Japan	27 345	25 682	25 751	24 265	23 069	22 981	24 849
Australia	23 773	27 329	25 670	23 090	23 745	20 336	23 991
Pakistan	25 130	24 936	22 532	24 411	24 774	18 923	23 451
Myanmar	23 000	22 500	22 000	21 500	21 000	20 404	21 734
Guyana	19 329	26 851	20 564	22 584	18 605	18 391	21 054
Germany	17 423	12 571	15 966	16 269	19 222	22 616	17 345
Russian Federation	36 926	20 921	13 299	11 544	11 646	9 144	17 247
Suriname	10 606	13 340	13 522	16 330	26 204	22 309	17 052
Spain	21 508	27 105	17 212	14 241	10 375	8 392	16 472
Taiwan Province of China	20 603	17 403	13 545	6 491	14 415	26 297	16 459
Netherlands	11 497	14 084	11 458	14 834	14 502	16 227	13 767
Estonia	12 819	11 241	14 240	12 966	13 586	12 381	12 872
Mozambique	11 195	11 139	10 913	14 964	13 395	14 779	12 731
Madagascar	12 127	11 776	13 223	13 314	11 315	10 900	12 109
Faeroe Islands	12 611	15 930	13 141	14 083	9 314	7 183	12 044
Venezuela (Bolivarian Rep. of)	9 882	12 128	9 981	11 480	11 480	11 480	11 072
Italy	12 333	9 499	8 619	9 262	6 716	17 671	10 683
Cambodia	5 000	8 800	10 000	12 300	12 600	13 500	10 367

Source: FAO, 2007.

- Asia is the most important area for shrimp fishing. China and four other Asian countries (India, Indonesia, Malaysia and Thailand) account for 55 percent of the world shrimp catch.
- The major species of cold-water shrimp, the northern prawn, accounts for only 12 percent of the world's shrimp catch.

FIGURE 16
Recent average annual shrimp catches, by country

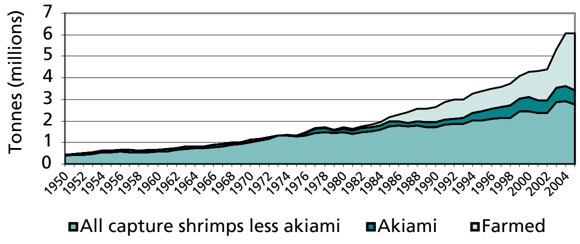


Source: FAO, 2007,
Note: Dates as per Table 4 (average of 2000–05).

SHRIMP FISHING EFFORT AND CAPACITY

Various schemes for quantifying fishing effort are used in the different shrimp fisheries. In the ten countries examined closely in this study (Part 2), several measures of fishing effort are used, including the number of hours of trawling, hours at sea, hauls, vessel days, vessel trips, vessel seasons and vessel years.

FIGURE 17
World shrimp production, 1950–2005



Source: FAO, 2007.

In theory, shrimp fishing effort for industrial and semi-industrial fishing operations should be relatively easy to collect. Information is routinely collected from most of the larger fishing operations in both developing and developed countries. There are, however, some surprises. Cascorbi (2004b) states that estimating total fishing effort in United States shrimp fisheries is not easy. The exact number of vessels taking part in Gulf and Atlantic shrimp fisheries is not known to management authorities: there is currently no federal licensing requirement for the South Atlantic region; state licensing regulations vary; and, because shrimpers follow the shrimp across state water boundaries, many shrimp vessels are licensed in several states simultaneously.

On the other hand, nominal shrimp fishing effort is known precisely, for example, in Australia's Northern Prawn Fishery, where the use of electronic logbooks is becoming increasingly more common. In this fishery, effort is often expressed in vessel fishing days but, for management purposes, the measurement of effective effort is complex (based partially on net headrope length) and is evolving over time. Effective effort is regularly calculated for stock assessment purposes, allowing for a range of technological innovations and skipper skills that have also evolved over time.

For small-scale shrimp fishing operations, fishing effort is more difficult to monitor. The number of gears available may be known, but information – the proportion used every day, the time during which they are used and the place in which they are used, etc. – is not often understood. This significantly influences the relation between effort and the resulting fishing mortality. In the relatively few cases where such data are collected, this is usually done by sampling a subset of the gear and extrapolating the results. However, in the small-scale shrimp fisheries of developing countries, there is usually no more than a vague idea of the number of units of a particular type of gear.

TABLE 5
Shrimp catches by FAO fishing area

Area	2000	2001	2002	2003	2004	2005
Pacific, Northwest	1 119 007	991 004	980 880	1 519 867	1 551 715	1 555 183
Pacific, Western Central	411 121	459 725	429 965	422 344	439 031	417 360
Indian Ocean, Western	311 715	290 315	315 842	329 481	303 587	315 166
Atlantic, Northwest	269 565	263 515	288 334	285 725	360 509	304 268
Indian Ocean, Eastern	275 944	229 384	206 171	218 468	246 060	205 107
Atlantic, Western Central	204 315	212 185	188 365	217 827	218 824	193 289
Atlantic, Northeast	172 670	142 017	148 919	127 780	123 304	114 576
Atlantic, Eastern Central	59 818	69 021	66 514	67 349	58 351	65 366
Asia – inland waters	42 954	49 933	114 239	123 406	61 884	64 817
Pacific, Eastern Central	59 851	54 287	51 821	66 854	55 000	53 543
Atlantic, Southwest	76 985	109 990	93 839	92 816	59 919	46 233
Mediterranean and Black Sea	35 273	29 047	31 402	31 892	30 707	42 308
Pacific, Southeast	14 793	15 592	12 242	13 495	13 464	17 863
Pacific, Northeast	20 381	22 952	29 973	18 272	12 813	14 690
Atlantic, Southeast	10 421	13 329	6 097	5 045	3 189	3 004
Africa – inland waters	2 100	2 400	2 400	2 400	2 250	2 250
Pacific, Southwest	2 842	3 034	2 308	2 288	1 831	1 510
Total	**3 089 755**	**2 957 730**	**2 969 311**	**3 545 309**	**3 542 438**	**3 416 533**

Source: FAO, 2007.

BOX 8
Fishing capacity

Different groups of people generally have a different understanding of capacity. Fishing technologists often consider fishing capacity as the technological and practical feasibility of a vessel achieving a certain level of activity – be it days fishing, catch or processed products. Fisheries scientists often think of fishing capacity in terms of fishing effort and the resultant rate of fishing mortality (the proportion of the fish stock killed through fishing). Fisheries managers generally have a similar view of fishing capacity, but often link the concept directly to the number of vessels operating in the fishery. Many managers express fishing capacity in measures such as gross tonnage or as total effort (e.g. standard fishing days available). Most of these ideas reflect an understanding of capacity primarily in terms of inputs (an input perspective). In contrast, economists tend to consider capacity as the potential catch that could be produced if the boat were operating at maximum profit or benefit (an output perspective). To reflect these different views of fishing capacity, an FAO technical consultation developed a definition of fishing capacity that is both input-based (e.g. effort, boat numbers, etc.) and output-based (catch).

> *Fishing capacity is the amount of fish (or fishing effort) that can be produced over a period of time (e.g. a year or a fishing season) by a vessel or a fleet if fully utilized and for a given resource condition* (FAO, 2004).

Ward *et al.* (2004) point out that an important feature of shrimp fishing effort, as in all fishing efforts, is plasticity. Even if a limit is imposed on the number of licences, effort can continue to expand as vessels grow in length, increase their net size or their engine power, improve the quality of their electronic fishing aids and/or establish communication networks, etc. As in almost all economic activities, shrimpers are profit maximizers and are extremely resourceful when it comes to improving their profits. The tendency for fishing vessels to increase their fishing power is referred to as "capital stuffing" or "effort creep".

A concept related to fishing effort is "fishing capacity". Box 8 provides a simple explanation of a topic that is sometimes elusive because of multiple interpretations.

The important fishing capacity issues in shrimp fisheries appear to be the quantification of capacity and the ability to manage capacity.

Quantification of shrimp fishing capacity and any overcapacity is not common in most shrimp fishing countries, except in some of the fisheries in developed countries such as Australia. The more common situation is that fisheries managers sense that overcapacity exists, that it is at least partially responsible for poor fleet profitability, and that steps should be taken to reduce fleet size in order to improve economic performance. The situation in Nigeria exemplifies the typical developing country situation.

Economic revival in the Nigerian shrimp trawl fleet will depend upon either prices rising or catch rates improving, as there is little scope to reduce costs. If prices do not 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 (Chemonics, 2002).

Fishing capacity problems in shrimp fisheries are not limited to developing countries. FAO (2005b) states that about half the current shrimping effort by United States vessels in the Gulf of Mexico could produce about the same yield. In Australia's Northern Prawn Fishery, despite almost continuous management interventions including limited entry and effort adjustments during the life of the fishery, overcapacity remains a problem (Cartwright, 2003). These United States and Australian examples illustrate two very different difficulties in managing shrimp fishing capacity, as described below.

- *The lack of mechanisms for limiting entry*. Most federally managed shrimp fisheries in the United States are open access, and there are few, if any, legal instruments available to prevent new entries into fisheries and associated growth of capacity. Many other countries, especially developing ones, also lack the required legal framework and management tools to limit entry.
- *Effort creep*. The Australian example illustrates the "effort creep" mentioned above. Although the managers of the Northern Prawn Fishery have been able to restrict entry into the fishery since 1977, capacity has nevertheless grown through improved technology and fishing strategies.

Another important fishing capacity issue associated with shrimp fisheries concerns small-scale fisheries. Even the shrimp fishing nations that are able to limit entry in large-scale fishing operations are often unable to restrict participation by small-scale fishers. These fisheries represent a challenge where a solution is likely to be found in participatory management through decentralized processes, improving incentives and legitimacy and involving the social sciences in the design of management schemes, etc. A characteristic of several countries in this study – including Cambodia, Indonesia, Madagascar and Nigeria – is the large and rising number of small-scale shrimp fishers who have few non-fishing alternatives.

Another important issue mentioned above is the sequential nature of small- and large-scale fisheries. Small-scale effort has a greater plasticity than industrial effort in many cases. Closing tropical lagoons with multiple series of nets can eliminate entire year classes before maturity, leading to a practical shutdown of large-scale fisheries.

4. Economic contribution of shrimp fishing

It is widely assumed that shrimp fisheries contribute substantial benefits to national economies. To obtain more information on this subject, attempts were made to collect data on some economic indicators across the ten study countries. Table 6 summarizes the readily available information.

The above information represents a heterogeneous assemblage of facts, collected in different ways and with varying degrees of rigour. As such, any summaries or comparisons among countries are difficult. Despite the limitations of the data, it is possible to make certain comments.

The contribution of shrimp fishing to GDP is not readily available in most countries. Where it is available, the general perception is that the shrimp fishing GDP contribution is small. This may be a distortion of the actual situation,[3] but nevertheless, in many countries, it results in the view that shrimp fisheries do not have a great importance in the overall economy. Other observations related to shrimp and GDP are given below.

- The greatest GDP contribution noted in Table 6 is for Madagascar (1 percent), but this figure does not include the component of important traditional shrimp fishing.
- In many countries/regions in this study, a large petroleum industry tends to overwhelm the economic importance of shrimp fishing. Study countries in this category are Indonesia, Kuwait, Nigeria, Norway, Trinidad and Tobago, Mexico and, to a lesser extent, the United States of America.

With regard to the consumption of shrimp, per capita intake in the developed countries (Australia, Norway, United States) is, as might be expected, considerably higher than in most developing countries. Relatively high consumption in the United States, combined with its large population, translates into the world's biggest market for shrimp. In several countries in the developing world (e.g. Indonesia, Nigeria), a great deal of the shrimp is used as a condiment and thus has a greater importance than might be suggested by the weight of the product alone. It should also be noted that, in order to obtain accurate shrimp consumption information for a developing country, there must be good data on small-scale shrimp catches, which is not often available. With regard to overall nutritional benefits from shrimp fisheries, the consumption of the bycatch from shrimp fisheries is important in most shrimp fishing countries in the developing world.

Of the information on economic benefits given in Table 6, the employment data seem to be the least reliable and least comparable across countries. Where reasonable employment data are available, they are usually confined to formal onboard jobs on industrial trawlers. In many cases, the number of jobs associated with small-scale shrimp fisheries is probably vastly greater than those on board large vessels. This is the

[3] It is important to note that, although a fishing subsector contribution to national GDP may seem small, it can be crucially important to a national economy. Iceland is a good example: its economy is highly dependent on fish and fishing, and fishery products contribute to 70 percent of exports. Despite this importance, the fishing sector contributes only 13 percent of GDP. This is because of the way that sector contributions are calculated – many fishing-related activities are accounted for in other sectors, such as manufacturing. Furthermore, it is a result of significant economic activity generated by fishing, such as retail trade and government, which is counted as value added in other sectors.

