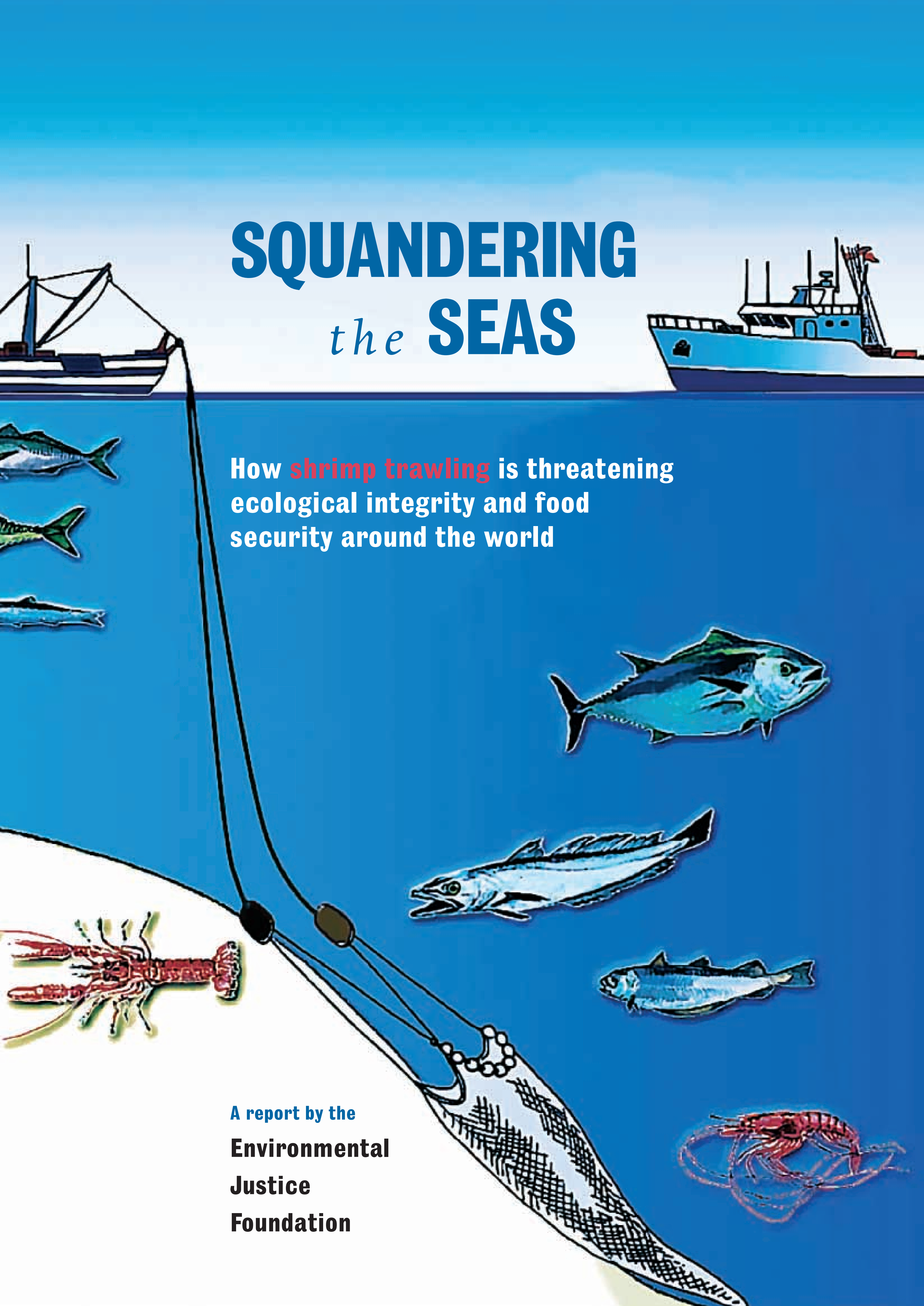
SQUANDERING *the* SEAS

How shrimp trawling is threatening ecological integrity and food security around the world



A report by the

Environmental Justice Foundation

This report is one of a series documenting EJF's international investigations into the social, economic and environmental impacts resulting from shrimp production and consumption.

More information about EJF's work and pdf versions of this and other reports in the series can be found at: www.ejfoundation.org

Environmental Justice Foundation Charitable Trust

Registered charity no. 1088 128

5 St Peter's St, London N1 8JD, UK
tel: 44 (0) 20 7359 0440
fax: 44 (0) 20 7359 7123
info@ejfoundation.org
www.ejfoundation.org

EJF is working internationally with its campaign partner

WildAid

www.wildaid.org

EJF would especially like to thank The Body Shop Foundation and The Rufford Foundation for their support and encouragement.

The Body Shop Foundation

The Rufford Foundation

www.rufford.org

Acknowledgements

This report was researched, written and produced by the **Environmental Justice Foundation Charitable Trust** (**Annabelle Aish**, **Steve Trent** and **Juliette Williams**).

Design **Dan Brown** (design@dbrown.co.uk)

Cover illustration © NOAA

Printed on 100% post-consumer waste paper.

EJF would like to thank the following people and their organisations for the invaluable time and assistance with information, ideas and visual materials used in this report:

Michael Aw, **Jacqueline Blomfield**, **Dr. Lindsay Chapman**, **Gary Day**, **Kirsty Dernie**, **Marydele Donnelly**, **Dr. Alasdair Edwards**, **Dr. John Everett**, **Dr. Mark Fonseca**, **Dr. Serge Garcia**, **David Hall**, **Dr. Stephen Hall**, **Dr. Keith Hiscock**, **Dr. Porter Hoagland**, **Dr. Simon Jennings**, **Dr. Mike Kaiser**, **Dr. Jud Kenworthy**, **John McQuaid**, **Jocelyn Mercer**, **Peter Neave**, **Dr. Elliott Norse**, **Dr. David Ong**, **Dr. Ian Poiner**, **Dr. Ross Robertson**, **Dr. Ali Ross**, **Dr. Keith Sainsbury**, **Dr. Rodney Salm**, **Todd Steiner**, **Dr. Amanda Vincent**, **Elizabeth Wood**.

In thanking these individuals, we in no way imply that they or their organisations endorse the report's content.

Thanks also to **OneWorld Action** and **The Rowan Trust** for their generous support of EJF's International Shrimp Campaign and our Partners in the Developing World.

The **Environmental Justice Foundation** is a London-based non-governmental organisation. More information about EJF's work and pdf versions of this report can be found at www.ejfoundation.org. Comments on the report, requests for further copies or specific queries about EJF should be directed to **Steve Trent** (steve.trent@ejfoundation.org) or **Annabelle Aish** (annabelle.aish@ejfoundation.org).

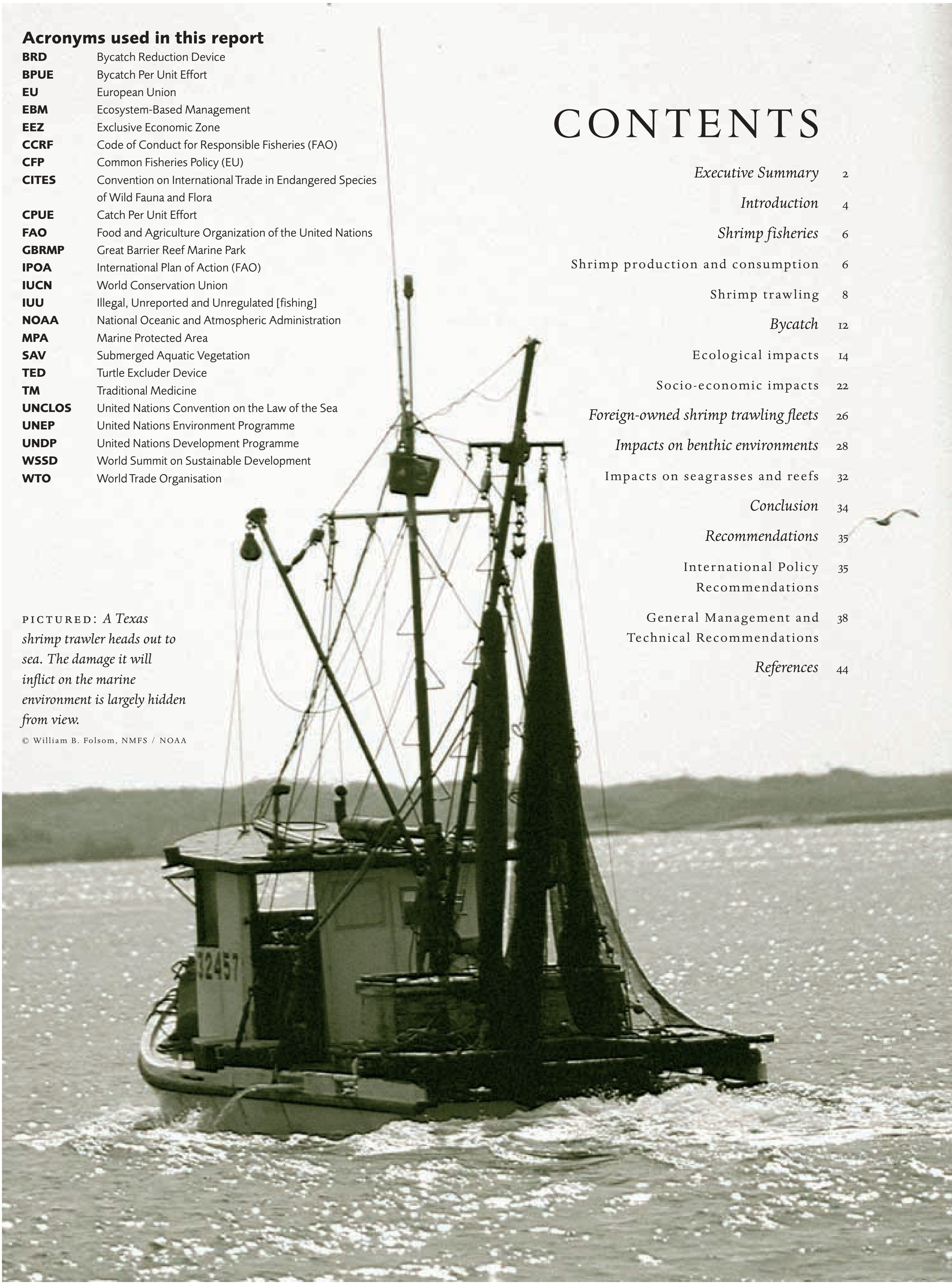
This document should be cited as: EJF. 2003. *Squandering the Seas: How shrimp trawling is threatening ecological integrity and food security around the world*. Environmental Justice Foundation, London, UK.

ISBN No. 1-904523-01-3

Acronyms used in this report

BRD	Bycatch Reduction Device
BPUE	Bycatch Per Unit Effort
EU	European Union
EBM	Ecosystem-Based Management
EEZ	Exclusive Economic Zone
CCRF	Code of Conduct for Responsible Fisheries (FAO)
CFP	Common Fisheries Policy (EU)
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CPUE	Catch Per Unit Effort
FAO	Food and Agriculture Organization of the United Nations
GBRMP	Great Barrier Reef Marine Park
IPOA	International Plan of Action (FAO)
IUCN	World Conservation Union
IUU	Illegal, Unreported and Unregulated [fishing]
NOAA	National Oceanic and Atmospheric Administration
MPA	Marine Protected Area
SAV	Submerged Aquatic Vegetation
TED	Turtle Excluder Device
TM	Traditional Medicine
UNCLOS	United Nations Convention on the Law of the Sea
UNEP	United Nations Environment Programme
UNDP	United Nations Development Programme
WSSD	World Summit on Sustainable Development
WTO	World Trade Organisation

CONTENTS



PICTURED: *A Texas shrimp trawler heads out to sea. The damage it will inflict on the marine environment is largely hidden from view.*

EXECUTIVE SUMMARY

Shrimp trawlers, particularly those in the tropics, can catch over **400 marine species** in their nets. These non-target species or 'bycatch' are often discarded by shrimp fishermen – either they are inedible or are simply not worth retaining when shrimp is worth up to 30 times more per kilogram.

Shrimp fisheries typically produce bycatch-to-shrimp ratios of **5:1 in temperate areas and 10:1 in the tropics**. However, higher ratios have been found, such as 21:1 in the case of the Australian Northern Prawn Fishery. This essentially means 21 kg of marine organisms are caught in order to obtain 1 kg of shrimp. Currently, **tens of millions of tonnes of bycatch** are taken by shrimp trawl fisheries worldwide each year. Most shrimp trawlers discard this non-target catch. Shrimp fisheries alone are responsible for **one third of the world's discarded catch**, despite producing **less than 2% of global seafood**.

Shrimp often ends up on the tables of wealthy consumers in the developed world. It is a **luxury item**. For poor fishing communities, fish is a **necessity**. Globally, **450 million people** rely on fisheries as a source of food and income. In Bangladesh, the fisheries sector provides 78% of animal protein intake for the average person. Equally high dependencies are found in other developing nations, yet it is countries such as these that face food security issues linked to overfishing.

People in the developing world witness shrimp trawlers – sometimes foreign-owned – destroy their traditional fishing grounds and incidentally catch and **squander local fish stocks**. In some cases this fishing is illegal, in other cases it is the result of fisheries agreements, such as those between the EU and African nations. Yet those who suffer the environmental costs of shrimp trawling are unlikely to see the financial rewards of these agreements.

Shrimp trawling frequently takes place in shallow coastal waters, which act as **nursery grounds** for many commercial fish species. Trawling removes vast numbers of juvenile fish that are needed to sustain fish stocks. In addition, by dragging large, heavy nets along the seabed, habitats that support marine life are damaged. One study found that the pass of a single trawl could remove up to **25% of seabed life**. In heavily-trawled areas, habitats have little chance to recover and in some cases may be permanently altered.