TABLE 6
Some indicators of the economic contribution of shrimp fisheries (data from the early 2000s)

	Contribution to GDP	Consumption (kg/person/yr)	Employment	Catch value (US$/yr)	Exports
Australia	Not readily available	2.2 kg	1 040 people in shrimp fishing; about 5% of all fishing employment	US$240–292 million	US$128 million; net importer
Cambodia	Not readily available	Not readily available	No data available; crude estimate of 8 000 people involved in trawling	Official estimate not readily available; US$2/kg catch valued at US$7.4 million	1 578 tonnes (no official information on value); US$4/kg exports valued at US$6.3 million; most valuable fishery export
Indonesia	Not readily available	About 0.5 kg	2 900 people on industrial trawlers; small-scale employment unknown, but very much larger	US$558 million	US$887 million; most valuable fishery export
Kuwait	About 0.01% of GDP	Not readily available	335 on board; almost all expatriates	US$7 million	US$1 million; net importer
Madagascar	Industrial and artisanal sectors contributed 1%; traditional sector contribution not readily available	0.1 kg is a crude estimate	Industrial/artisanal shrimp fishing employed 3 970 people; traditional (part-time) varies from 8 000 to 10 000 people.	US$70.2 million	US$68.2 million; most valuable fishery export
Mexico	Not readily available	0.66 kg	One estimate indicates 190 884 fishers employed	US$300 million	US$346 million; most valuable fishery export
Nigeria	Not readily available	Not readily available	One estimate indicates 1.2 million people have formal or informal jobs associated with shrimp fishing and post-harvest	US$70 million from industrial vessels	US$49 million; most valuable fishery export
Norway	0.25% of GDP	1.7 kg	998 people on board	US$228 million	$125 million; important export
Trinidad and Tobago	About 0.2% of GDP	Not readily available	324 fishers directly involved in shrimp trawling	US$2.72 million	US$800 000; most valuable fishery export
United States of America	Not readily available	1.9 kg	Not readily available	US$425 million	Exports are 15 000 tonnes; imports 500 000 tonnes

Source: based on Part 2 of this report; further details (specific source, date) available in the individual country studies.

case in Cambodia, Indonesia, Madagascar, Nigeria and Mexico (see Part 2). In some countries, such as Nigeria, the downstream employment figures are impressive, but the methodology used to estimate the number of jobs is not clear, and consequently the credibility is uncertain.

In addition to shrimp fishing for food, the capture of broodstock and postlarval shrimp for shrimp farming purposes employs a considerable number of people; Clay (2004) estimates a million people worldwide.

The gross value of the shrimp catch is known in most cases. Gross landed values vary widely in the study countries: from US$2.72 million to US$558 million. Despite the shortcomings of these statistics, it appears that these figures are often used by fisheries managers for making decisions, such as trade-offs between fisheries when they interact, simply because the numbers are available and comparable.

Shrimp is clearly an important export in the study countries. It is the most valuable fishery product export in Cambodia, Indonesia, Kuwait, Madagascar, Mexico, Nigeria and Trinidad and Tobago, and an important – although not the most important – fishery export in Australia and Norway. A complicating factor (and one that also affects shrimp consumption data) is that in most cases where shrimp fishing and shrimp farming exist within the same country, it is often difficult to distinguish between the two – and shrimp exports are a combination of farmed and captured products.

Although not listed in Table 6, the resource rent in a shrimp fishery is a kind of benefit that is available to the private and/or public sectors in various forms. Information on the amount of resource rent available is not known for most shrimp fisheries. In fact, resource rent calculations are only readily available for a few of the world's shrimp fisheries: that of Australia's Northern Prawn and Torres Strait, the Gulf of Mexico, the Gulf of Thailand, Greenland's Davis Strait and the European *Crangon.*

Some observations can be made in reflecting on the economic benefits for the shrimp fisheries in the study.

- The entry "not readily available" often appears in Table 6 and the subsequent text. In many cases, information could in fact be obtained, albeit through considerable research. In another sense, the data readily available reflects to some degree the economic information on hand for fisheries managers to use in decision-making.
- In the management of shrimp fisheries, some mechanism for balancing the benefits of fishing with environmental and other costs incurred is required. Given the scarcity and limitations of data on shrimp fisheries, there does not seem to be enough information on benefits in most countries to determine whether the costs incurred are justified, at least not in a quantitative sense.

5. Trade aspects

MAJOR FEATURES OF THE SHRIMP TRADE

World production of shrimp, both captured and farmed, is around six million tonnes (Chapter 16, section *General information on shrimp farming*), about 60 percent of which enters the world market. Shrimp is now the most important internationally traded fishery commodity in terms of value. Annual exports of shrimp are currently worth more than US$10 billion, or 16 percent of all fishery exports.

Currently, about 40 percent of the world production of shrimp is from farming; however, the proportion of farmed shrimp in international trade appears to be much higher. Although the precise composition is not known with certainty (farmed and capture shrimp are combined in export statistics), it appears that about 60 percent of internationally traded shrimp is from aquaculture. Ward *et al.* (2004) review the reasons for the greater popularity of the farmed product (Chapter 16). Another consideration is that the most important single species of capture shrimp in the world, the akiami paste shrimp, characteristically does not enter international trade, hence lowering the importance of the captured product in this trade.

Trade often amplifies the various effects of fishing practices, whether they are beneficial, such as employment, or harmful, such as environmental damage. Because most shrimp fisheries, especially those in the developing world, depend upon international trade for their continuation (EJF, 2003b), there is an opportunity to use trade for improving aspects of shrimp fisheries. To do so, however, requires an understanding of the shrimp trade.

Shrimp marketing is complex, with different markets requiring different product forms, methods of preservation, species and sizes. Clay (2004) indicates that in the United States alone, there are more than 70 classifications based on size and degree of processing. Chemonics (2002) and Cascorbi (2004b) describe the various characteristics.

- *Product forms*. There are several categories, with different markets:
  - green headless: the standard market form. It includes the six tail segments, with vein, shell and tail fin. "Green" does not refer to shell colour but to the uncooked, raw state of the shrimp. Also called "shell-on" or "headless";
  - peeled: green headless shrimp without the shell;
  - PUD: peeled, undeveined, tail fin on or off, raw or cooked. The vein, running the length of the tail, is the intestine, also called the “mud vein” or “sand vein”;
  - tail-on round: undeveined shrimp with tail fin on;
  - P&D: peeled, deveined, tail fin on or off, raw or cooked;
  - cleaned: shrimp that is peeled and washed, a process that removes some or all of the vein but not thorough enough to warrant the P&D label;
  - shell-on cooked: cooked tail, with vein, shell and tail fin;
  - split, butterfly, fantail: tail-on shrimp cut deeply when being deveined.
- *Preservation methods*. The main types are fresh, frozen raw, semi-processed or fully processed (i.e. as breaded shrimp). The great bulk of internationally traded shrimp is sold frozen, graded, as whole or tails, with fully processed tails representing the balance.
- *Sizes*. These have a great impact on the price that shrimp receives – the larger the shrimp, the better the price, by a substantial margin. Shrimp is graded by “count”,

i.e. the number per pound or kilogram. The important point is the significant price differential between grades; on average 15–18 percent per size grade.

- *Species*. Different shrimp species trade into different markets: cold-water northern pandalids, tropical white (mostly *Penaeus vannamei*), pink and brown penaeids and black tiger (*P. monodon*) all have distinct market niches, as do scarcer specialized species.

From the mid-1990s to 2005, a major feature in the world shrimp market was generally falling prices. Ward *et al.* (2004) indicate that from 1997 to 2002 in the United States, ex-vessel prices declined by 27 percent in the Gulf of Mexico and 24 percent in the Southern Atlantic States Shrimp Fishery, as imports increased by 300 percent. In Japan, there was a general downward trend in prices from the mid-1990s. In the European Union (EU), combined penaeid import prices mostly declined from 2000, but prices for some captured species increased. Cold-water shrimp prices, as judged from *Pandalus borealis* prices in the United Kingdom, show a downward trend from the mid-1990s. Although increased aquaculture production is the main cause of the fall in prices, Globefish (2003) also notes other causes in the early 2000s.

Demand weakened in key markets, particularly the United States of America, following the events of 11 September. Difficult economic conditions in Japan, as well as the weak yen, meant reduced demand and downward pressure on prices in that market. In the EU, the appreciation of the euro vis-à-vis *the dollar effectively reduced import prices for shrimp products normally quoted in dollar terms.*

Since late 2005, the shrimp price situation has changed. Because of higher demand and lower expected aquaculture production, especially in Thailand, shrimp prices have been increasing. At least part of the increased demand is from Thailand and China where domestic consumption is rising.

MAJOR SHRIMP MARKETS

Although over 100 countries export substantial quantities of shrimp, the international shrimp markets are concentrated in just three areas: the United States, Japan and Europe.

The United States represents the world's largest country shrimp market and United States Government shrimp import policies have a critical effect on major shrimp exporting countries throughout the world. In recent years, the country has produced commercially about 145 000 tonnes of shrimp per year, of which only about 4 000 tonnes are from aquaculture. The United States imports about 500 000 tonnes annually, over 80 percent of which are from aquaculture.

There have been important changes in the United States shrimp trade in recent years. The total supply of shrimp on the domestic market has increased dramatically over the past 20 years. Domestic production plus imports were about 200 000 tonnes in the early 1908s, but increased to over 650 000 tonnes in 2004. There has also been a large increase in shrimp imports. The United States market share supplied by imports increased from 48 percent in 1978 to 80 percent in 2004. The rise in low-cost imports has led to a fall of shrimp prices on the domestic market. Two decades ago, the major exporters of shrimp to the United States were Latin American countries (Ward *et al*., 2006). United States markets are greatly affected by unilateral action of the government, including measures relating to turtle conservation (see Chapter 5, section *Measures relating to turtle conservation*), anti-dumping action (see Chapter 5, section *United States anti-dumping action*), and the June 2007 blocking of farmed shrimp from China because of contamination with unapproved animal drugs and food additives (FDA, 2007). The latter action resulted in shrimp from China being diverted to other markets (e.g. Japan, EU), and more Thai and Indonesian shrimp going to the United States market. In addition, at least some shrimp shipments bound for the United States are being routed through other Asian countries to avoid the appearance of originating in China (i.e. "shrimp laundering").

TABLE 7
Characteristics of the main shrimp markets

	Main shrimp groups in imports			Preferred product
	White[a] (%)	Black tiger[b] (%)	Cold water (%)	
United States	26	72	2	Frozen shell-on tails (51%) Peeled tails (31%)
Japan	7	80	13	Frozen shell-on tails
Europe	34	33	33	Spain – whole shrimp France – whole shrimp United Kingdom – small peeled tails Netherlands – tails Italy – whole shrimp

Source: Chemonics, 2002.
a. Mostly *Penaeus vannamei.*
b. *Penaeus monodon.*

The Japanese shrimp market was formerly the largest in the world, but economic stagnation in the last decade led to its reduced importance. At present, shrimp imports into Japan are about 300 000 tonnes annually, or about 60 percent of United States imports. In 2006, Japanese imports of frozen raw shrimp were at a six-year record low of 229 952 tonnes, but the market now supports more imports of prepared products; in 2006, there was a 15 percent increase in imports of frozen value-added shrimp compared with 2005 (Eurofish, 2007). Again in 2006, there was a notable increase in imports of cold-water shrimp, with imports from Argentina increasing fivefold to 3 400 tonnes (O'Sullivan, FAO, personal communication, 2007). Asian countries are the major suppliers to Japan, with Viet Nam recently overtaking Indonesia as the most important provider. African nations, such as Madagascar, Mozambique and Nigeria, also export significant amounts to Japan, with Australia catering to some speciality niches. In the ten country studies (Part 2), several suppliers expressed the opinion that Japan is an important alternative shrimp market to the United States during periods of United States unilateral action affecting the shrimp trade.

The EU imports almost as much shrimp as the United States, with Spain as the main market, followed by France, the United Kingdom and Italy. In 2006, the six major supplying nations in terms of volume were Greenland, Ecuador, India, Canada, China and Brazil. (O'Sullivan, FAO, personal communication, 2007). With respect to shrimp marketing, the EU is not homogenous since each country has different suppliers and preferences.

Table 7 gives some of the important characteristics of the main international shrimp markets.

The various tariffs are important in the major shrimp markets Josupeit (2004; personal communication, 2007) reviews the situation in the United States, EU and Japan.

- In the United States, there is no tariff on frozen shrimp products. A 5-percent tariff is applied when shrimp is canned with fish meat. Anti-dumping tariffs apply to shrimp from specific countries (see Chapter 5, section *Important issues in the shrimp trade*).
- The EU tariffs are 18 percent for frozen *Crangon crangon*, 12 percent for other frozen shrimp and 20 percent for canned shrimp. The zero tariffs for the African, Caribbean and Pacific (ACP) Group of States are likely to expire in the coming years. There are also substantial tariff reductions for certain developing countries outside the ACP agreement. One important group, the Generalized System of Preferences (GSP)[4] countries, has a reduced duty of 14.5 percent for *Crangon crangon*, 7 percent for canned shrimp and 4.2 percent for frozen shrimp other than *Crangon crangon*. Brazil has been excluded from this tariff reduction. In July 2007, tariffs on cooked and peeled *Pandalus borealis* going for further processing in the EU were reduced from 20 to 6 percent for a 20 000-tonne quota (H. Josupeit, FAO, personal communication, October 2007).

---

[4] GSP: a grouping of 115 countries and territories.

- In Japan, tariffs are 1.8 percent for fresh, 4.8 percent for cooked and 6 percent for frozen and canned shrimp. Tariffs on Mexican shrimp have been eliminated under a trade agreement.

Josupeit (2004) concludes that tariffs have been reduced and are relatively unimportant in the United States and Japan. Tariffs are still high in the EU.

IMPORTANT ISSUES IN THE SHRIMP TRADE

Three important issues in the shrimp trade deserve special attention: the United States trade measures relating to turtle conservation, United States anti-dumping tariffs and ecocertification of shrimp fisheries.

Measures relating to turtle conservation

According to the United States Department of State, Chapter 609 of United States Public Law 101–162 provides that shrimp or products from shrimp harvested with commercial fishing technology that may adversely affect certain species of sea turtles protected under United States laws and regulations may not be imported into the country unless the President certifies to Congress by 1 May 1991, and annually thereafter. The foundation of the United States programme governing the incidental taking of sea turtles in the course of shrimp harvesting is the requirement that commercial shrimp trawl vessels use TEDs, approved in accordance with standards established by the United States National Marine Fisheries Service (NMFS), in areas and at times when there is a likelihood of intercepting sea turtles. The goal of this programme is to protect sea turtle populations from further decline by reducing incidental mortality in commercial shrimp trawl operations. The chief component of the United States sea turtle conservation programme is a requirement that commercial shrimp boats use TEDs to prevent the accidental drowning of sea turtles in shrimp trawls.

On 1 May 2007, the United States Department of State certified that 16 nations had adopted programmes to reduce the incidental capture of sea turtles in their shrimp fisheries, similar to the programme in effect in the United States. The Department also certified that the fishing environments in 24 other countries and one economy – China, Hong Kong Special Administrative Region – do not pose a threat of incidental taking of sea turtles. Shrimp imports from any nation not certified were prohibited, effective 1 May 2007 (Federal Register, 2004). The various categories and certified countries are on the basis that:

- national sea turtle protection programmes are comparable with that of the United States: Belize, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Guyana, Honduras, Madagascar, Mexico, Nicaragua, Nigeria, Pakistan, Panama, Suriname and the Bolivarian Republic of Venezuela;
- national fishing environments pose no danger to sea turtles because shrimping grounds are only in cold waters: Argentina, Belgium, Canada, Chile, Denmark, Finland, Germany, Iceland, Ireland, the Netherlands, New Zealand, Norway, Russian Federation, Sweden, the United Kingdom and Uruguay; and
- national fishing environments pose no danger to sea turtles because shrimp is only harvested using small boats with crews of fewer than five people, who use manual rather than mechanical means to retrieve nets, or catch shrimp using other methods that do not threaten sea turtles: the Bahamas, China, the Dominican Republic, Fiji, Hong Kong SAR, Jamaica, Oman, Peru and Sri Lanka.

The United States policy on TEDs is not without its critics. Many shrimp fishers outside the country are unclear as to the actual requirements, while others complain that they simply cannot afford gear similar to that used by relatively rich United States fishers. At a higher level, the Government is sometimes faulted for adopting unilateral measures that aim to compel other governments to alter their national policies to be more in line with United States objectives (Joyner and Tyler, 2000).

Country experience in compliance with United States TED requirements is reviewed in Part 2. The main observation that can be made from examining the situation in ten countries in several regions is that, if the intention of the TEDs policy is to change fishers' behaviour so that fewer turtles are killed in shrimp trawling, more effort needs to be made by the United States promoters of the programme to raise awareness among vessel operators as to the specific requirements and status of national compliance with the United States law. Currently, the confusion associated with TEDs seems to engender considerable animosity, limiting the potential benefits for turtle conservation. One important factor of success in the United States, where important reductions of turtle mortality have been achieved, seems to be the move from technological solutions developed and imposed by the administration to solutions developed by the fishing industry itself, in an enabling environment where conservation incentives are provided by the establishment of some sort of resource entitlement (Melvin, 2007).

Sea turtle conservation measures in shrimp trawl fisheries were originally promoted by the United States, but are now fundamental in many countries. All seven species of sea turtle are listed in the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

United States anti-dumping action

Another United States intervention affecting shrimp imports concerns anti-dumping action. While it directly affects only aquaculture shrimp exported to the United States by certain countries, it was designed to benefit United States shrimp fishers and certainly has an impact on the global shrimp trade because of the size of the United States shrimp market.

The rise in imports and, in particular, of farmed warm-water shrimp from low-cost producers has, over time, led to a fall in shrimp prices in the United States market, resulting in fishers becoming less competitive. This has led United States shrimpers to accuse foreign producers of dumping. On 31 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. On 6 July 2004, the Department imposed duties varying up to 113 percent on these countries. Some commentators see it from a different perspective (Box 9). Thailand and Ecuador are taking action with the World Trade Organization to protest against the United States duties.

BOX 9

An alternative view of shrimp dumping in the United States

Shrimp farming has proliferated for one simple reason: efficiency. Trawling for shrimp is costly, and the harvest often varies considerably from year to year with changes in weather and ecological conditions. Shrimp farms not only produce shrimp at much less cost, but also produce a steady and reliable volume. Seafood processors value the reliable volume: these companies buy harvested shrimp and produce finished products for consumers whose desire for shrimp does not fluctuate with weather and ecological conditions. As shrimp farming has expanded, world shrimp production has increased and shrimp prices have fallen. Shrimp prices are now so low that they threaten the market survival of United States shrimp trawlers. The trawlers have therefore turned to the United States Government and its anti-dumping law to protect themselves, not from dumping, but from market competition with their more efficient foreign competitors (Mathews, 2004).

In the short term, some market specialists feel this action resulted in higher shrimp prices to consumers. Internationally, supplies directed away from the United States market led to falling prices elsewhere. In the long term, however, the impacts of the anti-dumping measures have been mitigated by the creativity of foreign supplier of shrimp and by the action of the United States Government (see Chapter 8, section *Improving profitability*).

Ecocertification of shrimp fisheries

The concept that some consumers wish to buy marine products that do not contribute to overfishing or other destructive practices is behind "certifying" certain seafood and marine products as "sustainable". Organizations that are currently actively involved in certifying marine products include the Marine Aquarium Council, the Global Aquaculture Alliance and the Marine Stewardship Council (MSC). The MSC is the most widely known example of an independent organization certifying capture fisheries based on standards for sustainable management (Kura *et al*., 2004).

Leadbitter and Oloruntuyi (2002) review the development of the MSC. A marriage of economics and ecology between Unilever and World Wide Fund for Nature (WWF) International resulted in the creation of an ecolabelling programme and an overseeing authority. Now independent of its founders, the MSC operates as a non-profit, standard-setting body, which accredits independent certifiers to evaluate fisheries against its standard. The standard, called the *Principles and Criteria for Sustainable Fishing,* is based on the FAO Code of Conduct for Responsible Fisheries. It was derived from a two-year international consultation programme that involved stakeholders from fisheries economics, stock assessment, marine ecosystem analysis, conservation and the social and legal aspects of fisheries, and represented industry, environment groups, consumer and regional interests. The standard looks at sustainable fishing from three perspectives: the state of the fish stock, the impact of the fishery on the associated ecosystem and the performance of the management system.

If a fishery is certified as sustainable, its products are eligible to bear a distinctive logo or statement certifying that the fish has been harvested in compliance with conservation and sustainability standards. The logo or statement is intended to make provision for informed decisions of purchasers whose choice can be relied upon to promote and stimulate the sustainable use of fishery resources (FAO, 2005c).

As of September 2007, there were no MSC-certified shrimp fisheries. In 2005/06, the Oregon Pink Shrimp Fishery in the United States (a trawl fishery) entered into the process of full MSC assessment and, in October 2006, the Canadian Northern Prawn Fishery (another trawl fishery) did the same (MSC, 2007). The possibility of certification has been cited for several other shrimp fisheries, including the British Columbia Spot Prawn Fishery, the Industrial Shrimp Trawl Fishery in Madagascar, and Australia's Spencer Gulf Fishery. In the ten study countries (Part 2), the possibility of obtaining MSC certification was mentioned by shrimp fishery stakeholders in Australia, Madagascar and the United States as having the potential to exert a positive influence on shrimp fishing practices.

Would ecolabelling promote greater sustainability in shrimp fisheries?

- In support of ecolabelling for shrimp fisheries, Leadbitter and Oloruntuyi (2002) cite studies that show consumer interest in ecolabelled seafood in the United States, Hong Kong SAR and the United Kingdom, but state that studies of consumer purchasing intentions do not necessarily reveal actual purchasing decisions.
- Ward *et al.* (2004) study ways to increase the shrimp price for fishers in the United States and critically examine the contention that fisheries that operate on a "sustainable" basis can be rewarded by a higher price. They indicate that the crucial questions are: whether there is a significant consumer preference for

certified seafood among a certain segment of the population; and whether this segment will vote for this preference by paying a premium for the product. The report indicates that because ecolabelling is a relatively new concept, there is little empirical information to assess how individuals have responded to the label in the market.

- One fisheries management specialist has expressed the view that the MSC bar is set relatively high and almost all shrimp fisheries would struggle to reach it. Because only relatively well-managed, sustainable fisheries are likely to make the grade to MSC certification, the real impacts of certification on poor practices in most of the world's shrimp fisheries are likely to be limited (I. Cartwright, personal communication, May 2007).
- EJF (2003b) discusses shrimp trawling and argues that, in addition to the economic incentives provided by ecolabelling, the practice also acts as a starting-point in raising consumer awareness of fisheries sustainability issues.
- Clay (2004) points out that the most efficient way to address many of the issues related to the sustainability of fisheries is by consulting the few institutional buyers in the United States who decide which shrimp will be subsequently purchased by millions of consumers.

6. Bycatch issues

GENERAL

Most fishing results in catching species other than the target ones. Shrimp fishing, especially in the tropical shrimp trawl fisheries, is a very specialized activity producing large amounts of bycatch that is either discarded or partially kept on board. Where vessel technology allows for it, the proportion of bycatch landed tends to increase when shrimp catch rates decrease. Landed bycatch also tends to also be much higher in poor tropical countries than in developed ones. Bycatch is one of the most pressing and controversial aspects of shrimp fishing and much of the management attention associated with shrimp fisheries is focused on reducing it. The shrimp bycatch issue has generated a great deal of literature; it appears that more has been written on this subject than on any other aspect of shrimp fishing.

Why worry about bycatch? Bycatch, particularly that which is discarded, is a serious conservation problem because valuable living resources are wasted, populations of endangered and rare species are threatened, stocks that are already heavily exploited are further impacted and ecosystem changes in the overall structure of trophic webs and habitats may result (Harrington, Myers and Rosenberg, 2005).

As for several other aspects of shrimp fishing, public discussion on bycatch is polarized. For example, the Environmental Justice Foundation (EJF, 2003b) states that commercial shrimp trawling involves dragging the trawl along the bottom, and scraping up shrimp and everything else in the net's path. On the other hand, Eayrs (2005) indicates that there is a common perception among stakeholders that shrimp trawls sweep large expanses of the ocean, catching all animals in the path of the trawl, but that this is not an entirely correct generalization. Many shrimp fishers have used selective fishing methods for a long time, including trawls with a low headline height to minimize fish catches; ground chain arrangements that reduce the amount of seabed debris taken; avoidance of fishing grounds where bycatch is known to be high; mesh sizes large enough to allow some small animals to escape; and TEDS and BRDS.

As pointed out by Poseidon (2003), much confusion dealing with bycatch stems from uncertainty of the terminology used. In this report, terms related to bycatch and discards of shrimp fisheries follow the convention of Kelleher (2005).

- Discards, or discarded catch, are that portion of the total organic material of animal origin in the catch, which is thrown away or dumped at sea, for whatever reason.
- Discards are not a subset of bycatch as the target species is often discarded.
- Discard rate is the percentage of the total catch that is discarded.
- Bycatch is the total catch of non-target animals.

It is important to note that there are other types of bycatch nomenclature. For example, in Australia, the part of the "catch" that does not reach the deck of the fishing vessel but is affected by interaction with the fishing gear is considered bycatch. The nomenclature used in the United States is also quite different, as shown by the NMFS terms in the section below and in Box 10.

The terms "target" and "bycatch" are relatively clear in industrial shrimp fisheries of developed countries, but become increasingly irrelevant in the progression from large-scale fisheries in the developed world to small-scale fisheries in poor tropical countries where almost everything of economic value can become a target. In these cases, the term "trash fish" is often used. In this report, "trash fish" is defined as fish that have a low

BOX 10

Various estimates of bycatch and discards in the United States warm-water shrimp fisheries

The exact ratio of non-shrimp bycatch in Gulf and Atlantic shrimp trawl fisheries remains difficult to quantify. NMFS data suggest that there was a ratio of 10:1 in the 1970s, before measures were put in place to reduce growth overfishing of shrimp. Estimates of the bycatch ratio for Florida shrimp trawls range from 6:1 to 1:1. Studies in the late 1990s by the Texas Department of Parks and Wildlife found ratios in Texas State waters of approximately 4:1. In 2003, an industry representative asserted that the Gulf and South Atlantic Fishery had reduced the bycatch ratio from 10:1 to 3:1 since the mid-1980s. The best recent, non-industry estimates (NMFS in the late 1990s) suggest that for every pound (0.45 kg) of shrimp caught, about 4.5 pounds of bycatch are discarded in the United States South Atlantic and about 5.25 pounds of bycatch in the Gulf. BRDs are believed to reduce finfish bycatch by as much as 30 percent, which means that since 1997 (when BRD requirements were put into place), ratios could have reached 2.8:1 in the United States South Atlantic and 3.5:1 in the Gulf.