ABOVE: *Over 400 non-target species have been identified in tropical shrimp fisheries. Creatures that live on the seabed, such as octopuses, are particularly vulnerable to trawling.*

© Great Barrier Reef Marine Park Authority

Shrimp trawling is thought to **disrupt entire marine communities**, altering biomass, size structure and diversity. Populations of vulnerable species are rapidly reduced. These species tend to be slow-growing and long-lived with low reproductive output and/or those dependent on structurally diverse seabed habitats. Some of these, such as turtles, are **already endangered** as a result of other human activities. Shrimp trawling presents one of the greatest threats to their continued survival. Indeed, it is estimated that **150,000 sea turtles** are killed annually by shrimp trawlers. A creature that has lived on Earth for millions of years could be wiped out by consumer demand for a high value seafood.

Damage caused by shrimp trawling is so significant that leading scientists have compared it to **clear-cutting forests**. However, unlike deforestation, the impacts of shrimp fisheries are only just beginning to receive international attention.

Reports written by leading intergovernmental organisations, including the **United Nations Environment Programme**, the **Global Environment Facility** and the **Food and Agriculture Organisation**, state that many shrimp fisheries are presently unsustainable and advocate changes to current patterns of exploitation.

Shrimp trawling is one of the most **wasteful, destructive and inequitable** ways to exploit the oceans. The **Environmental Justice Foundation** is campaigning to promote a **precautionary** approach to shrimp fisheries that prioritises social and ecological sustainability. Within this report, EJF proposes a series of recommendations outlining how shrimp fisheries can be managed in a more just and responsible way.

A small price to pay for environmental justice

£5 / $6 per month could help kids get out of the cotton fields, end pirate fishing, protect farmers from deadly pesticide exposure, guarantee a place for climate refugees

This report has been researched, written and published by the Environmental Justice Foundation (EJF), a UK Registered charity working internationally to protect the natural environment and human rights.

Our campaigns include action to resolve abuses and create ethical practice and environmental sustainability in cotton production, shrimp farming & aquaculture. We work to stop the devastating impacts of pirate fishing operators, prevent the use of unnecessary and dangerous pesticides and to secure vital international support for climate refugees.

EJF have provided training to grassroots groups in Cambodia, Vietnam, Guatemala, Indonesia and Brazil to help them stop the exploitation of their natural environment. Through our work EJF has learnt that even a small amount of training can make a massive difference to the capacity and attitudes of local campaigners and thus the effectiveness of their campaigns for change.

If you have found this free report valuable we ask you to make a donation to support our work. For less than the price of a cup of coffee you can make a real difference helping us to continue our work investigating, documenting and peacefully exposing environmental injustices and developing real solutions to the problems.

It's simple to make your donation today:

www.ejfoundation.org/donate

and we and our partners around the world will be very grateful.

EJF ENVIRONMENTAL JUSTICE FOUNDATION

Protecting People and Planet

INTRODUCTION

This report presents the facts about shrimp trawling and highlights why immediate action is needed to protect marine ecosystems and the coastal populations whose lives are intimately connected to them.

Demand for shrimp is centuries old. This demand has been largely satisfied by shrimp fisheries in tropical, sub-tropical, temperate and boreal regions. Indeed, despite the growth of shrimp farming, fisheries remain the greatest source of shrimp production, yielding well over 3 million tonnes (MT)* in 2000[1]. Part of their success lies in the nature of the species: shrimp is a high value seafood that is plentiful and easy to catch[2]. These small crustaceans belong to the order Decapoda, just like crabs and lobsters. They are predators and/or scavengers found in both marine and fresh waters over a great climatic range. From a commercial standpoint, there are two main groups of shrimp: caridean shrimps (of tropical, temperate and boreal waters) and penaeid shrimps (largely of tropical and subtropical waters)[3]. The distinction between prawns and shrimps can be confusing. In some countries the penaeid species are referred to as 'prawns' and smaller carideans as 'shrimp'. In other parts of the world (such as some areas of the USA), this differentiation is the other way around. As many people use the words shrimp and prawn interchangeably, no distinction will be made in this report. For simplicity, the term shrimp will be used throughout.

Trawling is the most common method to fish for shrimp commercially. It is a 'catch-all' technique that involves dragging large, fine-mesh nets along the seabed. Yet, the social and ecological consequences of this process are begin-

* MT refers to 'metric tons', also called 'tonnes'. A MT is 1,000 kilograms, or about 2,204 pounds.

LEFT: *Despite the growth of shrimp farming, fisheries remain the greatest source of shrimp production, yielding well over 3 million tonnes in 2000.*

© Ralph F. Kresge / NOAA

OPPOSITE PAGE: *Shrimp: the target catch. While shrimp can withstand relatively high fishing pressure, the ecosystems in which it is found cannot.*

© Michael Aw

ning to take their toll. Issues of bycatch (non-target species caught along with shrimp and usually discarded) and damage to marine habitats from trawlers' nets are of increasing global concern. In particular, local fish stocks have become depleted in shrimping grounds, affecting both food security and employment levels in coastal communities around the world. While shrimp species can often withstand high fishing pressure, it is becoming clear that the ecosystems in which they are found cannot.

Trawling has always been a controversial fishing technique. As early as the 14th century there were protests in Europe over its potential effects on the seabed and creatures living there[4]. Since the early 20th century, shrimp fisheries have grown considerably. They have become commercialised and mechanised in developed nations, and now increasingly so in the developing world where abundant tropical shrimp populations provide much needed export revenue. As global demand for crustaceans has grown, sophisticated trawling equipment and navigation systems have been developed to supply shrimp to expanding markets. This, in turn, has ensured that no potentially productive areas are left untrawled[5].

Despite the sustained growth of shrimp trawling, the impacts of this technique have only recently become the focus of attention. One explanation for this is our distant relationship with the oceans; what occurs beneath the surface is mostly hidden from human view[6]. Yet, 'if it were the custom to harvest forests ... with a gigantic steel lasso to yank away whatever it could encircle, conservationists would be out there causing a riot' [7]. The scientific community has also been influenced by a largely terrestrial research bias and, as a result, the status of most marine species is unknown[8]. As we continue to exploit marine resources through destructive methods such as trawling, the danger of this ignorance is obvious. We know little about the long-term impacts of trawling, though Dr. Gary Meffe, of the University of Florida has claimed it is 'one of the most damaging kinds of habitat disturbance on earth'[9]. Equally, leading intergovernmental organisations, including the United Nations Environment Programme, Global Environment Facility and Food and Agriculture Organisation consider many shrimp fisheries to be unsustainable at present and urge a change in the current pattern of exploitation[10]. In most areas, such as the Gulf of Mexico, shrimp stocks are already declining and, as costs of fishing rise, many shrimpers are struggling to compete with cheaper farmed shrimp of a more standard quality [2,11]. The result: shrimpers having to fish harder for longer to obtain a good catch and make a living. This puts an already damaged marine ecosystem under further stress.

AS SHRIMP TRAWLING OCCURS WORLDWIDE, an international approach to its management is vital. This report presents the facts about shrimp trawling and highlights why immediate action is needed to protect marine ecosystems and the coastal populations whose lives are intimately connected to them. It shows that shrimp is too costly, not for consumers, but for the marine environments from which it is taken.

ABOVE: *Shrimp farm, Bangladesh.*

© Trent / EJF

Shrimp Aquaculture

Shrimp farming is responsible for around a third of global shrimp production. In the 1970s, aquaculture was hailed as the 'Blue Revolution': a way to reduce pressure on wild fish stocks and marine ecosystems. Yet, it has had its own, equally devastating, impacts. Farmed shrimp are fed over twice their weight in wild-caught fish before they are sold. Shrimp farms have also displaced thousands of people from traditionally occupied coastal areas, reduced food security, degraded agricultural land and polluted water sources. Finally, vast areas of mangrove forest have been destroyed to make way for shrimp pond construction, seriously affecting the coastal ecology of many tropical nations. To find out more about shrimp farming, please refer to EJF's companion reports.

SHRIMP FISHERIES

Shrimp production and consumption

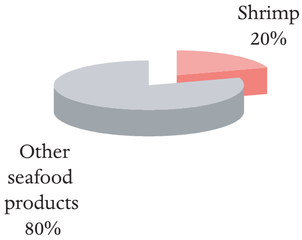
Shrimp is a very high value seafood product, accounting for 20% of the total value of internationally traded fishery products[1] (see Figure 1). In 2000, world shrimp production reached 4.2 million tonnes, of which around 3 million tonnes was from wild-caught sources[2]. The remainder comes from shrimp aquaculture, a method of production addressed in EJF's companion reports. Though world production of wild shrimp is estimated to have remained stable during 2000, 1999 saw a 10% increase[2].

Global shrimp production continues to be dominated by Chinese shrimp fisheries, which caught over 1 million tonnes in 2000[2]. India was the second largest producer of wild shrimp, having produced 353,000 tonnes in 2000, with Indonesia following closely at 260,400 tonnes. Other significant producers of wild-caught shrimp are shown in Table 1.

For some countries, figures for production of wild-caught shrimp do not solely represent shrimp caught within their waters, but rather by their national fishing fleets, which may fish abroad. For example, the EU has fisheries agreements with several African countries allowing it to catch and export shrimp in return for financial compensation.

In terms of global shrimp imports, a record 1.5 million tonnes was reached in 2000[2]. Shrimp are generally canned, frozen or freshly packed with ice for sale. Demand is highest in

FIGURE 1: *The value of internationally traded fishery products[1].*



LEFT: *Penaeid shrimp from China. Chinese fisheries produced over 1 million tonnes (MT) of shrimp in 2000.*

© Dr. James P. McVey, NOAA Sea Grant Program developed nations, with the US absorbing 20% of global imports, followed by the EU and then Japan. Shrimp prices vary between countries, but in Japan in 2000, Indian white shrimp sold for up to US$21/kg[2].

Because of the growth in demand for shrimp, fishing pressure on shrimp stocks in many countries has intensified over the last few decades. While the majority of wild-caught shrimp is generated by tropical and sub-tropical countries, temperate shrimp fisheries can also have high outputs. For example Canada produced 130,600 tonnes of shrimp in 2000, above Thailand (98,800 tonnes) and Malaysia (96,000 tonnes). In general, shrimp is resilient to high fishing pressure[3]. Nevertheless, in many countries, ecological limits to wild shrimp exploitation appear to have been reached. In fact, many large-scale shrimp fisheries, particularly in tropical and sub-tropical areas, have seen reductions in shrimp 'catch per unit effort' (CPUE). This is most likely due to 'growth overfishing', when too many shrimp are caught prematurely in their juvenile stages[4]. In Cameroon, shrimp landings reached a peak in 1977 (2438 tonnes) when there were 17 shrimp trawlers actively fishing. In 1996, with 54 shrimp trawlers in use, total landings only reached 571 tonnes[5]. In Panama, the economics of shrimp trawling are equally poor, with CPUE having declined rapidly in recent years. Yet shrimping continues; losses are often smaller if fishermen keep running their trawlers rather than stopping altogether[6]. Shrimp fishermen may also start a 'multi-target strategy', using the best bycatch fish to supplement their income. This approach is particularly prevalent in Asia.

Rising fishing costs combined with growing competition from shrimp farmers in the developing world has put many shrimp fisheries under further pressure[7]. By providing shrimp that is of a more consistent size and quality, and at lower prices, shrimp aquaculture is undercutting wild-caught shrimp production in some areas[8]. In order to maintain their livelihoods, shrimpers are being forced to fish more intensively for shrimp[3]. Nevertheless, wild-caught shrimp remains the largest contributor to world shrimp production, and total global output continues to grow. For many countries, it is a temptingly high value export. For example, the Australian Northern Prawn Trawl fishing fleet of 116 twin-rigged otter trawlers catch up around 8000 tonnes of prawns annually. This is worth between AU$100 million and $150 million per year[9]. Shrimp trawling can contribute to foreign exchange earnings, employment opportunities and industrial development, all of which are particularly vital in developing nations. However, the generation of these benefits is not necessarily sustainable.

TABLE 1: *Wild shrimp production by major producing countries, in 1000 tonnes[2].*

Countries	**Production in 2000** *(in 1000 tonnes)*
China	1023.9
India	352.9
Indonesia	260.4
USA	150.8
Canada	130.6
Thailand	98.8
Malaysia	96.0
Viet Nam	81.7
Greenland	81.5
Norway	66.2
Mexico	61.6
Philippines	37.5
Iceland	33.5
Korea Rep.	36.0
Brazil	31.6
Burma/Myanmar	30.0
Japan	27.1
Pakistan	25.9
Australia	22.5
Nigeria	20.4

Shrimp: the target species

Two main groups of shrimps are fished commercially. The caridean group is an extremely diverse collection of over 2500 species, which can be found in nearshore habitats from tropical to temperate zones. They are also found in pelagic (open-ocean) and deep-sea bottom environments. In total, they make up about 18% of the world shrimp fisheries. A well-known example of this group is the deep-sea shrimp, *Pandalus borealis*, on which Greenland's shrimp fishery is based[18].

The second group, penaeids, are less diverse with around 400 species. They exist largely in tropical and subtropical (mostly nearshore) habitats where they grow rapidly and typically have large population sizes. They account for 70% of the world's wild-caught shrimp production. Shrimp fisheries in tropical areas target mainly penaeid species[19]. An example species within this group is the giant tiger shrimp (*Penaeus monodon*), one of the most commercially important shrimps in Asia. In many shrimp fisheries, more than one species of shrimp is targeted. For example, in the Australian Northern Prawn Fishery, at least nine species of shrimp are caught. Three species make up 80% of the total annual catch (by weight): the white banana prawn (*Fenneropenaeus merguiensis*), the brown tiger prawn (*Penaeus esculentus*) and the grooved tiger prawn (*P. semisulcatus*)[15]. In comparison, in the Cameroon shrimp fishery the pink shrimp (*Penaeus notialis*), guinea shrimp (*Parapenaeopsis atlantica*) and caramote prawn (*Penaeus kerathurus*) make up the largest proportion of the catch.