Source: summarized from Cascorbi, 2004b.

commercial value because of their low quality, small size or low consumer preference. In some small-scale fisheries (e.g. Cambodia) trash fish is sometimes targeted.

QUANTIFYING BYCATCH

The amounts of bycatch and discards in shrimp fisheries have been the focus of discussions related to conservation and sustainability for many decades. Even for specific shrimp fisheries, there are widely varying estimates of the amount of bycatch. At least some of the variation is caused by different systems of measurement and the low level of actual monitoring. However, part of the problem lies with how bycatch is defined. For example, while Kelleher (2005) defines bycatch in terms of non-target animals, the NMFS in the United States adopts a more expansive definition that includes the retained incidental catch. Because retained incidental catches are at least secondary targets, bycatch estimates may differ by several orders of magnitude depending on the definition used. From an ecological and global perspective, the NMFS definition would appear to be the most suitable to facilitate an estimate of the total capture of all species in shrimp fisheries.

Even in relatively regulated fisheries in developed countries, estimating and subsequently comparing levels of bycatch is not straightforward (Box 10). The Box also illustrates the point made in the section above concerning differences in bycatch nomenclature.

Lack of effective and uniform monitoring of bycatch in many shrimp fisheries creates difficulties for determining the success of efforts to reduce bycatch (see section *Bycatch reduction devices*) and for the important task of estimating global bycatch from shrimp fisheries.

Although quantifying all bycatch from shrimp fisheries on a global level is crucial for gauging the overall bycatch situation, it is an extremely difficult task. Relatively few regions have reliable data on total species captured (shrimp, finfish and other marine invertebrates). In addition, spatial and temporal variations of species associated with shrimp habitats and differences in fishing operations prevent even a rough approximation of the total global catch. In general, bycatch is low and managed in cold-water shrimp trawl fisheries, but it is high and often unmanaged in tropical shrimp trawl fisheries. Combining these two generalities on a global scale to arrive at a total is fraught with difficulties. Furthermore, there is little quantitative bycatch information on non-trawl shrimp fisheries.

MAJOR BYCATCH ISSUES

Inferences from the national studies

In this study, a number of countries have been chosen as representative of various geographic regions, as well as for their variety of important shrimp fishing conditions: large/small fisheries, tropical/temperate zones, developed/developing countries and good/poor management. These ten countries are examined in Part 2. The major shrimp bycatch issues in the ten countries are thought to reflect the global situation and are summarized in Table 8. In many respects, the bycatch issues are different in warm- and cold-water shrimp fisheries. In Table 8, the shrimp fisheries operate in cold waters (Norway); in both cold and warm[5] waters (United States) or in warm waters (the remaining eight countries).

Some observations can be made on the issues in Table 8. The shrimp bycatch issues highlighted in the national studies are distinctly different between developed and developing countries, large- and small-scale fisheries, and warm- and cold-water shrimp fisheries. In developed countries, compliance with legislation and management plans appear to underpin many bycatch issues. In developing countries, it appears as though economic incentives, including trade sanctions (to encourage bycatch reduction), food security and other requirements (to encourage bycatch landing and reduction of discards) are the main drivers of the bycatch/discards issue. In the small-scale fisheries, many bycatch issues are associated with bycatch utilization and with conflict generated by the bycatch of large-scale shrimp fishing operations.

In addition to the main national bycatch issues highlighted in Table 8, specialized studies examining the bycatch of shrimp fisheries point to other important issues. These include the following:

- *Effects on individual species*. If shrimp bycatch removes a large proportion of the abundance of a particular species, the effect is the same as if the species were a target. Beyond a certain level of removal, that species can be threatened. It makes no difference whether the bycatch is landed or discarded. For example, in the 1980s and 1990s, the bycatch of juvenile red snapper in shrimp trawl fisheries of the Gulf of Mexico was identified as the reason why the commercially valuable red snapper could not recover from overfishing (Cascorbi, 2004b). Sharks, skates and rays are common in the shrimp trawl catch and are particularly vulnerable.
- *Effects on endangered species*. The effect described above is a particular source of concern when the species is already endangered by direct fishing or other threats such as pollution and the destruction of nesting beaches. The mortality of turtles in shrimp trawls is well known (see section *Warm-water shrimp trawl bycatch issues* below), but other threatened or charismatic species are also impacted, including dolphins, seahorses, dugongs, albatrosses and penguins.[6]
- *Effects on ecosystems*. If the abundance of key species is reduced through bycatch, major and unpredictable changes may occur in food chains. This impact is similar whether the removal results from targeted catch or bycatch. One aspect of this issue is the removal of shrimp predators by trawling that can result in profound changes in the food chain, such as increased abundance of prey, including squid and shrimp. This has been observed in both warm- and cold-water shrimp fisheries.

---

5 Eighty-five percent of United States shrimp production is from warm-water fisheries.

6 Gandini *et al.* (1999) studied the Shrimp Beam Trawl Fishery for Argentine red shrimp (*Pleoticus muelleri*) in Golfo San Jorge, Argentina and reported that 0.33 percent of the breeding population of Magellanic penguins is incidentally killed by the shrimp fishery every summer.

TABLE 8
Main bycatch issues of the ten shrimp fishing countries in the study

Country	Bycatch issues
Australia	Bycatch issues in northern Australian prawn trawl fisheries focus predominantly on unwanted fish bycatch and the incidental capture and mortality of sea turtles in trawl nets. Bycatch issues in southern Australian prawn trawl fisheries focus predominantly on unwanted fish and crustacean bycatch. There are several reasons why bycatch issues in Australian prawn trawl fisheries have received considerable attention over the past decade, including the following. • Australian fisheries management agencies have a legislative mandate to ensure that trawl fisheries comply with the principles of ecologically sustainable development (ESD). • Many Australian prawn trawl fisheries also have legislation or policies that require a reduction in the take of non-target species and a minimization of the impact of trawling on the ecosystem. • The drowning of sea turtles in trawls of northern Australia has received considerable attention. • "World Heritage" status has brought increased scrutiny of commercial fishing practices, especially trawling operations, to ensure that the exploitation of fisheries resources do not occur at the expense of the quality of the ecosystem. • All export fisheries require accreditation through a strategic assessment process, which, *inter alia*, gives consideration to levels of bycatch (Robins, Campbell and McGilvray, 1999).
Cambodia	• There are few, if any, measures in place to manage, control or reduce bycatch. • Unlike in many other countries, trash fish is a major bycatch issue here; trash fish could be considered together with shrimp as an actual target of trawling. The proportion of trash fish in the trawl catch is increasing.
Indonesia	• There is a high discard level of industrial shrimp trawlers in the Arafura Sea. • The adverse biological impacts of industrial bycatch on the small-scale shrimp fisheries are significant. • There is a scarcity of appropriate measures to mitigate bycatch problems, and enforcement of bycatch legislation is extremely difficult. • The trash fish situation is complex, characterized by: an increasing use of trash fish for aquaculture and other animal feeds; competition between the use of trash fish for fishmeal and for human food; sustainability of the current system; and the amount of fish that becomes trash through poor handling and post-harvest strategies.
Kuwait	• Although some studies show a high discard rate, the issue is not often raised here. • At present, there is a lack of incentives for using BRDs.
Madagascar	• The reduction of bycatch results in some economic losses to the industrial shrimp fishery – there is a requirement that each kilogram of landed shrimp be accompanied by at least a half a kilogram of fish. • The retained bycatch of shrimp trawling represents a significant amount of the national supply of fish. • The possibility of obtaining ecocertification appears to be providing an incentive for further reducing bycatch and discards.
Mexico	• The amount of discards from Mexico's shrimp fisheries, 133 000 tonnes, is considered to be large. • Mexico is among the 13 countries that currently meet the standard set by the NMFS with respect to the use of TEDs. A major shrimp bycatch issue in Mexico is retaining this status.
Nigeria	• All shrimp trawlers operating in Nigerian inshore waters are required to land 75 percent of the shrimp bycatch. There is much evidence that there is a thriving business of bycatch transfer to canoes. • The use of TEDs on shrimp trawl nets has been a requirement since September 1996, but is still not fully implemented, as documented by the United States import ban. • Traditional small-scale fishing gear catches large quantities of juvenile shrimp.
Norway	• Bycatch of juvenile cod, haddock and redfish (1–1.5 year-old fish) on shrimp grounds in the Barents Sea, as such small fish are not released by the Nordmøre grid. Shrimp grounds are closed for shrimp trawling when bycatch of these species exceeds a preset level. • Capture of small-sized shrimp (< 15 mm carapace length).
Trinidad and Tobago	• The incidental fish catch associated with shrimp trawling may be as high as 90 percent for the artisanal trawl fishery and most of these fish are juveniles of other important coastal fisheries. The high discard rate of the shrimp trawl fisheries is one of the most important sources of conflict between the trawl fishery and other coastal fisheries in national waters. • Implementation of management actions to improve selectivity and limit discards has been hampered by the lack of capacity to monitor activities at sea, limited data on catches and on economics of the fishery, and limited alternative technological options in the harvest sector. • The imposition of TED requirements on the semi-industrial and industrial trawl fleets has not been well accepted by the industry.
United States	• The major bycatch issues are: estimation of bycatch in the various fisheries; the impacts of shrimp fishing on protected species, non-protected species and the environment; and various initiatives to reduce this impact, both domestically and internationally. • Kelleher (2005) notes that with respect to general bycatch issues in the United States, three features are especially noteworthy: (i) the growing impact of the incidental catch of charismatic species in fisheries management and in trade; (ii) the emerging influence of civil society with regard to bycatch and incidental catch issues; and (iii) the importance of fisheries management plans in bycatch management. • The incidental take of juvenile red snapper has been a significant bycatch problem in the Gulf of Mexico Shrimp Fishery, the resolution of which has challenged fishery managers for many years.

Indeed, in the Mediterranean, fishers have allegedly "cleaned" upper slope grounds from predators (e.g. sharks, chimeras, etc.) to turn them into shrimp and hake fishing grounds.

- *Impacts on scavengers*. Seabirds and dolphins are known to consume discarded shrimp fishing bycatch. This may result in improvement of the reproductive rate of these animals, but may also lead to difficulties if they become dependent on the discards or are injured in the process of taking the bycatch.
- *Decomposition of discards*. The impact of the discards on the bottom detritus feeders and microbial fauna is not well known. The oxygen depletion that may occur when discards sink to the sea bottom of shallow, poorly circulated inshore areas may cause effects on the benthic community.
- *Conflict through bycatch*. The bycatch of large-scale shrimp trawling is often comprised of juveniles and adults of species important to small-scale fisheries, leading to reduced availability in the latter. In this situation, discarding is especially controversial.

FIGURE 18
Sorting shrimp from the bycatch

Photo courtesy of NOAA Fisheries Service.

Although shrimp bycatch creates various environmental problems, it is an important source of food in many communities. In Madagascar, consumption of the bycatch of shrimp fisheries constitutes about 6 percent of the national intake of fishery products. In Nigeria, trawler bycatch retained and sold ashore is an important food. In a review of a global programme to reduce bycatch from shrimp trawling, Westlund (2006) states that bycatches appear to play an important role in food security for poorer population groups in some countries, but their exact role is not yet well understood. A related issue, mentioned by ICES/FAO (2005), is the suboptimal situation in which communities become dependent on consumption of juvenile fish in the shrimp bycatch.

Warm-water shrimp trawl bycatch issues

Two issues are particularly important in warm-water shrimp fisheries: turtles and trash fish.

Turtles

The bycatch of sea turtles by warm-water shrimp trawling is one of the most contentious topics related to shrimp fishing. The subject has generated considerable publicity and subsequent management action has had a major effect on most of the large shrimp fisheries in the tropics.

There are seven species of sea turtles in the world. These are the loggerhead (*Caretta caretta*), green (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*), olive ridley (*Lepidochelys olivacea*), flatback (*Natator depressus*), leatherback (*Dermochelys coriace*) and Kemp's ridley (*Lepidochelys kempii*). All seven species are listed in Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).[7] Three species are classified as "critically endangered" on the World Conservation Union (IUCN) Red List: the leatherback, hawksbill and Kemp's ridley.

7 Appendix I includes species that are threatened with extinction and that may be affected by international trade. These species are prohibited from being traded internationally for commercial purposes, but some trade is allowed for non-commercial purposes (e.g. for educational facilities or scientific purposes).

The role of shrimp trawling as one of the threats to sea turtles has been recognized for some time. Hillestad *et al*. (1981) stated that "worldwide the shrimp trawling industry seems to capture more sea turtles than any other commercial fishery. Many of the most intensely trawled waters are adjacent to major sea turtle nesting beaches or feeding grounds". Some alarming reports[8] of turtle mortality have generated considerable publicity.