Shrimp trawling

The most common way to fish for shrimp commercially is by trawling, a technique used from Iceland to India[10]. Due to the diversity of shrimp species and habitat, productive trawling areas vary. Some shrimp trawlers target deep-sea bottoms, others exploit very shallow coastal waters of 10-60 m depth. Likewise, trawling equipment and techniques vary. This section outlines several generic elements of trawling.

While trawling has a long history in continental shelf waters, it grew particularly rapidly following the widespread use of diesel engines in the 1920s. Waters around developed nations, such as those of Europe and North America, saw the first explosion of this new technology; areas of the North Sea have now been trawled for many decades. Yet in the last 30 years or so, use of trawling gear has spread to the coastal zones of developing countries, fuelling a greater commercialisation of shrimp fisheries and causing global catches to rise quickly[11]. For example, in Peninsular Malaysia, penaeid prawn landings increased rapidly after the introduction of trawl fishing from 14,000 tonnes in 1965 to 63,000 tonnes in 1978 (present landings: 53,000 tonnes)[12].

Commercial trawling aims to target assemblages of shrimps by repeatedly targetting patches of productive seabed. Once groups of shrimp cease to supply a sufficient yield, trawlers will move on to the next aggregation. Fishing involves dragging the trawl along the bottom of the seabed at a rate of about 2.5 to 3.5 knots (around 4.5-6.5 km/hr), scraping up shrimp and everything else in the net's path. As such it is known as bottom (or demersal) trawling. One of the most common types of trawls used in the shrimp fishing industry is the 'otter trawl' (see Figure 2). This uses horizontal panels known as 'otter boards' to keep the mouth of the net open as the net is forced through the water[13]. The trawl net itself is like a large funnel-shaped bag in which all marine organisms are collected and transported into the 'codend' at the back. Sizes of the 'swept' width of the trawling gear vary, though they typically reach 25-30m[14].

ABOVE: *A double-rigged shrimp trawler uses two nets to increase shrimp catch per unit effort.*

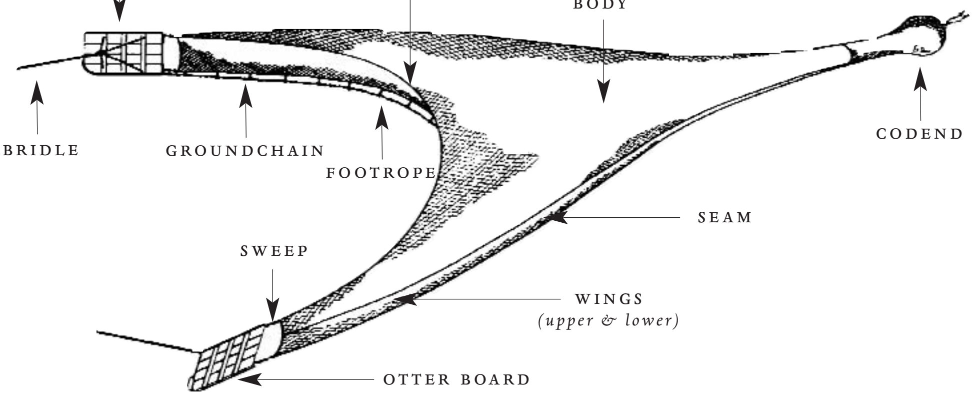
© Robert K. Brigham / NOAA

RIGHT: *The development of large rollers or 'rockhoppers' have made it possible to trawl over complex seabed habitats. In the past, these habitats acted as refuges for marine organisms; now they are equally at risk from trawling.*

© Oceana

FIGURE 2: *An otter trawl. These trawls are commonly used in shrimp fisheries*[15].

Picture by G.Day



'When filled with tens to thousands of kilograms of marine organisms, rocks, and mud and dragged for kilometres across the bottom, the cod end, like the otter boards, bobbins, rollers and tickler chains, can disturb the seabed.'

DR. LES WATLING, UNIVERSITY OF MAINE AND DR. ELLIOTT NORSE, MARINE CONSERVATION BIOLOGY INSTITUTE[11]

ANOTHER COMMON TYPE of trawl is a 'beam trawl', which differs from an otter trawl in that the net is spread horizontally by a wooden or steel beam. In both of these trawls, a footrope or sweep is sometimes fitted. This can be equipped with rollers or 'rockhoppers', large rubber or steel discs (of 60cm diameter or more) that help the bottom of the net roll over uneven seabeds. This technology has allowed trawlers to fish for shrimp in areas of more complex seabed habitats (such as seagrasses, boulders and coral heads) that would otherwise have damaged or congested their nets[11].

Other attachments include 'tickler chains' which run between the footropes, dragging along the seabed in front of the net, disturbing benthic sediments. This encourages bottom-dwelling marine organisms (such as shrimp) to move upwards into the mouth of the trawl[3]. The effects on the seabed are considerable: 'when filled with tens to thousands of kilograms of marine organisms, rocks, and mud and dragged for kilometres across the bottom, the cod end, like the otter boards, bobbins, rollers and tickler chains, can disturb the seabed'[11]. The ecological consequences of this are discussed later in this report. Trawl nets are pulled behind fishing vessels, sometimes singly, though increasingly in pairs or more[13]. Such 'multirig trawling' (shown in Figure 3) increases shrimp catch per unit effort (CPUE) but also multiplies the environmental impacts of the trawling.

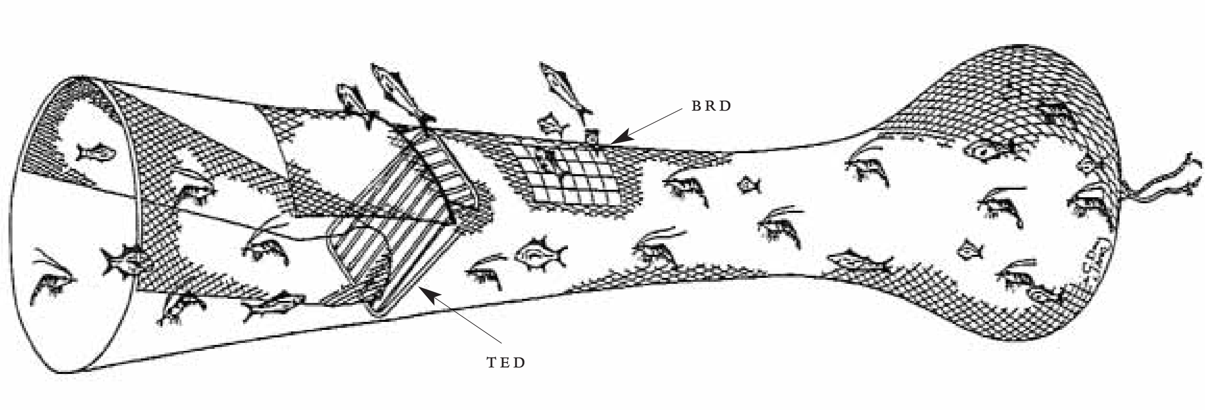
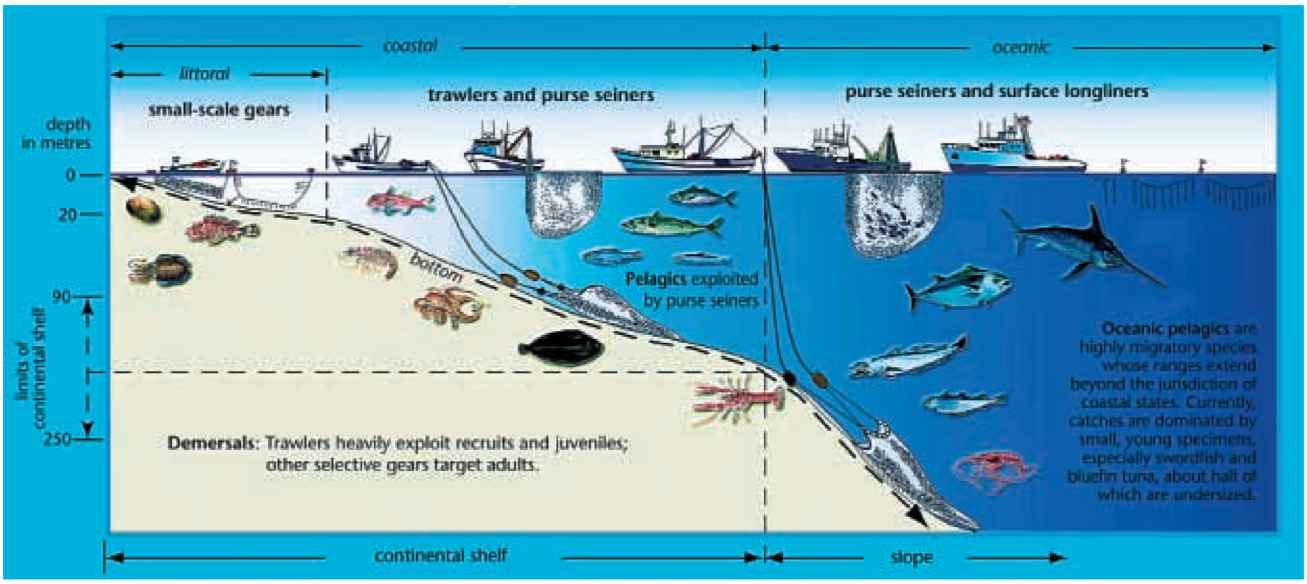


FIGURE 3: *Characteristic installation of a TED and a BRD in a shrimp trawl codend (refer to Figure 2 for full diagram of trawl net). Pictured is a top opening TED called the NAFTED and a square mesh window BRD (illustration G. Day)[15]. In general, the inclined grids (such as the TED shown here) are best for the exclusion of larger animals (such as turtles) whereas small escape devices are more effective at allowing fish and sea snakes to leave the net[12].*

BELOW: *Turtle Excluder Devices (TEDs) have been designed to specifically exclude turtles from shrimp trawls.*

DURING SHRIMP TRAWLING, many other marine organisms are inevitably caught in the net. This 'bycatch' or non-target catch is often discarded dead, causing considerable changes to the structure and balance of marine communities. Certain species, such as sea turtles, are particularly vulnerable and have seen rapid declines in numbers. In attempts to reduce bycatch in shrimp fisheries, Bycatch Reduction Devices (or BRDs) have been developed (see Figure 4). These improve the selectivity of shrimp trawlers, so they catch more shrimp in proportion to other organisms. Technological modifications fall into two categories: 1) those that separate species by differences in behaviour; and 2) those that mechanically exclude unwanted organisms according to their size[16]. Some BRDs work more effectively than others, but on average current designs exclude only about a third of non-target species[17]. Turtle Excluder Devices (TEDs) have been designed to specifically exclude turtles from shrimp trawls. Unfortunately, neither BRDs or TEDs are used extensively in shrimp fisheries, mainly because most shrimp fishermen either do not have access to this technology or are concerned that these devices reduce their shrimp catch (see also page 40).

FIGURE 4: *Common coastal and oceanic fishing gears. Note that trawlers target bottom-dwelling organisms by dragging large nets over the seabed.*



LEFT: *A shrimp trawler unloads its nets. Many shrimp stocks are now fully or over-exploited.*

Why do people fish for shrimp?

Because this small decapod is highly valuable, abundant and able to endure considerable fishing pressure[3]. Some shrimp fisheries have been able to expand for many years before seeing a stabilisation or decline in CPUE. For example, the Gulf of Mexico shrimp fishery had been growing for over 100 hundred years, and has only seen declines in shrimp stocks in the last few decades[3]. Paradoxically, following ecosystem modelling work on the Northern Great Barrier Reef prawn (shrimp) fishery, prawn biomass appeared relatively resilient to trawling. This was because 'prawns benefit from trawling through the removal of competitors and predators, and from the increase in food either directly from discarded bycatch or indirectly from an increase in prey species that feed on discards'[20]. This essentially means that under high-intensity trawling, the abundance of shrimp, a typically fast growing, short-lived 'prey' species, may actually decrease much less rapidly than expected. This is particularly troublesome from an ecosystem point of view, as 'the more you overfish the system and 'eliminate' their natural predators, the more the prey species (e.g. shrimp) may thrive'[21]. Similar responses have been found involving other prey species like squid and octopus, where part of the fisheries impact is obliterated by changes in predation. Indeed, it is perhaps this control of predation that has allowed shrimp fisheries to grow for many decades, with some observers comparing bycatch mortality to 'weeding a field of corn'[22]. Yet uncontrolled shrimp trawling is only 'sustainable' in the sense that it might be able to continue for longer than expected before shrimp stocks themselves become over-exploited. Currently many shrimp stocks (if not most of them) are already overfished, despite the 'compensatory' phenomenon of decreasing predation[21]. The ecological effects of this 'fishing down the food web' are profound, and in some cases may cause the collapse of entire marine systems.

Shrimp trawling country profile: Bangladesh (1998-9)[23]

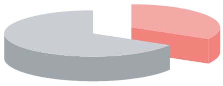
Target shrimp species: 10 species of shrimp caught in total, with the giant black tiger shrimp (*Penaeus monodon*) being the most valuable. Brown shrimps (*Metapenaeus spp.*) make up the highest percentage of the catch.
Number of trawlers: 45
Typical duration of trawl: 3 hours
Total fishing days: 7624
Overall length of trawlers: 20.5-44.5m
Type of trawl used: Multirig trawlers with 2-4 nets operated at a time. Tickler chains attached.
Mesh size: 45mm
Shrimp catch from trawlers: 3,700 tonnes
Amount of bycatch from shrimp trawlers: 35,000-45,000 tonnes (species composition depending on depth).
Shrimp/bycatch ratios: 1:8 to 1:15
Number of species found in the shrimp trawl catches: 100
Percentage of bycatch discarded: 80%
Shrimp trawling restrictions: Trawlers are not allowed within the 40 m depth contour, although they have been found operating at depths of 10 m off shore.
Total area covered by shrimp trawlers in the continental shelf of Bangladesh: 37533.53km^2
Impacts of trawling on marine living resources and habitat: No research carried out as yet though anecdotal observation during the past two decades has indicated a negative impact[23].
Reported problems with the shrimp fishery: Wastage of resources (discard of bycatch), catching a large number of shrimp broods (fry) and juvenile fish, conflicts between industrial and artisanal fishermen, habitat destruction by trawling, increasing poverty of coastal fisherfolk.
Countries that import shrimp from Bangladesh: USA, Japan, EU nations (and others).