- In 1990, the Committee on Sea Turtle Conservation of the National Research Council (NRC) published a report on the capture of sea turtles. An important finding of the study was that shrimp trawling in the United States results in the deaths of 5 000–50 000 loggerhead turtles and 500–5 000 Kemp's ridley annually. Collectively, all other fishing activity is responsible for an additional 500–5 000 loggerhead deaths and 50–500 Kemp's ridley deaths annually. The incidental capture of sea turtles in shrimp trawls was identified by the committee as the major cause of mortality associated with human activities – killing more sea turtles than all other human activities combined (NRC, 1990).
- Twenty thousand turtles, mainly olive ridleys, are taken by Costa Rican trawlers each year, around half of which die from the trauma (Arauz, 1998).
- Over 35 000 olive ridleys were recorded dead on Orissa beaches in India from 1993 to 1998, most of which were killed by trawling (Pandav and Choudhury, 1999).
- A project conducted in 1989 and 1990 estimated that 5 000–6 000 turtles were caught by trawlers annually in Australia's Northern Prawn Fishery (Poiner and Harris, 1996).

The NRC study cited above concluded that the best method currently available to mitigate the effects of trawling on turtles (short of preventing trawling), would be the use of TEDs. Subsequent legal action under the Endangered Species Act resulted in the requirement for TEDs on all United States shrimpers operating in the Gulf of Mexico and South Atlantic. In 1992, as a result of lobbying by United States shrimp fishers and environmentalists, the TED provision was broadened to include foreign fleets. The saga of the United States extending the TED requirement abroad is given in Chapter 5, section *Important issues in the shrimp trade*.

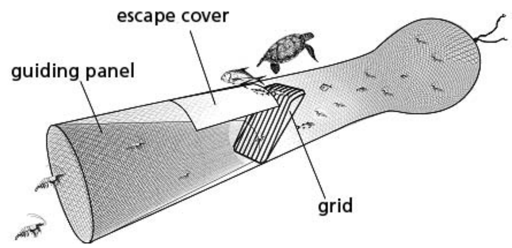
Since a TED is considered to be any modification to a shrimp trawl aimed at reducing the capture of turtles, there are consequently several designs. Much of the original TED design work was undertaken by the NMFS in the Gulf of Mexico Fishery, starting in the mid-1970s. In 1980, John Watson of NMFS introduced the first prototype TED and, in 1983, NMFS started a formal programme urging voluntary introduction of TEDs. Since that period, TED designs have evolved considerably (Watson and McVea, 1977; Watson, Mitchell and Shah 1986; Hogan, 2004).

The most common TED designs use an inclined grid to prevent large animals from entering the codend (Figure 19). The animals are guided by the grid towards an escape opening located either in the top or bottom of the codend. Smaller animals (including shrimp) pass through the bars of the grid and enter the codend. A less common TED design uses an inclined netting panel instead of a grid (Eayrs, 2005).

Gauging the effectiveness of TEDs in reducing sea turtle mortality is not straightforward. The efficiency of a TED is affected by the design, operational conditions, effectiveness of the rigging, maintenance of the device and skill of the crew. Furthermore, some turtles may die after contact with a trawl even if excluded by the TED, and many turtles survive even if captured in the trawl. Despite these difficulties, some estimates of sea turtle mortality reduction have been made for tropical fisheries in developed countries.

[8] Although the number of turtles killed appears large, the importance as a proportion of the populations concerned is not known.

FIGURE 19
A turtle excluder device using an inclined grid



Courtesy of NOAA Fisheries Service (William B. Folsom).
Note: The oval metal ring and bars deflect the turtles. The cut in the netting is where the cover flap will be placed. The bars force the turtle to the opening covered by the flap, which opens and allows the turtle to go free.

- Studies of Australia's Northern Prawn Fishery prior to the TED requirement indicated that an average of 0.0509 and 0.0754 turtles per trawl were captured for the tiger prawn and banana prawn season, respectively. Since TEDs became mandatory in 2000, the catch of sea turtles is estimated to have decreased to 0.0072 and 0.0092 for the two seasons (Robins *et al.*, 2002).
- In the United States, in order to be approved by NMFS, a TED design must prove to be 97 percent effective in excluding sea turtles during testing based upon specific testing protocols (Federal Register, 2004). Some studies, however, have suggested that the actual exclusion is considerably less, especially for larger turtles.

TEDs also have costs – mostly because they inadvertently reduce the capture of the target shrimp. The most common causes of shrimp loss are grid blockage and delayed exclusion of large animals from the trawl (Eayrs, 2005b). The actual reduction is hotly debated. Cascorbi (2004b) reviews the situation in the warm-water shrimp trawl fisheries of the United States and reports that some fishers claim that TEDs reduce the shrimp catch by as much as 30 percent, although federal government tests indicate an average of 10 percent. Samonte-Tan (2000) assumes that shrimp loss from TED use is 14 percent and calculates that it costs shrimp trawl fishers in the Gulf of Mexico US$37.2 million annually.

There can be a number of advantages in using TEDs, which can offset costs, particularly where they have been modified to exclude large animals including sharks, rays and other large bycatch species and fish (Eayrs, Buxton and McDonald, 1997). These include:

- ability for gear to stay longer on the bottom, decreasing the time wasted during sorting and hauling;
- possible reduction of damage to the net caused by large animals;
- quicker sorting time;
- reduced injuries to the crew from dangerous animals; and
- higher quality of shrimp catch.

The means to reduce turtle mortality by shrimp trawling are well known, but come with a price. Justification for the extra costs is probably better understood by fishers in developed countries than in small-scale fisheries of the developing world. During periods of low profitability such as the present (Chapter 8), all shrimp fishers, regardless of location, are more likely to be critical of factors affecting their income.

Trash fish

Discards in the small-scale shrimp fisheries of most tropical developing countries are low or negligible. As indicated in the first part of this chapter, it is often difficult to distinguish between target species and bycatch in multispecies, small-scale and large-scale fisheries (e.g. non-specialized trawl fisheries) that catch shrimp. The low-value catch, which is sometimes a target (e.g. by small Cambodian trawlers) is often referred to as "trash fish". The term has recently 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 for livestock/fish, either directly or through reduction to fishmeal/oil* (Funge-Smith, Lindebo and Staples, 2005). Although the improved use of trash fish reduces discards, in turn reducing the ethical issue of waste, some other issues arise in trash fish-producing fisheries, including shrimp fisheries.

- *Direct versus indirect human consumption*. Trash fish is increasingly used directly for human food in many countries, as discussed above. It is also increasingly used indirectly for human food through aquaculture and other animal feeds, either in fresh form or after reduction to fishmeal. Key issues behind this competition are the loss of yield for human consumption because of the low conversion rate of fish to human food though culture and the diversion of trash fish food from poor customers in producing countries to rich aquaculture species consumers in the developed world. The effect of this transfer is not known
- *Sustainability of the current system*. The high risk stemming from landings that are usually not properly registered, leading to unknown removals of non-identified species has already been stressed above, particularly the risk of growth overfishing through harvesting of juveniles of commercial species.
- *Processing performance*. The amount of fish that becomes trash as a result of poor handling and post-harvest strategies is an ongoing issue.

The management of trash fish in capture fisheries is a significant challenge in Southeast Asia, even compared with that of managing other types of fisheries. Trash fish generally comes from non-target (multi-target) fisheries, using relatively unselective gear. The landings are particularly difficult to monitor since they are often far from major landing sites. There is a strong demand for trash fish that is also changing rapidly as markets evolve. These market drivers are also occurring on a local scale, which is difficult to monitor or influence (WorldFish, 2005).

A critical issue is that the increasing demand for trash fish in some regions of the world creates economic incentives for bycatch increases, rather than bycatch reduction. If shrimpers would "unspecialize", returning to the pre-shrimping original function of multispecies fishing boats, with multiple targets and reduced discarding, the specific bycatch/discard problem would become less acute. In addition, it would be subsumed under the general (and not easier) issue of exploitation and management of multispecies resources in data-poor situations. This is in fact happening in many developing countries where, because of higher demands for human consumption and other uses, shrimp fishery discards are now close to zero.

Cold-water shrimp trawl bycatch issues

In general, bycatch problems are less severe in cold-water shrimp trawl fisheries than in those of the tropics. Although the cold-water fisheries can also produce large amounts of bycatch, efforts to promote bycatch reduction and utilization have enjoyed considerable success. The shrimp trawl fisheries of the northeast Atlantic are sometimes cited as positive examples of what can be done in bycatch reduction. Roberts (2005) reviews the bycatch situation in North American shrimp fisheries.

All the major trawl fisheries for cold-water shrimp in the United States and Canada have plans in place to reduce bycatch. Both countries' northern shrimp fisheries have mandatory Nørdmore grate requirements. The Oregon and Washington pink shrimp fisheries have mandatory grate or soft BRD requirements. These and other measures such as seasonal closures and trawl modifications have reduced bycatch to less than 5 percent of the total catch, and so are deemed effective.

Another important feature is that the capture of sea turtles is not a major issue in the shrimp fisheries of temperate regions. In reviewing the issue in North America, Roberts (2005) indicates that no sea turtles have been caught in cold-water shrimp fisheries in Canada or the United States. With respect to restrictions placed on imports of shrimp into the United States, the Government has certified that 16 nations have shrimp fisheries only in cold waters, where the risk of taking sea turtles is negligible: Argentina, Belgium, Canada, Chile, Denmark, Finland, Germany, Iceland, Ireland, the Netherlands, New Zealand, Norway, the Russian Federation, Sweden, the United Kingdom and Uruguay.

One of the most important bycatch issues in the cold-water shrimp trawl fisheries is the effect on non-target commercial species. In the North Atlantic, the use of the Nordmøre grid has had a major effect on reducing the quantities of bycatch of the important cod, haddock, Greenland halibut and redfish. The grid is not very effective at reducing the capture of small individuals, however, and significant numbers of the young of these commercially important species are vulnerable to capture by shrimp trawls. In many cases, the management strategy to address this problem has been to close areas when and where such small fish occur. A similar issue relates to the capture of small-size individuals of the target shrimp species.

Estimating the quantities of bycatch is an important issue in some fisheries, especially those that involve fishers from more than one country. Compatible bycatch estimation and verification techniques are required if results are to be meaningful. In 2006, Russian and Norwegian fishery scientists continued to work on developing a common methodology for determining quantities of bycatch and discards in the shrimp fishery of the Barents Sea (IMR, 2007). Much of the work of fishery observers on board cold-water shrimp trawl vessels consists in estimating bycatch levels.

Kelleher (2005) states that a number of countries that participate in cold-water shrimp fisheries of the North Atlantic pursue a "no discards" policy, which is one of the factors responsible for relatively low discard rates in the major fisheries of the region. The Norwegian discards ban, discussed in Part 2, means that when commercially important species are captured as bycatch and as juveniles of the target species, the catch must be taken ashore and deducted from the total allowable catch of the concerned species. The "discard ban" does not mean that Norwegian fisheries, including the shrimp fisheries, discard unwanted fish, but rather, stipulates that important species are not to be discarded.

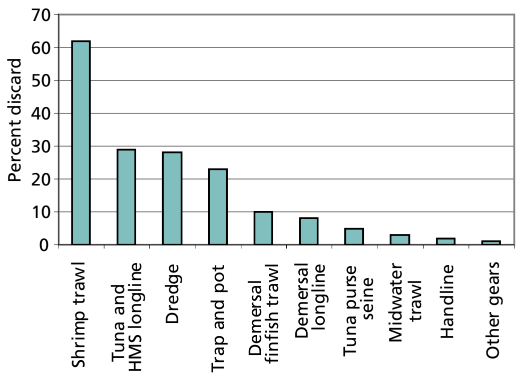
THE FAO DISCARDS STUDY

Bycatch that is discarded results in waste of ecological and economic resources and, as such, is especially troublesome. In a major study, Kelleher (2005) estimates the quantity of discards in the world's marine fisheries from 1992 to 2001. Kelleher's results indicate that the shrimp trawl fisheries, and tropical shrimp trawl fisheries in particular, are the single greatest source of discards, accounting for 27.3 percent (1.86 million tonnes) of estimated total discards. The aggregate or weighted discard rate for all shrimp trawl fisheries is 62.3 percent and is very high compared with other fisheries (Figure 20).

Kelleher indicates that shrimp trawl fisheries have consistently high discard rates because of a range of factors.

- Shrimp is often less than 20 percent of the demersal biomass on many shrimp fishing grounds.
- The relatively small mesh size required to capture shrimp inevitably results in large quantities of bycatch.
- Vessels are designed for shrimp retention and have limited freezing and hold capacity for bycatch.
- Transhipment at sea is often discouraged by vessel owners, or prohibited by authorities because of concerns over theft or illegal/ unrecorded transhipment.

FIGURE 20
Discard rates by gear type



Source: Kelleher, as summarized in FAO, 2004.

- Shrimp grounds are often at a considerable distance from the markets for bycatch, rendering its retention and transport to market uneconomical.
- Bycatch species are often of small size and their relatively low value makes bycatch retention uneconomical;
- Enforcement of regulations on minimum landings of bycatch and on discard reduction may be deficient.

The tropical shallow-water shrimp fisheries account for 70 percent of total estimated discards from shrimp trawl fisheries. Almost all of these fisheries target penaeid shrimp and have an average discard rate of 55.8 percent. Three countries, China, India and Thailand, all with low or negligible discard rates, account for over half of the penaeid shrimp catch. Most shrimp trawl fisheries in South and Southeast Asia have insignificant discards, with the notable exception of the Arafura Sea Shrimp Fishery. The latter, as well as the fisheries in the Gulf of Mexico, United States Atlantic, Ecuador and on the Guiana shelf, accounts for a large proportion of the discards from tropical shrimp fisheries. Several smaller shrimp fisheries have discard rates in excess of 80 percent: those of Kuwait, French Guiana, Panama and Suriname.

The cold-water shrimp trawl fisheries exhibit an even greater variety than tropical shrimp in terms of fishing gears, fishing depths and substrates. In aggregate, they have a weighted discard rate of 39 percent and contribute approximately 220 000 tonnes to the global discard estimate. The highest recorded discards occur in the fishery of Peru (74 000 tonnes with a discard rate of 81 percent). The fisheries for Pandalidae (*Pandalus, Heterocarpus* sp.) concentrated in the North Atlantic (Canada, Norway, Iceland) account for approximately 13 000 tonnes of discards. The mandatory use of Nordmøre grids and other BRDs in most of these fisheries results in a relatively low discard rate (weighted discard rate of 5.4 percent).

Kelleher indicates that a complex of biological, economic and regulatory factors determine fishers decisions to discard. These factors are generally specific to each fishery and the decision to discard may vary according to fishing trip, fishing operation, season or fisher. Consequently, discard information has a high level of inherent variability, often requiring extensive discard sampling to generate accurate assessments of quantities.

BYCATCH SPECIES

In the subtropical and tropical regions of the world, the bycatch from shrimp fisheries includes a large number of finfish species characteristic of warm-water tropical fauna, such as: small jacks (Carangidae), pompanos (Carangidae), goatfishes (Mullidae), lizardfishes (Synodontidae), mojarras (Gerridae), threadfins (Nemipteridae and Polynemidae), tooth ponies (Leiognathidae), flounders (Bothidae), rays (Dasayatidae), sea trouts and croakers (Sciaenidae), catfish (Siluridae), snappers (Lutjanidae), lizardfish (Sauridae), scads (Decapterridae), tonguesoles (Cynoglossidae), grunts (Pomadasidae), barracudas (Sphyrenidae), squids and cuttlefish (cephalopods), as well as hairtails, ribbon fish, sardines, anchovies, shads and groupers. Discards are mostly made up of species maturing at sizes under 20 cm and weighing less than 100 g (Villegas and Dragovitch, 1984; Van Zalinge, 1984; Clay, 1996).

A substantial amount of invertebrate species is also taken by shrimp trawls. In Australia's Northern Prawn Fishery, 234 species of invertebrates have been noted in the bycatch; other crustaceans make up 4–5 percent of all bycatch and cephalopods about 1–2 percent (NORMAC, 2002). In Indonesia's Arafura Sea Shrimp Trawl Fishery, research from 1990 to 1998 showed that organisms other than shrimp or fish represented from 3 to 6 percent of the total catch (ICES/FAO, 2005).

The bycatch species composition is very different in cold-water shrimp fisheries. For example, in the Canadian Northern Shrimp Trawl Fishery, Atlantic cod (*Gadus morhua*), American plaice (*Hippoglossoides platessoides*), redfish (*Sebastes* spp.) and

Greenland halibut (*Rheinhardtius hippoglossoides*) account for 90 percent of the bycatch (Koeller *et al.*, 2000). In a non-trawl fishery, the Southeast Alaska Pot Fishery for spot prawns and coonstripe shrimp, invertebrates – mainly squat lobster (*Munida quadrispina*) – and several species of crab, molluscs and echinoderms made up over 90 percent of the bycatch (Roberts, 2005).

An important bycatch issue in both warm- and cold-water-shrimp trawl fisheries is the catch of juveniles of important commercial fish species. Several fisheries are involved, for example: the bycatch of cod off Norway; rockfish off Oregon; red snapper and Atlantic croaker in the Gulf of Mexico; king mackerel, Spanish mackerel and weakfish off the southeast United States and plaice, whiting, cod and sole in the southern North Sea. This is a very important driver of management interventions related to shrimp bycatch.

INTERNATIONAL INITIATIVES TO REDUCE BYCATCH

Several international efforts are currently under way to reduce shrimp trawl bycatch. These include assistance from international organizations, trade requirements and international legal instruments. All three types of initiatives are applicable to the bycatch of warm-water shrimp fisheries, while the international legal instruments are relevant to cold-water shrimp fisheries.

Starting in 2002, FAO implemented a five-year global project: the United Nations Environment Programme (UNEP)/Global Environment Facility (GEF) project *Reduction of Environmental Impact from Tropical Shrimp Trawling through the Introduction of Bycatch Reduction Technologies and Change of Management*. This project, funded by GEF, concentrates on four main tropical regions. Eleven countries and one regional organization participated fully in the project: Cameroon, Colombia, Costa Rica, Cuba, Indonesia, Islamic Republic of Iran, Mexico, Nigeria, Philippines, Trinidad and Tobago, the Bolivarian Republic of Venezuela and the Southeast Asian Fisheries Development Centre (SEAFDEC). The overall objectives of the project are to reduce bycatch taken by shrimp trawlers, reduce capture of juvenile fish, particularly of species used for human consumption, and increase knowledge of the impact of shrimp trawling on marine habitat. The project was reviewed in late 2006. Box 11 gives some of the important findings of the review.

Another international initiative to reduce trawl bycatch (partially supported by the GEF project) is being carried out by SEAFDEC, an intergovernmental body established to promote fisheries development in Southeast Asia. Current members are Brunei Darussalam, Cambodia, Indonesia, Japan, Lao People's Democratic Republic, Malaysia, Myanmar, the Philippines, Singapore, Thailand and Viet Nam. SEAFDEC started work on BRDs in 1996 and has been involved in developing the Thai turtle-free device and four types of juvenile and trash excluder devices (JTEDs) for shrimp trawls: the rectangular shaped, the circular shaped, the rigid sorting grid and the semi-curved rigid sorting grid JTEDs. The development and testing of the devices have continued in collaboration with the GEF project, including support to the Philippines and Indonesia with practical demonstrations and sea trials and experiments. Several collaborative workshops and training events have also been organized jointly by SEAFDEC and the GEF project. SEAFDEC's efforts have been especially valuable in the development and production of promotional and information material on bycatch reduction (Westlund, 2006).

Because of its broad geographic scope, the United States unilateral policy with regard to the use of turtle excluder devices (see Chapter 6, section *Warm-water shrimp trawl bycatch issues*) could be considered a bycatch reduction initiative that is international in its impact. Thirteen countries meet the United States TED requirements and 24 countries and one economy are certified as having fishing environments that do not pose a danger to sea turtles.

BOX 11

Major findings of the mid-term review of the UNEP/GEF project on *Reduction of Environmental Impacts from Tropical Shrimp Trawling*

Substantial results have been produced with regard to data collection, and testing and demonstration of BRDs and improved gear. Outputs produced to date include:

- tests on BRDs and decision on what devices should be promoted/recommended for regulations completed for some fisheries (e.g. in Calbayog in the Philippines, Colombia, Pacific coast of Mexico, etc.) and trials well under way in most other countries. Probable bycatch reductions are estimated at around 30-40 percent;
- revised or new legislation adopted in Nigeria and Mexico; work started on legal reviews in others; recertification of Nigeria for shrimp exports to the United States through the reintroduction of TEDs;
- recognition of the need for a reinforced, wider fisheries management approach, including, for example, effort controls through closed seasons/areas and limits on number of trawlers;
- extensive technical regional and global collaboration established, cooperation initialized and steps taken towards harmonization of bycatch reduction at the subregional level (Nigeria/Cameroon/Gulf of Guinea countries, Mexico/Latin America and the Caribbean, SEAFDEC/Southeast Asia);
- knowledge of bycatch composition and quantities, and improved information collected on the socio-economic role of bycatches (Nigeria, and Trinidad and Tobago);
- cooperation between governments (officials and researchers) and the shrimp trawl industry/private sector established or strengthened in countries where it existed pre-project;
- awareness of the importance and usefulness of BRDs and the knowledge of possible technical solutions enhanced among relevant national institutions and administrations, as well as within the fishing industry;
- an FAO manual/guide on BRDs published, *A guide to bycatch reduction in tropical shrimp-trawl fisheries* (Eayrs, 2005); training materials on juvenile and trash fish excluder devices developed by SEAFDEC; and project Web site set up.

Source: Westlund, 2006.

Several international legal instruments and agreements also focus on bycatch in general (Box 12).

BIOLOGICAL RESEARCH ON BYCATCH

Warm-water shrimp fisheries

In order of increasing complexity, biological research on shrimp bycatch has consisted of determining bycatch quantities, species composition, impacts on the bycatch species and impacts on the ecosystem.

In shrimp fisheries in tropical developing countries, bycatch research is most often limited to estimating bycatch quantities. Although Kelleher (2005) asserts that "on-board observer reports are considered indispensable for accurate estimation of discards", not many tropical developing countries have comprehensive observer programmes on shrimp vessels, and there are few, if any, such programmes on small trawlers. The bycatch research situation in many developing countries is in the same category as Bangladesh where ICES/FAO (2005) state: *There has not been much research so far on shrimp fisheries in general and on shrimp trawling in particular. Valid*

BOX 12
Global attempts to reduce discards

*The United Nations General Assembly Resolution 49/118 (*1994) concerns fisheries bycatch and discards, and their impact on the sustainable use of the world's living resources. In this resolution, the United Nations promotes the issue of bycatch and discard reduction in FAO's development of a Code of Conduct for Responsible Fisheries and suggests its inclusion in the UN Conference on Straddling Fish Stocks and Highly Migratory Fish Stocks. It also urges regional fisheries organizations to review and, where possible, address specific jurisdictional issues in bycatch and discard reduction.

The United Nations Fish Stocks Agreement states that signatories should "...minimize pollution, waste, discards, catch by lost or abandoned gear, catch of non-target species … and impacts on associated or dependent species … through measures including, to the extent practicable, the development and use of selective, environmentally safe and cost-effective fishing gear and techniques".

The Kyoto Conference on Sustainable Contribution of Fisheries to Food Security in 1995 produced a declaration intended to "promote fisheries through research and development aimed at […] (iii) reduction of discard mortality; (iv) development and use of selective, environmentally safe and cost effective fishing gear and techniques".

The FAO Code of Conduct for Responsible Fisheries, Article 7.6.9 addresses bycatch and discards.

> *States should take appropriate measures to minimize waste, discards, catch by lost or abandoned gear, catch of non-target species, both fish and non-fish species, and negative impacts on associated or dependent species, in particular endangered species. Where appropriate, such measures may include technical measures related to fish size, mesh size or gear, discards, closed seasons and areas and zones reserved for selected fisheries, particularly artisanal fisheries.*

Source: Poseidon, 2003.

scientific information in this regard is still lacking. No estimate of the type and amount of bycatch has ever been made.

Shrimp bycatch studies appear to be most advanced in Australia; certainly the country has the most sophisticated research involving bycatch for tropical shrimp fisheries. Two Australian studies are especially relevant and can provide an indication of what has been achieved in shrimp bycatch research.

Environmental effects of prawn trawling in the far northern section of the Great Barrier Reef: 1991–96. This was undertaken by the Commonwealth Scientific and Industrial Research Organization (CSIRO) and the Queensland Department of Primary Industries and Fisheries (QDPI) on the environmental effects of trawling in a 10 000 km^2 area closed to fishing in the northern Great Barrier Reef region. The report of the study had many conclusions related to bycatch, some of which are summarized by CSIRO (1998).

- *Fish.* A total of 243 species of fish were captured in prawn trawls. These trawls mainly capture small species of fish that are associated with the seabed. Many larger species of epibenthic and pelagic fish are not taken, so prawn trawls impact on only part of the fish community. Although recreationally and commercially important species of fish occur in the study areas, prawn trawls seldom catch juveniles or adults of these species. There is little overlap, therefore, between recreational or commercial line fisheries and prawn trawl fisheries in this part of the Great Barrier Reef. The results suggest that for species that can be captured by a prawn trawl, with the exception of two species (*Diagramma pictum* and *Scolopsis taeniopterus*), all size/age stages are vulnerable. The extent of the impact of prawn trawling on fish populations is probably low, given the generally low fishing effort in the study area.

- *Birds.* The only species of seabird apparently affected by feeding on discards is the crested tern. Populations of this species have increased by two orders of magnitude over the time of the trawl fishery. This increase may have been the result of greater availability of discards for young birds.

Ecological sustainability of bycatch and biodiversity in Prawn Trawl Fisheries: 1996–99. This was undertaken by CSIRO and QDPI for Australia's Northern Prawn Fishery, the Torres Strait Prawn Fishery and the Queensland Banana Prawn Fishery. The Northern Prawn Fishery Management Advisory Committee (NORMAC, 2002) gives the main results.