BYCATCH

'There is a growing body of evidence clearly demonstrating the serious character of discarding bycatch of various marine populations, including some fishes, marine mammals and turtles.'

DAYTON ALVERSON *ET AL.*, CONSULTANTS TO THE FOOD AND AGRICULTURE ORGANISATION[2]

FIGURE 5: *Total global discards from fisheries*[2].



Most fisheries are unselective to some degree, in that they catch non-target species along with their target catch during the process of fishing. As explained, this is known as bycatch or 'the difference between what a fisherman looks for principally, and what he manages to catch in reality'[1]. Shrimp trawling, with its large fine-mesh nets, is one of the worst offenders and bycatch is usually discarded, dead and wasted, over the side. Indeed, shrimp fisheries are responsible for a higher proportion of discards than any other fishery type, accounting for one third of the global total[2] (see Figure 5). On a weight per weight basis, 14 of the 20 highest discard ratios were associated with shrimp trawl fisheries[2], especially those in the tropics (see Figure 6 for fisheries with top ten highest discard ratios). Taking into consideration that these fisheries produce less than 2% of global seafood[3], such figures are staggering.

Bycatch to shrimp ratios vary according to the fishery in question. The most recent figures suggest that they can be as high as 40:1, as recorded by one study on a Venezuelan shrimp fishery[4]. This means that 40 kg of bycatch was caught in order to yield 1 kg of shrimp. Other high bycatch to shrimp ratios are found in Indonesia (26:1)[5] and Australia (21:1)[6]. On average, it is estimated that shrimp trawling produces bycatch to shrimp ratios of 5:1 in temperate and sub-tropical waters, and 10:1 in tropical waters[7] (see Figure 7). Yet, as the previous figures indicate, these can often be much higher. High bycatch rates are partly linked to the nature of demersal trawling: large numbers of fish (and other organisms) congregate on or just above the seabed. Queensland's East Coast trawl fishery (Australia) is estimated to have caught a minimum of 750 kg of bycatch per boat per day, with an annual total of 56,486,250 kg or 56,000 tonnes[8]. In Indonesia, shrimp trawling bycatch is estimated at between 40,000 and 170,000 tonnes a year[9]. Such high figures are found around the world, culminating in tens of millions of tonnes of bycatch caught by shrimp fisheries every year*.

Bycatch is not automatically a problem in all fisheries. If bycatch is minimal and does not contain large numbers of endangered or vulnerable species, it doesn't necessarily cause ecological harm. But 'if the bycatch represents 80-90% of the catch (as in some shrimp fisheries) and most species in the area are overfished, the problem starts'[1].

ABOVE: *High value shrimp is separated from the unwanted bycatch.*

*In 1992, independent estimates of maximum total bycatch in shrimp fisheries converged at between 16 and 17 million tonnes[2,10]. Given the expansion of commercialised shrimp trawling in the last decade, current levels of bycatch are likely to be considerably higher.

FIGURE 6: *Fisheries with the ten highest recorded discard ratios by weight*[2]*. Note how nine out of ten of these are shrimp fisheries (in pink).*

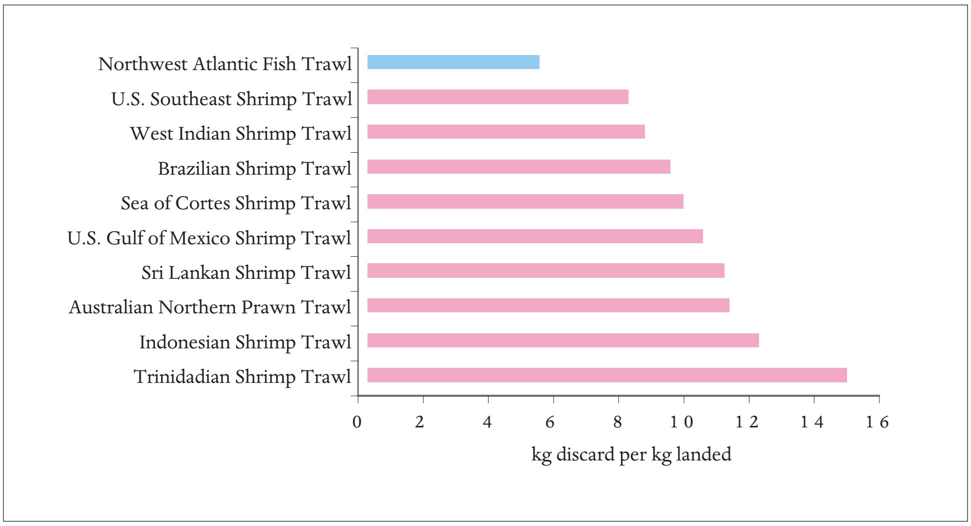
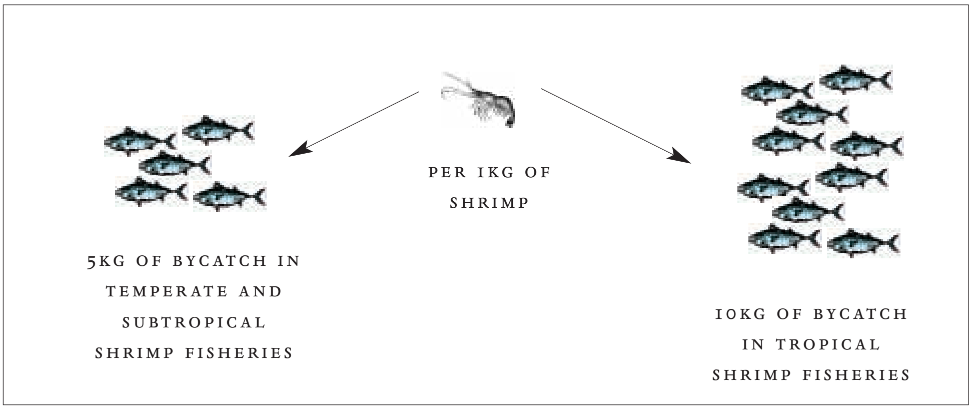


FIGURE 7: *On average, it is estimated that shrimp trawling generates bycatch to shrimp ratios of 5:1 in temperate and sub-tropical waters, and 10:1 in tropical waters*[7]*. Can we afford this ecological exploitation?*



The fate of shrimp fishery bycatch

Types and numbers of species found in shrimp trawlers' nets vary according to depth, seabed characteristics, fishing effort and shrimp catch[11]. Very few shrimp fisheries regularly monitor their bycatch or how it changes over time. In general, however, it is fish species that account for the majority of bycatch; in the Northern Great Barrier Reef prawn trawl fishery, for example, 69% of bycatch (in terms of weight) is fish[12]. The majority of discarded bycatch is already dead, or unlikely to survive once returned to the sea[12]. In general, round fish (such as cod, hake, pollock, croakers, groupers and snappers) are more prone to mortality; their large air/swim bladders rupture when removed from the high-pressure environment of the sea-floor[13]. Reptiles, such as sea snakes and turtles, are air breathing and therefore vulnerable to drowning in nets. Other marine organisms die from stress and physical damage as they are caught, sorted and then released. Research on two shrimp fisheries in Australia indicate that 'almost all the discards from these fisheries are likely to be returned dead or dying to the ocean, where they are a potential food source for scavengers such as sharks and seabirds[14]. This low survival rate means that the capture and discard of non-target species is equivalent to 'direct fishing mortality', in other words as if these species had been fished as *target* species[14]. In 1996, a global assessment of fisheries bycatch and discards for the FAO, claimed that 'there is a growing body of evidence clearly demonstrating the serious character of discarding bycatch of various marine populations, including some fishes, marine mammals and turtles'[2]. The ecological and socio-economic consequences of this are discussed below.

Sea snakes are commonly found within shrimp fishery bycatch in the tropics, and are particularly vulnerable to overfishing.

Ecological impacts

ABOVE: *Several species of rays are benthic, and as such are usually found close to the sea bed. They are prone to being caught incidentally when shrimp trawls are dragged over their habitats.*

© Bill Keogh / NOAA (*above*) © Michael Aw (*above right*)

OPPOSITE RIGHT: *Many elasmobranchs (sharks and rays) are long-lived, slow-growing and tend to produce few young. As K species, they are particularly susceptible to shrimp trawling.*

© Michael Aw

High levels of bycatch caught by trawlers fundamentally disrupt the marine communities of which shrimp are just one part. Although global data on bycatch indicate that tremendous quantities of marine life are being removed, very little research has been conducted on the effects of this removal. In fact, for many of the species incidentally caught in shrimp trawl nets, there is very little information (and sometimes none at all) from which to evaluate the sustainability of their mortality[1]. In general, temperate seas tend to support large numbers of comparatively few species, while tropical seas contain many species in smaller numbers[2]. This is why shrimp trawling in the tropics is hypothesised to be especially harmful in terms of its effects on biodiversity. Indeed, trawling technology was developed in northern hemisphere for use in cold temperate waters, and has been particularly harmful in tropical seas[2]. Bycatch in tropical shrimp fisheries can comprise hundreds of species[3]. For example a recent report indicated that 437 vertebrate species (e.g. fish, sharks, rays) and 234 invertebrate taxa (e.g. crabs, squid and scallops) are incidentally caught in Australia's Northern Prawn Fishery[4]. Furthermore, as a much larger part of the world's shrimp production originates from the tropics, the total bycatch from this area is higher[5]. Nevertheless, the impact of shrimp trawling on temperate seas, both in terms of bycatch and benthic disturbance, should not be underestimated. As there have been no comparative analyses of shrimp trawling in these two climatic zones, it is unknown where the activity has a greater ecological impact on a local level[5].

In order to ascertain the vulnerability of a species to shrimp trawling one must assess (1) their relative vulnerability to capture by trawls, and (2) the relative capacity of their populations to endure increased mortality due to fishing[6]. Unfortunately, very little of this kind of research has been done. What is known, however, is that shrimp trawling bycatch alters the biomass, size-structure and diversity of communities. A common change is the replacement of larger, longer-lived species by smaller, shorter-lived ones[7]. Part of the explanation behind the declines in certain species lies with their biological characteristics. Scientists define species according to their position along what is called the '*r-K* spectrum'. As Dr. Callum Roberts[8] clarifies 'some species fall more towards the

FIGURE 8: *'r' and 'K' species have distinct characteristics and tolerate different levels of fishing mortality*[8].

'K' species

VULNERABLE TO TRAWLING

- Slow to mature
- Long-lived
- Low natural mortality
- Often low fecundity and/or considerable parental care

'r' species

LESS VULNERABLE TO TRAWLING

- Fast to mature
- Short-lived
- High natural mortality
- Often high fecundity and/or no parental care

'*K*' end, being long-lived, slow-growing and late reproducing[7]. Others are typical '*r*' species with fast growth, high natural mortality and early reproduction. *K* species are highly vulnerable to over-exploitation and can support only low levels of fishing effort, while *r* species can support more intense fishing. Whereas shrimp tend to fall towards the *r* end of the spectrum, many of the other species caught alongside it are *K* species (see Figure 8). Because shrimp fisheries capture such a broad range of species, it is impossible to hold fishing pressure at different levels for different species. Fishing pressure is therefore set high to get maximum productivity from shrimp stocks, to the disadvantage of those *K* species caught as bycatch. This explains why larger, slower-growing species are found at particularly low densities in shrimping grounds, indicating considerable change in species assemblages[9a]. For example, there is evidence of large, high-value emperors (*Lethrinus*), snappers (*Lutjanus*), and groupers (*Epinephelus*) being replaced by thread-fin bream (*Nemipterus*) and lizardfishes (*Saurida*) in heavily trawled areas of North Western Australia[9b]. Similar changes to marine systems have been recorded in Gulf of Thailand[10]. Again, there have been few scientific studies on declines of different bycatch species; some populations are not measured, and for those that are, scientists lack accurate baselines to judge whether decreases are significant[8]. One decline that scientists are convinced *is* serious is that of sea turtle populations, of which shrimp trawling is the greatest cause (see page 20). In addition, seahorses, due to their complicated pairing rituals and low fecundity (breeding rate), are thought to be particularly vulnerable to shrimp trawling[11] (see page 18). Other *K* species susceptible to trawling are elasmobranchs (such as sharks and rays); in particular sting rays and nurse sharks, as bottom dwellers, are more likely to be captured by shrimp trawlers[4].

'If most of the fish on the Gulf of Mexico floor are wiped out, scientists don't know what the long-term effects will be. Ecosystems often behave in unpredictable ways when even much smaller changes take place.'

JOHN MCQUAID, PULITZER PRIZE-WINNING JOURNALIST[15]

A further element that exacerbates effects on marine communities is the location of shrimp trawling grounds. In many countries, particularly in the tropics, trawlers come very close to shore in search of shrimp[12]. These nearshore habitats often act as nursery areas for juveniles of many fish species. As such, they contain millions of young fish that are necessary to maintain adult populations. Each day these juveniles gradually add to stocks further offshore as they mature and move away. When vessels trawl in these nursery grounds, large numbers of juvenile fish are caught. Sustained nearshore trawling and subsequent mortality of juveniles is thought to affect many fish populations, particularly those of commercial importance[13,14]. In some areas where shrimp trawling has been occurring for several decades, high bycatch levels have had very obvious effects.. In the Gulf of Mexico for example, the bycatch to shrimp ratio has actually been declining since the 1970s[15]. Rather than being a sign that the ecological impacts of trawling are decreasing (as some shrimpers have claimed) it shows that bycatch species have been significantly depleted. For example, croakers (Sciaenidae) are about 40% as abundant as they were 20 years ago. Sadly, 'if most of the fish on the Gulf floor are wiped out, scientists don't know what the long-term effects will be. Ecosystems often behave in unpredictable ways when even much smaller changes take place.'[15]

By selectively removing those species vulnerable to high levels of mortality, food chains and predator-prey relationships are also affected[16]. For example, benthic species, such as groupers and snappers, are 'apex predators' that exist at the top of the food chain. Their elimination may have severe impacts on marine food chains, the long-term consequences of which are not fully understood[17].

Some species may see an increase in their population as a result of trawling. Scavengers, such as seabirds, feed on bycatch as it is discarded[18]. This discarding is thought to be a possible factor behind the increase in certain seabird populations in the North Sea. Currently, the number of seabirds potentially supported by fishery waste in the North Sea (from a range of fisheries, including shrimp) is estimated to be roughly 5.9 million individuals in an average scavenger community[19]. Equivalent studies suggest that some seabirds, such as Crested Terns *(Sterna bergi)* in the Northern Great Barrier Reef, derive up to 40% of their diet from shrimp trawling discards during the trawling season[18].

Shrimp trawlers also attract sharks and dolphins[20]. Dolphins are known to feed on organisms exposed by trawling action, as well as on discarded bycatch. There are concerns that dolphins (and other species) may actually become dependent on bycatch. An increase in these species may initially be seen as a positive change, but in fact this disrupts the natural balance of the marine ecosystem. Furthermore, many species can be harmed during the process of feeding on bycatch. For example, bottlenose dolphins in the Gulf of Mexico have been observed entering shrimp trawls to feed on the catch inside, risking injury and sometimes death[20]. Trawlers can also destroy the habitat and food sources on which cetaceans depend. In the Gulf of California, the survival of an endangered porpoise, the marine *'vaquita'* is in doubt, due to continued shrimp trawling in the Upper Gulf of California Biosphere Preserve[21]. Despite being an officially protected area, more than 130 commercial shrimp trawlers operate openly in the biosphere preserve due to inadequate enforcement by the Mexican government. Not only is this area a habitat for the endangered porpoise, it also serves as a marine nursery for the entire region, according to Karl Flessa, a scientist at the University of Arizona[21].

If bycatch is not consumed by scavengers in the water column, it descends uneaten to the seabed. This has its own environmental consequences; decomposing fish use up oxygen, increasing BOD (Bio-chemical oxygen demand) and potentially leading to hypoxic conditions. The seabed becomes 'poisoned'[10] and important habitats are degraded.

LEFT: *Bangladeshi groupers. Groupers are 'apex predators' that exist at the top of the food chain; their elimination by shrimp trawling may have severe, long-term ecological repercussions.*

© FAO

ABOVE: *Large numbers of seabirds scavenge on bycatch as it is discarded from shrimp trawlers. This may significantly increase seabird populations dependent on unsustainable sources of food.*

© Dr. James P. McVey, NOAA Sea Grant Program

Impacts on seahorses

Seahorses are found in both tropical and temperate seas with most species occurring in the Indo-Pacific and West Atlantic regions[1]. Populations of seahorses are declining globally; direct consumption by the Traditional Medicine (TM) and aquarium trade play a part, but bycatch in shrimp trawls is potentially the biggest single pressure on seahorses today[2a]. Currently, 20 species of seahorses are listed under the IUCN (World Conservation Union) Red List of threatened species. Recent agreements at the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) have allocated greater protection to seahorses in terms of their trade[2b]. However, few measures have been taken to stop the devastating bycatch of these creatures by shrimp trawlers.

Unfortunately, very little is known about the population dynamics of most seahorse species or their geographical distributions. In fact, there is even confusion surrounding how many species of seahorse actually exist. As such, the impact of removing millions of seahorses can only be assessed indirectly[1]. However, anecdotal evidence suggests that seahorse numbers have declined very rapidly in the last decades, in some areas of Southeast Asia possibly up to 50%[3]. In countries such as India, Indonesia, the Philippines and Vietnam, shrimp trawlers have been observed catching seahorses incidentally. Unlike many other non-target species, seahorses are not discarded but are often sold on to those involved in the TM trade.

Like sea turtles, seahorses are particularly at risk from shrimp trawling. They have complicated courtship and mating rituals, and are usually found in a monogamous long-term partnership[3]. If one of the pair is killed, its partner will stop reproducing for a prolonged period[1]. Unusually, the males become 'pregnant' and carry their young for up to 6 weeks before giving birth. This complex reproductive strategy makes them vulnerable to over-exploitation by shrimp trawlers.

Seahorses can be found in near-shore habitats of less than 20 m depth, similar to those environments inhabited by many commercial shrimp species[3]. Most spend a great deal of time attached to benthic structures such as blades of seagrass. This low mobility combined with the fact that they are 'site-faithful' means that trawling is likely to be very disruptive; even if seahorses are not brought to the surface, populations may be affected by the destructive action of the trawls. Seahorses may also be impacted by discarded bycatch, which is known to poison benthic environments and deplete oxygen availability. In short, not only does trawling cause direct seahorse mortality but it also degrades the habitats on which they rely[4].

Pipehorses are close relatives of seahorses, both belonging to the same family: Syngnathidae. They share many of the seahorses' behavioural and reproductive characteristics. During 2000, more than 45,000 pipehorses were killed by the Australian East Coast Trawl Fishery. Knowledge about the ecology and biology of pipehorses is equally limited and the impact of trawling on their populations is unclear[5].

LEFT: *A seahorse in shrimp bycatch, India. Seahorse numbers have declined very rapidly in the last decades, possibly by up to 50% in some areas of Asia.*

© Project Seahorse

ABOVE: *Currently, shrimp trawling is thought to be the biggest single pressure on seahorses. These small fishes are particularly vulnerable due to their complicated pairing rituals and low reproductive output.*

© Project Seahorse

Impacts on sea turtles

Sea turtles are among the most ancient of marine reptiles, having lived on Earth for over 110 million years[1]. It is thought that as recently as the early 19th century some turtle populations were very large, numbering millions[2]. Yet today most sea turtle species' populations are small and declining. Their existence is being compromised by unnaturally high levels of mortality, the greatest cause of which is shrimp trawling[3]. Indeed, sea turtles are one of the most critically endangered groups of species taken incidentally by shrimp fisheries[4].

Turtles are mostly found in tropical and temperate seas, with one species, the leatherback turtle (*Demochelys coriacea*) known to migrate to high latitudes in search of food[5]. Turtles enter shallow coastal areas either to feed or during their breeding seasons, when they nest on nearby beaches. It is in these near-shore areas that they are particularly susceptible to being caught by shrimp trawlers. Drowning is the most common cause of mortality; as air-breathing reptiles, turtles need to return regularly to the surface. Trawl hauls that last several hours exceed any turtle's ability to hold its breath. Turtles usually die trapped in nets or shortly after release from exhaustion or injury.

In their modern form, sea turtles comprise 7 species, all of which are endangered or vulnerable to extinction[1] and all of which have been found in shrimp trawlers' nets. For example, Poiner and Harris[6] recorded 5 species of turtles caught in just one shrimp fishery: the Australian Northern Prawn Fishery. These were: olive ridley (*Lepidochelys olivacea*), flatback (*Natator depressus*), green (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*) and loggerhead turtles (*Caretta caretta*). All types of turtles are slow growing and reach sexual maturity only after 10-50 years (depending on the species). As they have few natural predators and a long reproductive cycle, they are very susceptible to overfishing. It is difficult to get an accurate assessment of the number of sea turtles killed in shrimp trawls, however, predictions tend to fall around 150,000 annually[7]. This represents a huge loss to global populations.

Initiatives to reduce this high mortality began in the USA. By 1989, the numbers of kemp ridley turtles (*Lepidochelys kempi*) in the US Gulf of Mexico had

ABOVE: *Baby loggerhead turtles hatch out of their nest. Sea turtles are one of the most critically endangered groups of species to be taken incidentally by shrimp fisheries*[4].

declined dramatically as shrimp trawlers were catching an average of 5,000 of these turtles every year[8]. In response to public and scientific concern about decreasing turtle populations, Turtle Excluder Devices (TEDs) were introduced. TEDs are grid-like structures that direct turtles (and other large species) out of trawl nets through a hole above the grid[4] (see Figure 3; see also pages 39 and 40 for further information on TEDs). TEDs are compulsory in the US, and are now also required in foreign shrimping fleets that export shrimp to the US (following extensive negotiations at the World Trade Organisation)[9]. In general, fishermen have resisted using TEDs due to fears of reduced shrimp catch (a percentage of shrimp escape along with turtles). There is evidence of shrimpers tying up the escape flap of TEDs, rendering them ineffective; in 1997, it was thought that 41% of Texan shrimpers were violating the TED law[10]. Compliance is even more uncertain in developing nations where regulations are infrequently enforced after the annual US inspections to certify TED use[11]. Those countries that do not export wild-caught shrimp to the US may not even require the use of TEDs. Furthermore, even when TEDs *are* used, turtles may be injured as they escape, thus leaving them more prone to mortality. This is particularly the case in areas where shrimp trawling is intense and turtles are caught repetitively[11]. Equally, some turtle species, such as the leatherback turtle, are usually too large (at around 2m long) to pass through escape holes, which only have to be a minimum of 89cm x 30.5 cm[12]. Larger TEDs are being developed in the US and their compulsory use, combined with shorter trawling times, should reduce turtle catch rates and mortality[11]. However, conservation measures need to be introduced and enforced internationally. For now, the global number of dead turtles found washed up along coastlines does not appear to be declining. The case study of Orissa in India (right) gives some indication of what is happening to turtle populations in many parts of the world.

BELOW: *Around 150,000 turtles are killed by shrimp trawlers every year. This represents a huge loss to global turtle populations[7].*

© Great Barrier Reef Marine Park Authority

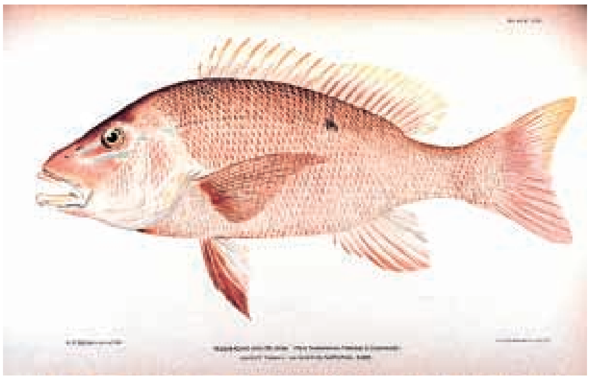
ABOVE: *This sea turtle, like many others, did not survive its encounter with a shrimp trawler.*

© WPSI / Operation Kachhapa / WildAid

Case study of Orissa, India

India is one of the world's leading wild shrimp exporters; in 1997 23,000 trawlers operated in Indian waters[13]. Unfortunately, the Indian coastline also serves as important feeding and nesting grounds for endangered sea turtle populations[13]. Orissa is situated along India's East Coast, lining the Bay of Bengal. Its coastline stretches for 480 km and harbours considerable populations of olive ridley, hawksbill and leatherback turtles. The coast is particularly famous for its nesting sites, with 100,000 nesting olive ridley turtles in the Gahirmatha area alone. This is the largest nesting site for this species in the world[14].

By the early 1980s shrimp trawling had been identified as the major cause of the mass of sea turtle carcasses regularly washed up along the Orissa coast. Consequently, the government introduced the Marine Fishing Regulation Acts of 1982 and 1983, which prohibited any mechanised fishing (such as trawling) within 5 km of the coastline. This was extended to a 20km 'no-fishing zone' off three major rookeries (turtle nesting sites) in the 1990s[14]. However, this legislation, as well as the mandatory use of TEDs, as yet remains unenforced. Recent video footage has shown a blatant disregard for the 'no-fishing zones' along the whole of the Orissa coastline[15]. Equally, none of the 3000 trawlers operating in Orissa use TEDs[16]. The consequences are clear: in 2000 another 10,000 dead turtles were found on the Orissa coastline, with a total of over 40,000 strandings in the last 5 years[17]. This incidental catch is too great to be sustained by turtle populations in the long-term. Urgent action is required and many conservationists argue that a blanket ban on trawling in this area is the only solution[16].



Socio-economic impacts

ABOVE: *Red snapper. Shrimp trawling has caused overfishing of juvenile red snapper in the Gulf of Mexico. This has had a substantial impact on the commercial red snapper fishery.*

Impact on commercial species

Shrimp trawling not only affects marine ecosystems but also the millions of people who rely on healthy fish stocks for food and employment. As the ecological structure and diversity of the seas are altered, many commercial fish species are directly impacted. For example, intensive trawling for shrimp in the northern Straits of Malacca (Malaysia) is causing erosion of overall fish stock biomass. In particular, demersal fish biomass (those fish associated with the sea floor) decreased by over 60% between 1971 and 1981[1]. This situation is mirrored in many areas of the world, from West Africa to the Gulf of Mexico, where fish stocks are vital to local economies and food security. Indeed, one of the main reasons trawling is generating worldwide concern is because it could threaten the viability or profitability of many other fisheries[1].

The ecological reasons behind productivity declines have already been discussed. One major factor is the encroachment of trawlers onto commercial species' nursery grounds. Vessels trawl close to shore, often beyond legal limits, where there tends to be an abundance of valuable shrimp. But concentrated fishing in these areas causes serious degradation to fish stocks at the nursery stage[2]. Indeed, in many areas, shrimp bycatch consists of mostly juvenile fishes (and invertebrates); as these juveniles are killed before reaching maturity, recruitment to adult fish populations cannot be sustained[3].