- *Species vulnerability*. Since the 1980s, 411 fish species have been recorded in the Northern Prawn Fishery (NPF) bycatch. The species ranked as least likely to be sustainable, and therefore the priority for management, monitoring and research, were highly susceptible to trawls. They are benthic or demersal, their main habitat is soft sediments and their diet may include prawns. Their recovery capacity is low. In applying this process, important gaps in current knowledge of bycatch species have been highlighted, but the ranking must be used with caution. Future research should be aimed at developing a greater understanding of the biology of these species and their distribution in the region of the fishery. The biology of elasmobranchs makes them more susceptible to overfishing than bony fishes because they are long lived, slow growing, reach maturity at a later age and have few young. Fifty-six species of elasmobranchs have been recorded in the bycatch of the NPF. Most are dead when landed on deck (56 percent), and survival is lower for smaller individuals. Most elasmobranchs caught by trawlers are small and would fit through TEDs. The biology of sea snakes also makes them more susceptible to overfishing than bony fishes. The fishing mortality of the 13 species of snakes in the NPF bycatch is about 49 percent. TEDs and BRDs appear to be effective in reducing sea snake catch.
- *Effects on fish bycatch*. 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, there would be 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 these areas. In general, the mean size of species was greater in the open areas. Although the results were equivocal with regard 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 trawling impacts.
- *Future research and monitoring*. The high diversity of the bycatch of these tropical prawn fisheries and the fact that most species are rare mean that managing the sustainability of the bycatch is a significant challenge. There are clearly some species that are more susceptible to trawling and are unlikely to recover if depleted; these species are the least likely to be sustainable. Consequently, future research and management should concentrate on them. A monitoring programme will be critical to assess whether the bycatch mortality is sustainable or not.

Poiner *et al*. (1998) indicate important areas for future shrimp trawl bycatch research. They indicate that the priorities should be to document the recovery of seabed fauna after depletion, examine ways to assess sustainability of the harvest of bycatch species, and measure the recruitment, growth, mortality and reproduction of structurally dominant large seabed organisms.

Cold-water shrimp fisheries

There is a significant amount of research on bycatch for cold-water shrimp fisheries. Poseidon (2003) indicates that from 1994 to 1998 the EU alone funded 50 studies related to discards, bycatch and selectivity as part of its Biological Studies Programme, and 14 projects (at a combined cost of €11.2 million) as part of its Programme of Research and Technological Development; many of these involved European shrimp fisheries. The considerable bycatch research cooperation of Denmark, the Faeroe Islands, Greenland, Iceland, Norway and Sweden has been facilitated by the Nordic Council of Ministers. A substantial amount of shrimp bycatch research is also being carried out in Canada and the United States.

Two types of biological research on the bycatch of cold-water shrimp fisheries are especially important: studies on the effects on commercially important fish and studies on the dynamics between target and bycatch species.

Recent research has provided some insight on the effects that taking bycatch will have on other commercially important fish. Graham, Polet and Revill (2005) indicate that numbers of discarded fish may have little meaning unless they are suitably modelled in order to determine their detrimental effects upon the affected stocks; a high discard rate of very young fish may not be problematic if most would die from natural mortality. Revill *et al*. (1999) estimated that a complete reduction of bycatch in the *Crangon* Beam Trawl Fishery of the southern North Sea may result in an additional 2 000 tonnes of cod, 1 500 tonnes of whiting, 12 000 tonnes of plaice and 600 tonnes of sole being landed annually by North Sea whitefish fishers.

BYCATCH REDUCTION DEVICES

The large amount of bycatch generated by shrimp trawl fisheries has resulted in worldwide attention. Various programmes and mechanisms have been introduced to reduce the unwanted and wasted portion of the catch.

Although bycatch issues can be quite different with regard to warm- and cold-water shrimp trawl fisheries, many devices to reduce bycatch are shared between the two. Developments in one group have had impacts on the other, especially those of cold-water on warm-water shrimp trawl fisheries. In general, BRDs in the latter are required to deal with a more heterogenous group of animals than those of cold-water fisheries and, consequently, there is a greater variety of devices.

Broadhurst (2000) reviews the evolution of bycatch reduction through technological changes to trawl gear. Innovation in bycatch reduction is examined in 47 prawn trawl fisheries around the world, starting with the efforts in cold-water European shrimp trawl fisheries in the mid-1960s. The Broadhurst study indicates that, despite the wide variety of BRDs, most can be classified under the following two broad categories.

- *BRDs that separate species by behaviour*. These BRDs operate by exploiting behavioural differences between shrimp and fish, using strategically placed funnels, horizontal and/or vertical panels and escape windows. They take advantage of the principle that fish, unlike slow-moving benthic invertebrates, have certain characteristic responses to towed trawls.
- *BRDs that separate species by size*. These BRDs use relatively simple oblique panels or grids, usually located within or immediately forward of the codend. Such features tend to partition the catch mechanically, according to size, and exclude individuals that are larger that the openings in the panels/grids. TEDs (see section above, *Warm-water shrimp trawl bycatch issues*) are in this category.

BOX 13
The Nordmøre grid

The Nordmøre grid is the most widespread gear-related technical measure used in the North Atlantic Shrimp Fishery to reduce bycatch. The concept came from a shrimp fisherman, Paul Brattøy, who lived in the Nordmøre area of Norway, hence the name. He developed the grid, which had comparatively large bar spacing initially used to exclude the bycatch jellyfish often found in shrimp grounds.

In 1989, after a few months of testing and modification, the Nordmøre grid was introduced to the shrimp fishery. Fishing grounds that were closed because of high bycatch of juvenile cod and haddock were opened for shrimp trawling when a grid was installed in the trawl. Fishers were at first reluctant to use the device, but when a few skilled shrimpers proved that they managed both to handle the grid and to access shrimp grounds yielding extremely good catches, the grid was a success. Soon a large proportion of the coastal fleet used the grid voluntarily.

Following the success of this device, a series of formal experiments was undertaken in Norway, with a grid system having narrower bar spacing (19 mm). The research demonstrated considerable reductions in the bycatches of cod, haddock, redfish, Greenland halibut and polar cod with a minimum loss of shrimp (approximately 5 percent). In 1991, Canadian researchers tested grid technology on the Gulf of St Lawrence Fishery. A number of vessels were fitted with 19-mm Nordmøre grids with retaining bags fitted to the escape opening; the catch retained was used to estimate the quantity of bycatch escaping from the trawl as well as monitor potential shrimp loss. On average, the reduction of bycatch was 97 percent, with only a 2 percent loss of shrimp. Other experiments in the Eastern Scotian Shelf showed bycatch reductions of 97, 100, 95 and 100 percent for plaice, cod, redfish and haddock, respectively (Graham, 2005; Isaksen, 1997).

The Nordmøre grid, a BRD that separates species by size, is very important in the North Atlantic Shrimp Fishery and in several other fisheries. Box 13 describes the development of this gear.

A great deal of work has been done to improve the efficiency of BRDs with regard to excluding bycatch and minimizing impact on the target shrimp. It is generally acknowledged that, because of the large diversity in shrimp trawl fisheries, no particular design is appropriate for all fisheries, but rather, the most effective design for a fishery depends largely on the characteristics of that fishery. Broadhurst (2000) indicates that important factors to consider include size of trawls, location of use, handling of gear, species to be excluded and regulations governing the fishery. Considerable testing and adjustment are often required to arrive at a suitable design for a particular fishery.

The Nordmøre grid remains the most important BRD in cold-water shrimp fisheries. In 2005, regarding warm-water fisheries, FAO produced a manual on reducing bycatch in tropical shrimp trawl fisheries. The guidebook (Eayrs, 2005) was designed for fishers, net makers and fishing technologists, as well as fishery managers and policy-makers interested in a practical guide to the design, use and operation of BRDs. Some of the most important devices and modifications in the guidebook are given in Box 14.

An important aspect of BRDs is the fate of the excluded animals. If they suffer high mortality as a result of their contact with the BRD and/or fishing gear, then the bycatch reduction may not produce the desired benefits. Eayrs (2005) states that, with few exceptions, there has been little work in tropical shrimp trawl fisheries to assess the survival of fish that have escaped from a BRD. An FAO study of the mortality of fish

BOX 14
Devices and modifications to reduce bycatch

BRD. A "bycatch reduction device" is any modification designed principally to exclude fish bycatch from a shrimp trawl. These devices may also exclude other animals and non-living material, but because fish usually dominate the bycatch, most research has attempted to exclude these animals from the trawl. Most BRDs are located in the codend of the trawl since this is where the catch is accumulated and the opportunity to escape is high.

TED. A "turtle excluder device" is any modification to a shrimp trawl designed to reduce the capture of turtles. These devices are sometimes called "trawl efficiency devices" because they can also prevent the capture of other large animals including sharks, stingrays, jellyfish and some large fish. The most common TED designs use an inclined grid to prevent large animals from entering the codend (Figure 19).

JTED. A "juvenile and trash excluder device" is designed to exclude small fish – usually juvenile or trash fish – from the trawl and maintain the catch of shrimp and large fish. The JTED was designed by SEAFDEC and has been tested in shrimp fisheries in several Southeast Asian countries.

A square-mesh codend is constructed entirely from square-mesh netting, which can allow a substantial amount of small fish and other bycatch to escape. This is because square-mesh netting stays open for the duration of the tow, unlike diamond-mesh netting, which closes under the weight of the catch.

A square-mesh window is usually a panel of square-mesh netting located in the top panel of the codend or trawl body. As fish pass through the trawl, they move towards the device and swim through the square escape openings. The selection of mesh size is vital, and trial and error are needed to find the mesh size that maximizes fish exclusion and prevents shrimp loss. Like the fisheye, the size and location of the square-mesh window are also important. The top of the codend is the favoured position, since this reduces shrimp loss; it should not be too close to the catch in the codend or shrimp will be lost (Figure 21).

A *fisheye* is an elliptical steel or aluminium frame fitted to the codend through which fish swim to escape. Fisheyes are usually placed in the top or sides of the codend so that only strong swimming fish can escape, while shrimp passively enters it (Figure 21).

A *fishbox* is designed to alter the movement of water in the codend. It is a box-like device fitted to the top of the codend with an opening through which fish can swim and escape. A metal plate or foil generates water turbulence adjacent to the escape opening, and many fish species actively seek this region because swimming is easier. Fish then move from there out of the trawl.

Other modifications to reduce bycatch. A range of simple rigging modifications to the trawl may be used to reduce the capture of bycatch. These modifications include a triangular or diamond-shaped cut in the top of the codend, changes to the ground chain settings, longer sweeps between the otter board and trawl,[1] headline height reduction, a length of twine stretched between the otter boards to frighten fish away from the trawl, a large mesh barrier across the trawl mouth and large cuts in the top panel of the net ahead of the codend.

Source: Eayrs, 2005.

[1] This can be used to reduce the capture of small sea urchins, other benthic animals and seabed debris, although it may sometimes increase fish catches.

escaping trawl gears (Suuronen, 2005) makes the following observations on improving the survival of escapees.

First, fish that escape from a fishing gear should do so quickly and, in the case of towed gears, should not enter into the aft part of the codend, where the risk of serious injury is greatest. Installing escape panels or other sorting devices at strategic positions in a fishing gear can enhance escape and the survival of juveniles and non-target species. Furthermore, facilitating the voluntary escape of fish through various constructional and operational solutions would increase the likelihood of their survival. The use of non-abrasive netting materials, the exclusion of debris and large objects from codends, and better design, operations and rigging of nets could improve survival.

Hill and Wassenberg (1990) studied the fate of teleosts, non-commercial crustaceans and cephalopods discarded from trawlers in Australia's Torres Strait. These groups make up about 80 percent of discards by weight, have a high mortality rate and are therefore the most likely animals to be eaten by scavengers. The remaining 20 percent of discards consists of animals such as turtles, sharks, bivalves and sponges, which are caught in low numbers and appear to have a low mortality from trawling. Fish make up 78 percent, non-commercial crustaceans 18 percent and cephalopods 3 percent, by weight of the material studied. Nearly all fish were dead when discarded, and about half sank. Approximately half of the non-commercial crustaceans were alive when discarded, and all sank. Few cephalopods (2 percent) were alive when discarded, and about 75 percent sank.

The use of BRD devices, as with the more specialized TEDS (described in the section above, *Warm-water shrimp trawl bycatch issues*), is not without costs. Expenditure must be made for the devices themselves and there is at least some loss of target shrimp. In many small-scale shrimp trawl fisheries, the reduction of bycatch is relatively more expensive because of the practice of selling the available bycatch.

FIGURE 21
A fisheye (top), a square-mesh window (middle) and a square-mesh codend (bottom)

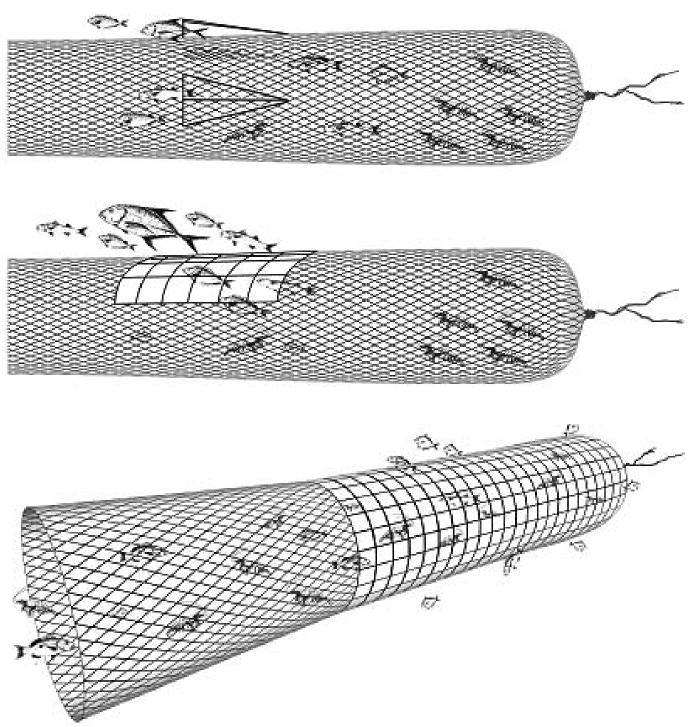


FIGURE 22
Factors affecting the efficiency of a bycatch reduction device

EFFECTIVENESS OF BYCATCH REDUCTION EFFORTS

Numerous factors affect the efficiency of a BRD, many of which are shown in Figure 22 (Eayrs, 2005).