Commercial fisheries have seen declining catch rates due to shrimp trawling, though in many cases population-level effects on fish stocks have been difficult to quantify[3a]. One fishery that has been the subject of considerable research is that of red snapper (*Lutjanus campechanus*) in the Gulf of Mexico. When trawling near to shore, shrimping fleets harvest the '0-1' aged red snapper, which share their habitat with adult shrimp. Overfishing at this juvenile stage has had a substantial effect on the commercial red snapper fishery. Indeed, Gulf of Mexico shrimp trawlers caught and threw away approximately 34 million red snapper in 1995, while the snapper fishery averages only 3 million fish[3b]. Scientists now argue that any recovery of these stocks will require a sizable reduction in shrimp fishery bycatch, rather than changes to the management of the red snapper fishery itself[4]. The south and mid-Atlantic croaker (Sciaenidae) populations face a similar situation; shrimp bycatch mortality has had a large negative impact on population growth rates[3a].

In Greenland, past use of trawls for deep sea shrimp trawling was responsible for large bycatch of Greenland halibut, redfish and polar cod. Catches of these seabed species have since declined and now only juvenile-sized fish are found in shrimping areas[5]. A further study analysed impacts of North Sea shrimp fishery bycatch on the recruitment of important flat fish species, such as plaice and sole. Again, very high mortality of the '0' age group of these species is significantly affecting commercial stocks[6]. Aside from the ecological damage caused, the economic repercussions of catching and discarding non-target juvenile fish are considerable. For example, high levels of bycatch in EU brown shrimp (*Crangon crangon*) fisheries have caused losses of 6%-16% of the North Sea spawning stock of plaice[7]. Because these fish are discarded, potential landings lost are calculated to be around 12,000 tonnes a year, with a market value of €17.9 million. Annual losses of sole and cod are estimated at €3.9 million and €2.7 million respectively[7].

LEFT: *An Indian fisherman repairs his sail. For artisanal and subsistence fishers in developing nations, shrimp trawling can cause devastating declines in traditional fish stocks.*

© FAO

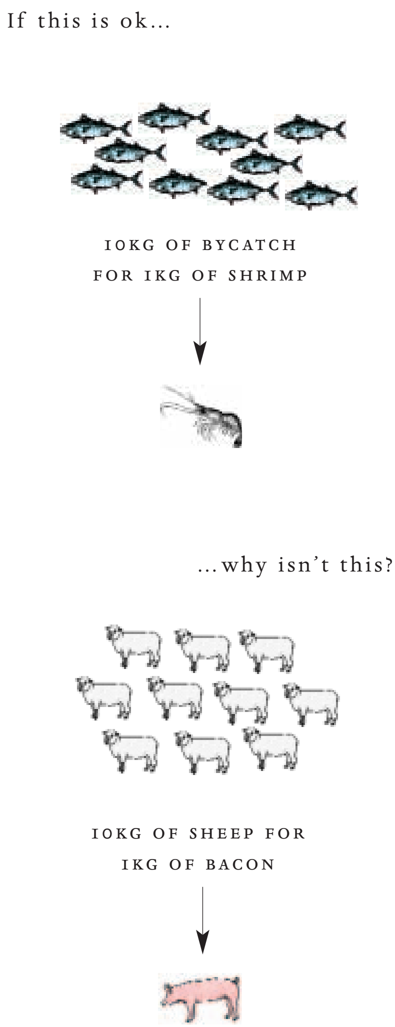
Impacts on artisanal fisheries

Impacts on commercial fishing fleets represent a loss in profit and job opportunities for fishing companies and their employees. Yet for artisanal and subsistence fishers in developing nations, declines in fish stocks can mean hunger and a loss of livelihood where few other options exist. This is the situation that many traditional fishers around the world now face. In the Bay of Bengal the 'abundance and diversity of coastal fishery resources have supported vibrant small-scale fisheries for centuries'[8]. Yet now, due to sustained – but not sustainable – shrimp trawling, numbers of higher value *K species* like red snappers, groupers and large croakers have fallen, leaving these fishermen struggling to sell lower-value fish. Some can no longer make a living from fishing[8]. Given that the fisheries sector contributes about 78% of animal protein intake in Bangladesh, coastal communities may well suffer from lowered dietary protein in the long-term[8]. Local fishers in many countries where shrimp trawling takes place share the same plight. In the Philippines, the encroachment of trawlers into prohibited zones has resulted in uneven catch and income for small-scale and subsistence fisheries[9]. Equally striking stories come from Venezuela, where growing shrimp trawling fleets often illegally fish in shallow coastal areas that had been reserved for artisanal fisheries[10]. Again, these waters often serve as nursery sites for commercial species. Similarly, fishing for shrimp in equivalent zones in Cameroon has resulted in high bycatch of juvenile fish, causing conflict between trawlers and artisanal fishers[11].

Shrimp trawlers not only remove fish biomass but also damage local people's fishing gear, especially where it is fixed to the seabed (such as fish traps)[12]. This causes intense antagonism, as fishermen lose equipment needed to sustain their livelihoods. In Nigeria, an increase in brown shrimp trawlers within 'non-trawling zones' has generated opposition from artisanal fishers who claim trawlers destroy and tow away their nets, ram their canoes and 'threaten their very existence'[13]. In fact, competition between shrimp trawl fisheries and local artisanal fisheries is so extreme that some small-scale fishermen in the Philippines have had to resort to illegal 'dynamite' and 'cyanide' fishing to earn an income[9]. These fishing methods have catastrophic impacts on coral reef ecosystems.

As the commercial value of artisanal fisheries is perceived to be less important, they are rarely researched or monitored. Yet they sustain millions of people in poor coastal regions that have no other resources to rely on. Consumers in wealthier nations need to remember how local fish stocks are affected by shrimp fisheries, and compare this to a theorical equivalent wastage of farmed livestock (see Figure 9). The identical stories told by fishing communities from around the world indicate an emerging tragedy that can be averted. In Margarita Island in Venezuela, local fishermen have claimed their catches have increased significantly since the implementation of a new fishing law, which raised fines for shrimp trawlers caught illegally within six nautical miles of the coastline[14]. Now juvenile fish are being given the opportunity to reach commercial size and replenish local stocks. Such increased enforcement of fishing legislation could help local fishermen in many other countries rebuild their lives.

FIGURE 9: *Shrimp trawling bycatch: comparing fish bycatch mortality to the theoretical culling of farmed livestock. This diagram gives some indication of how wasteful shrimp fisheries are.*



Bycatch utilisation

For many people, discarding millions of tonnes of fish protein that could be used to feed hungry communities is ethically unacceptable[1]. Utilisation of bycatch fish not only provides food but also employment for impoverished coastal communities. A large number of people sell bycatch from shrimp fisheries for human consumption or for the production of animal feed. Some have argued that, given these dependencies, any reduction in the amount of bycatch caught by shrimp fisheries would affect the livelihoods of these people[2]. Consequently, organisations such as the FAO have done much to promote bycatch utilisation.

Yet, discussions on bycatch utilisation sometimes fail to address more fundamental ecological questions. Indeed, even if all the by-catch could be processed, part of the problem (creating a shrimp-dominated ecosystem) would remain[3]. Therefore, it is debatable whether high levels of bycatch should be permitted at all. Utilisation may encourage local people to become reliant on an unsustainable source of protein and this raises issues of longer-term food security. In particular 'if a market for presently discarded fish is generated, it is going to be difficult to reverse the situation'[2]. For example, in Mozambique there is shortage of alternative protein supplies because of years of civil unrest[2]. Fishermen want to take advantage of high demand to sell the non-target fish species caught by shrimp trawlers, and therefore are reluctant to use bycatch reduction devices. Equally, the depletion of shrimp stocks in some parts of Asia, coupled with increasing demand for fish, have meant that vessels originally designed to catch shrimp now work as 'multi-species fisheries'. These make use of nearly all fish species caught to produce products such as surimi, fish balls, canned, dried, frozen products as well as bait, fertilisers and animal/fish feeds[4]. Considerable demand for these products has been generated.

In South Asia, particularly in India, fish that is unfit for human consumption is generally used as animal feed. In other countries, such as China, bycatch from shrimp fisheries is used almost entirely to feed the Chinese aquaculture (fish farming) industry[1]. Similarly, the Thai shrimp fishery supplies 1.2 million tonnes of 'trash fish' to feed the growing aquaculture sector[1]. Yet it is not ecologically

BELOW: *An African child with his father's fish catch. Small-scale fishermen who used to make a living from fishing now often rely on bycatch from shrimp trawlers.*

efficient to use this bycatch to feed farmed species such as shrimp, when some of it could have been eaten by coastal people directly. In the case of shrimp aquaculture (another unsustainable method of shrimp production[5]) over 2 kg of fish feed is required to produce 1 kg of shrimp[6]. Furthermore, this farmed shrimp is not used to feed local people, but is destined for wealthy consumers in the developed world.

Indeed, 'the solution reached in many countries, that of utilisation of bycatch, is not the most satisfactory way to utilise resources'[1]. Nevertheless, it is worthwhile outlining systems of bycatch utilisation. In general, more bycatch is discarded in the developed than the developing world. In the Australian Northern Prawn Fishery, around 97% of bycatch from shrimp fisheries is discarded[2]. Most bycatch utilisation occurs in Asian countries, and this practice is growing. Recent figures suggest that although only around 20-30% of bycatch is used in Central America and the Caribbean, utilisation is also increasing in this region[2]. This greater utilisation could be linked to growing human populations and declining fish stocks. Bycatch use in African countries is generally low.

Bycatch usage depends on whether there is a market for a particular size or species of fish. Fish that are too small (juveniles), inedible or damaged are likely to be discarded[1]. Even if shrimp trawlers catch adult commercial fish species, several factors complicate their utilisation. For example, per kilogram, fish is often much lower in value (20-30 times less) than shrimp; so even if the bycatch species could be sold, the investment made in sorting, processing, storing and transporting them to market may not be recouped. Furthermore, many countries don't have systems to collect bycatch from trawlers, and shrimp fishermen may not want to use up space (and ice) to store lower value fish[1]. So, while the technical means for preserving and processing fish onboard trawling vessels is available, this practice is largely guided by socio-economic feasibility and market forces[2]. Most countries rely on informal and opportunistic systems of bycatch utilisation with local operators/fishermen taking advantage of the 'unwanted' fish resources. In countries where trawlers work very close to shore, small crafts can reach them relatively easily. Often small-scale fishermen who used to make a living from fishing now rely on bycatch from shrimp trawlers. One author, commenting on the utilisation of bycatch, argued, 'it is ironic, perhaps, that the use of shrimp trawlers in coastal waters has sometimes been blamed for the disruption of traditional fishing patterns…yet that same activity may be alleviating some of the problems it has created by giving fishermen alternative income-generating opportunities'[2]. Yet these income-generating opportunities may not be ecologically or socially sustainable solutions.

Utilisation of bycatch in the developing world[2, 4]

Asia: Much bycatch is used. Products include: fresh fish, traditional products, novel foods, animal and aquaculture feeds.

Africa: Little bycatch is used, largely due to difficulties in transportation/processing. Products include: traditional fish products, dried fish, fresh fish.

Latin America: Little bycatch is used due to low consumption of fish and preference for fresh, larger-sized fish. Products include: fresh fish, novel products and animal feeds.

ABOVE: *In Asian shrimp fisheries, a high percentage of bycatch is used for human consumption or animal/fish feed. However, such utilisation may also encourage local people to become reliant on an unsustainable source of protein.*

RIGHT: *Bycatch is more likely to be discarded in the developed world. In the Australian Northern Prawn Fishery, around 97% of bycatch from shrimp fisheries is discarded.*

FOREIGN-OWNED SHRIMP TRAWLING FLEETS

'The EU are driving local fishing communities into greater poverty, as well as robbing the marine environment.'

Klaus Töpfer, Director of United Nations Environment Programme[6].

In some cases, it is not nationally-owned shrimp trawlers that exploit marine ecosystems, but foreign-owned vessels. Some shrimp trawling is done illegally, such as in Somalia. Such 'fish-pirates' are a major problem all over the world[1] and at the World Summit on Sustainable Development (Johannesburg, 2002), the eradication of unregulated fishing was identified as crucial for the future sustainability of fisheries worldwide. As many developing countries don't have the means to control or monitor illegal trawling, they are particularly at risk[1]. Shrimp caught by these trawlers may be sold on, via supermarkets in wealthy countries, to consumers who are not aware of the impact on local fisheries. In the case of Somalia, foreign vessels come to take advantage of the rich and relatively unexploited waters; both Russian and Kenyan shrimp trawlers have recently been observed trawling illegally[2]. This pirate fishing has expanded greatly following the collapse of the Somali government in 1991. Once again, trawling occurs over sensitive nearshore ecosystems and destroys the stationary fishing nets and traps set by subsistence fishermen[2]. Given that Somalia is the world's hungriest country, with 75% of the population undernourished[3] this loss of protein is unacceptable. Moreover, illegal fishing extends beyond Somalia: in one West African coastline survey, it was found that 50% of vessels were fishing illegally and 10% of vessels were apparently lacking a licence[4].

Even if shrimp trawling is conducted legally, through international agreements, its impacts can be equally damaging. Several West African nations, including Senegal, Angola and Guinea-Bissau, have ongoing fisheries agreements with the EU. These were signed following the 1982 UN Convention on the Law of the Sea, which gave all countries jurisdiction over a 200-mile coastal zone. Traditional fishing vessels were not able to exploit these 'new' fishing areas, so governments signed fishing rights away to foreign nations with more technologically-advanced fishing fleets[5]. Many fisheries agreements are with the EU; as European fisheries are depleted by over-exploitation, the EU move their otherwise redundant fleets from countries such as Spain, Portugal and France to these West African waters. African countries receive financial compensation in return; foreign exchange gained from these agreements is often desperately needed. But the ecological impacts of shrimp trawling and subsequent effects on local fishing communities have been devastating[6]. Once some of the most abundant fishing areas in the world, some African nations have seen their stocks crash by 80%[6]. Klaus Töpfer, director of the UN Environment Programme, argues that the EU 'are driving local fishing communities into greater poverty, as well as robbing the marine environment'[6]. In fact, a 2001 report by the UNEP warns that coastal countries that open their waters to foreign fishing fleets may lose billions of dollars more than they gain because of this environmental over-exploitation[7].

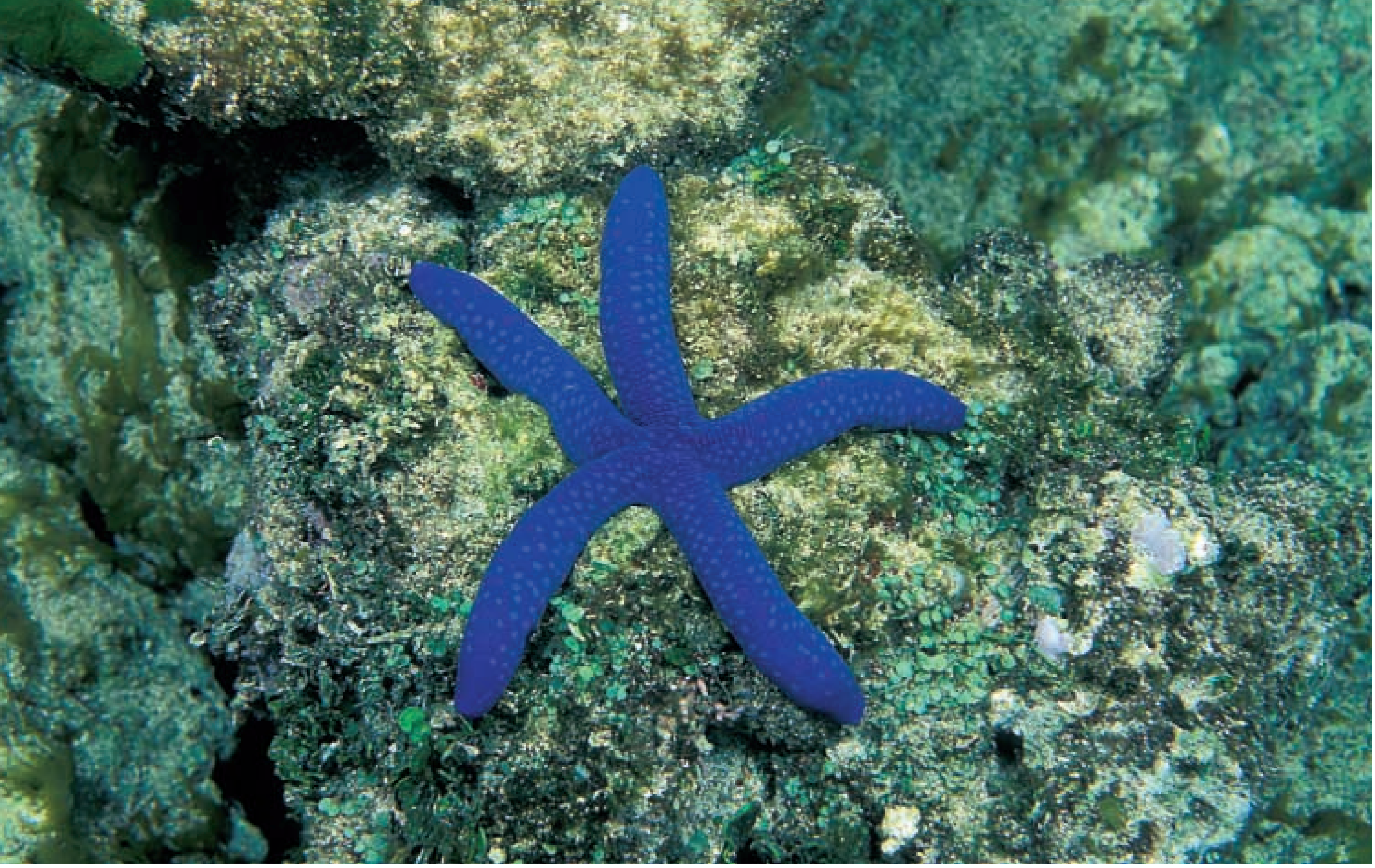
It is often the poor fishing communities that pay the price. In many areas trawled for shrimp, local fishers are progressively catching less and have to sail further out to sea to find fish[5]. Moreover, commercial shrimp fisheries do little to provide alternative jobs, neither do they significantly contribute to local

coastal economy; most shrimp is frozen or processed at sea and unloaded in the vessels' home port.

Unbelievably, these fishing fleets are being subsidised by EU public money. For example, EU subsidies enable European vessels to trawl for shrimp in Guinea-Bissau by underwriting up to 46% of their operation[8]. This allows fishermen to continue trawling even when no profit is made from their catches. Consequently, fishing capacity is maintained, rather than reduced, when outputs decline. This process undermines the sustainable use of marine resources and distorts trade[8]. Similar stories of exploitation are reported in Madagascar, where traditional fishing zones are encroached upon by French and Japanese shrimping vessels flying the Malagasy flag. Once again, these vessels are reportedly 'spoiled by the authorities', with EU and French public funds poured into maintaining French fishing capacity[9].

Many developing nations are aware of how destructive fishing agreements can be. Yet resisting the entry of foreign fishing fleets is not straightforward; some governments, reluctant to sign or renew agreements with the EU, have been put under considerable pressure[10]. During May 2002, the EU allegedly threatened to block access to European markets of Moroccan agricultural goods if Morocco delayed in re-opening fishery negotiations[11]. One point of contention was Morocco's wish to reduce shrimping zones for EU vessels, and decrease the amount of shrimp caught by 50%. Negotiations between Senegal and the EU also became deadlocked in 2002. Yet, the financial rewards were so substantial that Senegal eventually agreed to initiate a protocol with the EU to renew the long-standing fisheries agreement between the two regions. Financial compensation amounted to an annual €16 million (US$ 15.9 million), up from €12 million the previous year[12]. Clearly fishing to provide local food, employment and development must be given absolute priority[13]. In recent fishing access agreements, such as that with Angola, the EU has allocated funds to support small-scale fishing and has agreed to improve monitoring and control of fishing activities. Yet, whether the EU's actions will be enough to rectify past damage from over two decades of heavy fishing in African waters remains to be seen. Several environmental organisations have argued that the recent EU-Angola fishing agreement will increase the unsustainable exploitation of marine resources; in particular, no determined biological rest period for shrimp (or fish) stocks has been put in place[14]. As Julie Cator of WWF argues, 'Imagine being able to pay to enter a supermarket and then loading up your trolley with almost anything you wanted. That's what the EU has negotiated with famine-hit Angola'[14]. Furthermore, it is not only European fishing fleets that need to be better managed: Japanese, Korean and Russian fleets are also known to fish in African waters. Local people want to stop this over-exploitation. They know that unless fisheries agreements are modified and shrimp trawling practices change, there will be little hope of maintaining viable fish stocks to feed themselves and their families.

ABOVE: *Senegalese fisherman. The Senegalese are heavily reliant on fish as a source of protein. Foreign fishing fleets place added pressure on shared marine resources.*



IMPACTS ON BENTHIC ENVIRONMENTS

'Bottom trawling and use of other mobile fishing gear have effects on the seabed that resemble forest clearcutting, a terrestrial disturbance recognized as a major threat to biological diversity and economic sustainability.'

Dr. Les Watling, University of Maine and Dr. Elliott Norse, Marine Conservation Biology Institute[7]

Traditional fishing methods may modify seabed (benthic) habitats, but their impacts are minimal compared to damage caused by large commercial trawlers. Shrimp trawling is thought to affect benthic fauna, habitat, diversity, community structure and trophic interactions in both tropical and temperate seas[6]. Trawling nets, and their attachments, are designed to maximise contact with the seabed, crushing, burying and exposing marine animals[7]. Otter and beam trawls can cut 0.3 m into the seabed when used in waters deeper than 30 m[8]. Trawling also churns and re-suspends bottom sediments, as well as any toxic chemicals they may contain. Overall, the seabed is gradually smoothed over by the mechanical action of trawlers, which destroys the structural diversity it needs as a habitat for marine organisms[6]. Dr. Peter Auster, (Science Director at the National Undersea Research Center for the North Atlantic and Great Lakes), argues that structurally complex habitats are critical for many species of marine life and provide cover for juvenile fish and their prey, including crab, shrimp, starfish and marine worms[9].

In some cases, trawlers cover the same patch of seabed every year, similar to a tractor repeatedly ploughing a field. This gives benthic environments little opportunity to recover. In general, recovery following trawling disturbance takes a long time because 'recruitment' of new organisms is irregular and some structure forming species can take decades or more to mature[7]. Thus, trawling is particularly destructive where the 'return interval' (the time between one trawling occurrence and the next) is shorter than the time required for an ecosystem to recover[7]. Repeated trawling over a number of years can lead to an irreversible loss of seafloor habitats, and even localised extinctions[5,10,11].

ABOVE: *Starfish live in shallow waters of the tropics where shrimp trawling commonly occurs.*

© Great Barrier Reef Marine Park Authority

Seabed environments

Seabed ecosystems are very varied. Contrary to common perceptions, the sea floor is not covered by homogenous, featureless accumulations of sediments, but is sandy and muddy with a complex 3D structure[1]. This structure is made up of non-living objects (rocks, shells, etc.) and living organisms (seaweeds, sponges, bryzoans, molluscs), as well as the results of biological burrowing[1]. Some areas are covered with 'submerged aquatic vegetation' (SAV) such as seagrasses; in other areas (both temperate and tropical), reefs are found[2]. These intricate marine structures often sustain very diverse ecological communities.

Sandy and muddy bottoms, inhabited by many commercial shrimp species, are among the least studied environments. Nevertheless, their role in marine ecosystems should not be underestimated. For example, the lagoonal and inter-reefal areas targeted for trawling in the Great Barrier Reef Marine Park (GBRMP) were assumed to be barren areas. However, during a study on shrimp trawling in these habitats, more than 1000 new seabed species were discovered[3]. (Typical species found on the soft seafloor of the Great Barrier Reef Marine Park are listed in Figure 10.) Benthic communities are a particularly essential part of marine food webs[1] and many bottom-dwelling species play important ecological roles such as bio-turbation, oxygen production and nutrient recycling. These communities are also known to contain high species diversity[4].

Of course, trawling for shrimp occurs in a wide range of marine habitats, from coastal areas as shallow as 10 m deep in Indonesia, to deep-sea environments hundreds of metres below the surface in Norway. This diversity, combined with a lack of research, makes it hard to generalise about the impacts of shrimp trawling. Effects will depend on the exact type of fishing gear used, the habitat, the intensity of the trawling, and how long trawling has occurred. Nevertheless, many scientists, such as Elliott Norse (President of Marine Conservation Biology Institute) and Les Watling (Professor of Oceanography at the Darling Marine Center, University of Maine), argue that, in general, the environmental effects of trawling present great cause for concern.

FIGURE 10: *Species found in epibenthic* communities of the soft seafloor in the Great Barrier Reef, Australia[5]. Shrimp trawlers target soft benthic environments as they are often inhabited by commercial shrimp species.*

Echinoderms (e.g. feather stars, sea stars, pincushion stars, brittle stars, basket stars, sea urchins and sea cucumbers)
Molluscs (e.g. sea snails, sea slugs, limpets, scallops, oysters, clams, nautilus, cuttlefish, squid, octopuses)
Crustaceans (e.g. prawns, crabs, lobsters, barnacles)
Demersal fishes (those associated with the sea floor)
Bryozoans (lace corals and other moss animals)
Ascidians (sea squirts)
Sponges
Cnidarians (e.g. jellyfish, sea anemones, hard and soft corals, gorgonians (i.e. sea fans, sea whips))
Seagrasses (shallow water and deep water)
Algae (e.g. *Halimeda* mounds)

* *Those organisms living at, or just above, the sediment surface.*

BELOW: *These strawberry anemones are among the many benthic organisms at risk from shrimp trawling.*
© Cordell Bank Expeditions

ABOVE: *The productivity of many fish stocks depends on healthy benthic habitats.*

WHILE TRAWLING DAMAGES ALL BOTTOM ENVIRONMENTS, it is of particular concern in two zones: 1) deep water areas, where severe natural disturbance is so rare that species are less able to recover from trawling[12a] 2) tropical shallow waters that act as nursery grounds for juvenile fish species[12b]. Worryingly, habitat degradation is generally agreed to be the 'most egregious threat to the long-term sustainability of fishery resources' yet remains one of the least understood determinants of fisheries productivity[2]. While over-exploiting the marine environment should be avoided, it is possible for fish stocks to recover from high fishing pressure. However, when habitat destruction 'strips away the biological productivity upon which fisheries depend' the recovery of overfished stocks may take much longer[13]. Leading scientists have claimed that 'bottom trawling and use of other mobile fishing gear have effects on the seabed that resemble forest clearcutting, a terrestrial disturbance recognised as a major threat to biological diversity and economic sustainability'[7] (see Table 2). Clearly, although benthic structures are generally much smaller than those in forests, their complexity is equally essential for biodiversity[7].

In Bangladesh, the shrimping zone is criss-crossed by trawlers, and 'from the estimate made so far on the destruction of benthic fauna and their habitats by the shrimp trawling activities, the situation is alarming'[1]. Unfortunately, such 'estimates' are all we have to gauge the damage. Likewise, in Indonesia, the bottom habitats in the Arafura Sea have hardly been studied, either before or after the use of shrimp trawlers[14]. Research is limited, particularly in the developing world, and even where there is funding and scientific interest, studies are often confounded by a lack of control sites. Because trawling has occurred so extensively, it is hard to find 'untouched' sites on which to carry out research. Some areas of the North Sea have undergone fishing disturbance for five decades and continue to be trawled many times a year[6]. This means habitats are already pre-disturbed and additional experimental trawling may produce little further change[13]. But in a few parts of the world where pristine continental shelf areas still exist, new trawling causes dramatic shifts over time-scales as short as a few years[15]. Structurally varied seabed habitats with diverse communities may have taken millennia to develop, yet are quickly changed to low productivity areas of mud and sand[10].

TABLE 2: *Forest clearcutting and Bottom trawling: Similarities and Differences*[7].