Despite their considerable differences, almost all BRDs reduce bycatch when deployed in the environment for which they are developed. The reductions achieved in various fisheries are well-documented, as shown by the following authors.

- Graham (2005) states that the widespread use of Nordmøre grids in the Northern Shrimp Fisheries of the North Atlantic has resulted in large-scale reductions in the levels of bycatch that typified the fisheries in earlier years.
- Parsons *et al.* (1998) acknowledge the reduction in bycatch by the mandatory use of sorting grids in the North Atlantic, but indicate that the capture of small fish (which pass through the bar spacings) is still problematic and that it is difficult to assess the efficacy of the grids in reducing the bycatch of these fish.
- Cartwright (2003) indicates that TEDs and BRDs have reduced the turtle bycatch by up to 99 percent, bycatch of small fish by 8 percent and sea snakes by 12 percent in Australia's NPF. This has occurred at the cost of a loss of prawn catches of around 6 percent.
- Harrington, Myers and Rosenberg (2005) cite three different studies on the effectiveness of BRDs in reducing the finfish catch in the Gulf of Mexico shrimp trawl fisheries; the devices reduced the catch of finfish by 43 percent, 45 percent and 16.5 percent.

The above examples of bycatch reductions come from relatively large-scale fisheries and reflect the situation around the world, i.e. the most successful examples of bycatch reduction are from large-scale fisheries. This observation is consistent with that of Kelleher (2005) who studied the global discard situation and commented on shrimp bycatch reduction.

Bycatch reduction devices are used in a wide range of shrimp fisheries with apparent discard reductions in Pandalus *fisheries (0.2–-29 percent discards), less impact in other cold-water fisheries for* Nephrops *and other species (44–50 percent discards), and even less impact in tropical fisheries (67–89 percent discards). The low impact in some tropical fisheries may be due to poor enforcement of BRD regulations, as experimental results clearly indicate significant reductions in unwanted bycatch. Reduction in discards in developing countries is more likely to arise from increased utilization of bycatch, rather than reduction of bycatch. Many shrimp trawl fisheries in developing countries are* *marginally profitable and any reduction in shrimp catch through the use of BRDs may result in significant economic losses.*

BYCATCH IN NON-TRAWL SHRIMP FISHERIES

The above discussion of bycatch from shrimp fisheries is largely focused on shrimp trawling, which produces most of the bycatch. Other types of shrimp fishing produce varying amounts of bycatch, at levels generally well below those of trawl fisheries.

The stow net fishery for paste shrimp (*Acetes* sp.) in China is one of the world's largest shrimp fisheries (Chapter 3, section *Catches by shrimp species*). Liu-Xiong (1995) reviews the catch composition of the stow net fishery in several coastal provinces of China. In Fujian Province, stow nets caught 241 species, including 190 species of fish, 42 species of crustaceans and nine species of cephalopods. *Acetes* made up 19.7 percent of the catch, with the next most important components being the hairtail *Trichiurus haumela* (18.7 percent) and cods Bregmacerotidae (4.07 percent). Chen Amoa (1994) analysed the sampling results of five stow net monitoring stations in the waters of Zhejiang Province from 1987 to 1993; shrimp accounted for 44.7 percent of the catch by weight; small fish 37.4 percent; and hairtail and other economical species, 17.9 percent.

Other examples of bycatch composition in non-trawl shrimp fisheries are given by the following authors.

- Badrudin, Sumiono and Murtoyo (2001) report that tidal trap nets in Riau Province, Indonesia, catch over 40 groups of fish/invertebrates, including four groups of shrimp. The combined shrimp catch is less than 10 percent of the total, but virtually nothing is discarded.
- Roberts (2005) states that cold-water shrimp trap fisheries are generally considered to have low rates of bycatch. The bycatch rate as a percentage of target catch in the Southeast Alaska Shrimp Pot Fishery is 10 percent or lower in terms of numbers. Bycatch rates in the British Columbian and Washington Pot Fisheries also appear to be low. A study of the Californian Pot Fishery found higher levels of bycatch in terms of weight, but no tally of the number of species was carried out. In addition, bycatch in pot fisheries for cold-water shrimp generally consists of invertebrates that are released alive.

BYCATCH MANAGEMENT

"Bycatch management" is defined as interventions to reduce bycatch in order to reduce waste and threats to vulnerable or endangered species, and make better use of bycatch, to reduce waste.

In the various shrimp fisheries, several measures have been taken to reduce bycatch, including: complete bans on trawling; bans on fishing in areas and/or periods when bycatch is known to be high; reduction of overall fishing effort; and the most common modifications of fishing gear, mainly through the use of BRDs. Other measures to reduce bycatch are bycatch quotas, discard bans and limits in the shrimp-to-bycatch ratio. Some observers feel that because most shrimp fisheries in the world are overexploited, fishing effort reduction would have the dual benefit of improving catch rates and reducing bycatch. EJF (2003b) shows that, conceptually, the means for reducing bycatch can be placed into two categories (Box 15).

An important issue is that bycatch enhancement is not always compatible with bycatch reduction; in some circumstances, the improved use of bycatch could result in greater demand and consequently more bycatch. It is important that bycatch enhancement (for improving food availability, economic efficiency, reducing waste) be compatible with sustainable use.

Several authors comment on lessons learned from successful efforts to manage bycatch in both warm- and cold-water shrimp trawl fisheries.

BOX 15
Concepts of reducing bycatch

Total bycatch = bycatch per unit effort x fishing effort. Accordingly, in order to decrease total bycatch of shrimp fisheries, one or both of the following factors needs to be reduced:

- *bycatch per unit effort*. This can be reduced by: technological changes (e.g. installation of TEDs/BRDs); operational changes (e.g. reduction of speed and duration of trawling); training (e.g. to avoid areas of high bycatch); and management actions (e.g. setting of bycatch limits for individual vessels);
- *fishing effort*. This can be reduced by: regulatory bans (e.g. use of spatial and temporal closures); regulatory limits (e.g. use of quotas), trade-related measures (e.g. reducing fishing subsidies); consumer behaviour (e.g. establishment of ecolabelling schemes); and gear changes (e.g. use of passive fishing gear).

Source: EJF, 2003b.

Setting targets/requirements and allowing innovation. In Australia's NPF, an important lesson learned is that, rather than government research on bycatch reduction technology and its promotion, a better approach is for regulators to set the targets/requirements and allow industry to innovate them (I. Cartwright, Australian Fisheries Management Authority [AFMA] personal communication, January 2006). This is similar to the sentiment expressed by Harrington, Myers and Rosenberg (2005) in a recent review of United States bycatch and its reduction.

Clearly, management programmes need to be adaptive and make continuous improvements rather than consist of fixed regulations that are not performance-based. Regulations are needed to provide incentives to reduce bycatch and disincentives to continue fishing practices with high bycatch rates.

Robins, Campbell and McGilvray (1999) review the history of prawn bycatch reduction efforts in Australia and comment that the greatest advances in the rates that fishers adopt TEDs and BRDs have occurred after respected individuals within the fishing industry have developed or modified gear that reduces bycatch.

The importance of follow-up evaluation. Graham (2005) describes the process of developing effective discard mitigation measures for use in the North Sea *Crangon crangon* Fisheries: the compilation of a detailed fleet and effort inventory (1995/96); the quantification of discard levels (1996/97); the modelling of discards to determine the impacts on affected stocks (1999); the development of mitigation measures (1999/2001); the modelling of the potential benefits to the affected stocks of introducing mitigation measures; the introduction of appropriate legislation; and the undertaking of follow-up evaluation of effectiveness of technical measures and legislation. AFMA (2002) states that there are two main elements in the process of managing bycatch in Australian shrimp fisheries. First, industry needs to adopt measures to reduce the amount taken and second, the management agency will have to monitor the success of the measures.

The importance of bycatch management plans. In the recent FAO discards study (Kelleher, 2005) the global situation was reviewed. The study makes several recommendations, including advocating the development of bycatch management plans. Poseidon (2003) notes the importance of bycatch management plans in Australia, Japan and the United States. ICES/FAO (2005) examine bycatch management in several countries and state that one of the important lessons learned is that at the local, regional and national levels, bycatch/discard action plans should be developed for shrimp fisheries. These plans should identify objectives and goals with regard to the

BOX 16

Australia's checklist for developing a bycatch management plan

The most important consideration in the development of bycatch reduction plans is that they should be developed consistently and transparently, and implemented effectively. The basic steps are the following.

- Determine the availability of data and their usefulness.
- Decide what the bycatch issue is.
- Look at all the options available (utilize, avoid or reduce).
- Decide on the way(s) to address the problem (strategies) and determine whether new ways need to be developed.
- Outline practical and effective actions to achieve the objectives of the policy.
- Review progress or evaluate the effectiveness of the programme.

Source: Australian Government, 2006.

use or reduction of bycatch/juveniles/trash fish, suggest strategies for achieving them, and identify key performance indicators. Box 16 gives a summary of the Australian Government's checklist for developing a bycatch management plan.

The role of fisheries extension. In reviewing TED/BRD requirements, Eayrs (2005) indicates that compliance rates are linked to effective extension programmes that keep fishers well informed about developments. In this way, fishers are given up-to-date information about TED/BRD regulations, as well as operational details of performance, and are able to make informed decisions on their fishing operations.

Learning from experience. In reviewing the many attempts to reduce shrimp bycatch, Robins, Campbell and McGilvray (1999) comment that, in hindsight, Australia has benefited greatly from overseas experiences in the development and implementation of technology that reduces fishery bycatch, thereby avoiding "reinventing the wheel".

From the fisher's perspective, the disincentives to use the most common method of reducing shrimp bycatch, BRDs, are: the expense of the device; the loss of some shrimp from using the device; the extra work in deploying and maintaining the device; and, mainly for small-scale fisheries, the loss of income or food from selling or consuming the bycatch. The main incentives for using a BRD can include: improved quality of the shrimp catch; less bycatch, enabling longer tows; concern over prosecution for non-use; concern that more restrictive regulations will be imposed; less effort needed to sort bycatch; greater fuel efficiency; and the possibility of ecocertification with its enhanced marketing opportunities. In balancing the disincentives/incentives for reducing bycatch, it can be observed that the small-scale fisheries have more disincentives (i.e. more reasons to keep their bycatch) and fewer incentives to bring in only shrimp than the larger operations.

There have been some remarkable reductions in the shrimp bycatch from large- and medium-scale shrimp fisheries. The situation appears manageable and it is likely that further reductions to bycatch levels could be made, albeit with some sacrifices by fishers. One of the main challenges at this point is to determine the acceptable levels of bycatch, considering the costs and benefits once they are reached.

The objective of reducing bycatch in many small-scale shrimp fisheries[9] of developing countries is particularly challenging. The food security and economic incentives do not favour bycatch reduction, and enforcement of any requirements for reduction can

[9] Included in "small-scale fisheries" are the very large number of "mini-trawlers" that are common in tropical developing countries.

be extremely difficult considering the large numbers of vessels and landing sites, the impracticality of placing observers on board and the expanding markets for bycatch. Some fisheries specialists feel that creating awareness of the problems caused by taking bycatch will alter the behaviour of small-scale shrimp fishers, taking them in the right direction, but others consider this to be "wishful thinking", especially in the open access situations in which small-scale shrimp fisheries characteristically operate.

With regard to attempts at bycatch reduction in small-scale shrimp trawl fisheries, two especially relevant concepts emerged during the course of the present study.

- Much of the work on bycatch reduction in these fisheries is focused on BRD gear technology but, for reasons cited above, regulations relating to technical innovations are difficult or impossible to enforce. Furthermore, in many situations, the better the devices function (excluding valuable bycatch), the more they will be resisted.
- If enforcement is such a difficult problem for any regulations dealing with bycatch in small-scale fisheries, then management interventions that are easier to enforce should be encouraged. Accordingly, protected areas where no shrimp fishing (or no fishing of any kind) is allowed may overcome some of the chronic compliance problems. Eayrs (2005) points out additional advantages: area or seasonal closures, particularly in locations that are nursery grounds for juvenile fish and other animals, afford total protection to all bycatch while it remains within boundaries, and it is unlikely that BRDs will ever achieve a comparable level of protection.

Where reducing bycatch in small-scale shrimp fisheries is extremely difficult (and in any case, counter-intuitive when all catch is used), efforts should concentrate on using a participatory ecosystem approach to fisheries to ensure sustainability of the species mix in its ecosystem. Future bycatch reduction efforts, where justified (e.g. in high discarding practices, emblematic species, endangered species), should concentrate largely on medium- and large-scale shrimp fisheries, following an ecosystem approach to fisheries.