	Forest Clearcutting	**Bottom Trawling & Dredging**
	Similarities	
Geographic Range	subpolar – tropical	subpolar – tropical
Geologic substratum	severe disturbance; exposes soils to erosion and compresses them	severe disturbance; overturns boulders, homogenizes sediments, leaves grooves
Life in substratum	kills roots, favors decomposers	kills and exposes infauna, favors scavengers that eat them
Structure-formers	removes most	removes or damages most
Associated wildlife	eliminates most late-successional species, encourages pioneer species	eliminates most late-successional species, encourages pioneer species
Bio-geochemistry	releases pulse of carbon to atmosphere by oxidizing organic material	releases pulse of carbon to water column and atmosphere by oxidizing organic material, increases oxygen demand
	Differences	
Recovery Time	decades – centuries	years – centuries
Disturbance return time	40-200+ years	40 days – 10 years
Area impacted annually	Around 0.1 million kilometres squared	Around 14.8 million kilometres squared
Ownership	private and public	public
Scientific studies	many	few
Public awareness	high	low
Legal status	increasingly prohibited in favour of alternative logging methods & preservation	prohibited in very few areas

LEFT: *Sponges are delicate structures at risk from shrimp trawlers. Anecdotal evidence suggests that trawlers fishing for redspot king prawns off Townsville (Australia) removed about 200 tonnes of sponges each year for the first 3 years, having a detrimental impact on the biodiversity of the Great Barrier Reef World Heritage area*[3].

One particularly striking investigation took place in Australia. Conducted by Dr. Ian Poiner and his colleagues at the Commonwealth Scientific and Industrial Research Organisation, this 5-year study in the Great Barrier Reef Marine Park was the first large-scale research project on the ecological effects of tropical shrimp trawling[3]. It revealed that 'the pass of a single trawl removes up to 25% of seabed life, including large sponges and flowerpot corals. Thirteen passes can kill off up to 70-80%.' As so little is understood about these sandy inter-reefal benthic communities, it is unknown how long they will take to recover; some scientists estimate up to 20 years[3] (see Figure 11). As with the impacts of bycatch, one of the greatest problems is the depletion of vulnerable species. These include those that are removed easily from the seabed and/or those that are slow to recover from the effects of trawling[5]. Research in the Great Barrier Reef has shown that more than 80% of least resilient fauna can be removed by trawling every year[3]. Due to their delicate structure, sponges and flowerpot corals (*Turbinaria* spp.) are some of the most vulnerable organisms, the latter decreasing at about 40% per trawl. Anecdotal evidence suggests that trawlers fishing for redspot king prawns off Townsville (Australia) removed about 200 tonnes of sponges each year for the first three years of the fishery[3].

This process leaves less susceptible species to dominate the ecosystem. These are often faster growing 'opportunistic' species that are physically resilient or not so reliant on structurally diverse habitats. Abundance-biomass curves demonstrate that communities within the areas closed to 'towed' fishing gears (such as trawls) are dominated by higher levels of biomass and emergent fauna that increase the complexity of benthic habitats. Conversely, areas fished using towed gears are dominated by smaller fauna and scavenging species[16]. Significantly, the increase in opportunistic species does not compensate for the total biomass removed by bottom trawling[17]. Further examples of species change are linked to turbidity. When sediments get churned up by trawling action, suspended particles of mud and sand in the water column can increase by up to 1000%. This re-suspension buries some organisms. In addition, suspension-feeders (such as bivalves) that consume nutrients in the water column are overwhelmed by the increase in sediment and debris[18]. Thus, frequent re-suspension can change the dominant species of bottom communities from suspension feeders to deposit feeders[1]. Other studies have shown that high levels of suspended sediment can increase the relative abundance of fish that locate food by touch or chemical sensors, and decrease those reliant on vision[15]. This means that those species sensitive to high turbidity may move away from freshly trawled areas[3].

FIGURE 11: *The effects of shrimp trawling on seabed environments*[3].

Seabed environments

- diverse and productive ecosystems
- sustain commercial fish stocks, especially at juvenile stages
- essential component of oceanographic environment

but...

↓

After **1 trawl**... a **25%** removal of seabed life

↓

After **13 trawls**... **70-80%** removal of seabed life

↓

Long-term damage to marine ecosystems? **Unknown.**

Impacts on seagrasses and reefs

In general, shrimp trawling occurs on sandy and muddy bottom habitats. However, developments in trawling technology (such as the introduction of rollers/rockhoppers) have made it possible to trawl over many different kinds of benthic structures, such as reefs and seagrass beds. Global positioning systems have also helped shrimp trawlers access a greater range of areas. Unfortunately, these recent advances have 'all but eliminated what were de facto refuges from trawling'[7].

Seagrass beds are of great ecological value, providing habitats for a large number of plants and animals (including the juveniles of many commercial fish species) as well as acting as a food source for green turtles (*Chelonia mydas*) and dugongs (*Dugong dugon*). They also play a key role in stabilising coastal sediments. Yet, with the development of 'rollers' attached to the front of nets, trawling over seagrass beds has become more feasible. Trawling gear is designed to roll over the seabed, minimising penetration and debris accumulation[19]. This type of gear is used by shrimpers in Tampa Bay, Florida to trawl over *Thalassia* (turtle grass) beds. While one short-term study found that the effect of trawling on these seagrass areas is limited[19], no long-term research has been carried out. In particular, the study did not assess possible damage to *Thalassia* sexual reproduction even though repetitive disruption of beds in the summer is known to damage seagrass reproductive structures[2]. By re-suspending sediment, trawling also reduces light availability, and hence the level of photosynthesis possible in the seagrasses. Several experts believe that the impacts of trawling on submerged aquatic vegetation (such as seagrass) are of significant concern and should be avoided at all costs[2].

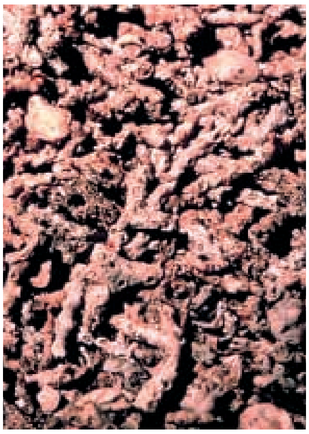
Similar appendages have allowed trawlers to fish for shrimp over deep-water reefs. Deep-water reefs are typically found at depths of 70-4000 m worldwide, and can take centuries and even millennia to build up. They are poorly studied[20] though current evidence suggests they support very rich communities of associated invertebrates and fish. Bottom trawling with rockhopper gear can severely impact these types of reefs, 'quickly pulverising ancient ocean bottom structures that took eons to form, and under normal conditions would stand for

ABOVE: *Oculina corals on Florida reefs. These corals may form linear colonies 3 to 4 m in length.*

© NOAA

TOP: *Seagrass beds are of great ecological value, providing habitats for a large number of plants and animals (including the juveniles of many commercial fish species).*

© Paige Gill, Florida Keys National Marine Sanctuary / NOAA



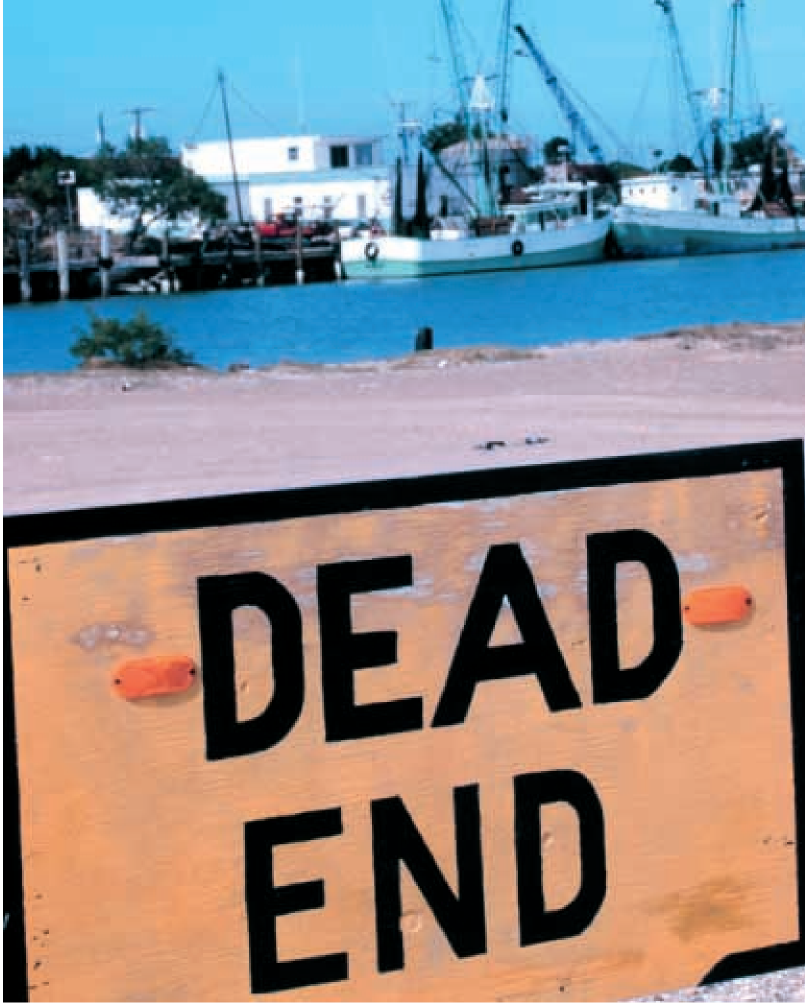
ABOVE: *Oculina varicosa rubble. These reefs were destroyed by commercial fishing gear such as shrimp trawls.*

BELOW: *These tropical reefs are 'islands' of high biodiversity and productivity. Although not specifically targeted by shrimpers, tropical reefs can be damaged both directly and indirectly by trawling.*

centuries to come'[21]. During NOAA's Islands in the Stream 2001 Expedition, researchers noted extensive damage on the Oculina reefs off the coast of Florida, which appeared to be caused by shrimp trawling. These Oculina reefs contain linear coral colonies 3 to 4 m in length as well as vast coral thickets that shelter hundreds of marine species. Moreover, the Institute of Marine Research of Norway has documented severe degradation of deep water *Lophelia* reefs, again due to shrimp trawling[22]. Some of these Norwegian *Lophelia* reefs were thought to have existed for over 2,000 years[23].

Also within northern Europe, *Sabellaria spinulosa* reefs provide habitats for many marine organisms; more than 80 species were found in these reefal communities in the Bristol Channel, UK[24]. Their high productivity also makes them particularly valuable benthic environments. However, large areas of these reefs have been lost due to destructive fishing practices. In the Wadden Sea for example, shrimp fishermen actively searched for *Sabellaria spinulosa* reefs to maximise their catches of pink shrimp; intensive trawling appears to have destroyed both the reefs and the shrimp fishery in the process[24]. Regeneration of these habitats is estimated to take between 15-150 years[24].

The ecological importance of tropical coral reefs is perhaps even higher than that of their cold water relatives. In general, tropical reefs are not targeted shrimping grounds; the hard calcareous substrate tends to damage nets, despite gear modifications. However trawling may occur incidentally over those 'patch reefs' surrounded by soft-bottom areas[1, 3, 25]. These reefs are essentially 'islands' of high biodiversity containing corals, sea squirts, sponges and coralline algae, amongst others[5]. Other than the direct physical effects of trawling, reefs may also undergo considerable indirect disturbance[26]. Ongoing research on coral reefs in the Tortugas Ecological Reserve (Florida) has shown that soft-bottom communities are the proximal source of nutrition for most fish on and around the coral reef itself[26]. This means that trawling in these areas can have 'potentially profound cascade effects for nearby coral reef ecosystems'[26]. Fundamentally, the inter-connectivity of adjacent ecosystems, such as coral reefs, seagrass beds and soft seafloor habitats, should not be underestimated. They are not systems that exist independently of each other and the ecological impacts of trawling may be more widespread than currently assumed[5].



© William B. Folsom, NMFS / NOAA

CONCLUSION

'Trawling is like bulldozing a forest to catch songbirds.'

Dr. Sylvia Earle, internationally recognised oceanographer and former chief scientist of NOAA[24].

Shrimp is one of the most valuable seafood commodities, accounting for approximately 20% of the value of internationally traded fishery products[1]. As long as trawling continues to generate money and jobs by satisfying demand for shrimp in wealthy nations, its regulation will be resisted or ignored. Equally shrimp trawling's impact on biodiversity and other fisheries will be fiercely contested by those with vested interests in its continuation. Nevertheless 'stakeholders' exist far beyond the shrimp fishing industry itself[2]. Shrimp trawling affects many social groups; when fisheries decline because of over-exploitation or habitat destruction, people lose their jobs, face lower dietary protein levels, or have to pay more for fish[3]. Globally, people eat more fish than any other type of animal protein, especially within poor coastal communities, and fishing supports the livelihoods of 450 million people[4]. This includes not only fishermen and their families, but also those employed in connected activities such as net making, fish processing, and distribution. These people are dependent on what is a free, open-access resource; if this is jeopardised, they may have few other livelihood options. And as the global population expands, pressure on fish stocks will increase, particularly in coastal regions where population growth rates are high[5]. According to the FAO, over 70% of the world's fish stocks are overfished or fully exploited. Wasteful and damaging shrimp fisheries just exacerbate this scenario. Crucially, we need to start appreciating the value of oceans, both in terms of the goods and services they can provide the human race, but also in terms of their intrinsic ecological value. As a global environmental resource, the protection of the seas is an international responsibility. And, just as on land, ecosystems in the seas are being threatened. Unless we develop a marine conservation ethic that mirrors our terrestrial ethic[2], the future of coastal resources in the face of sustained shrimp trawling is bleak.

RECOMMENDATIONS

The following recommendations are divided into two distinct sections 1) International Policy Recommendations and 2) General Management and Technical Recommendations. Both sets of recommendations are intended to guide interested parties in the development and implementation of shrimp fisheries management regimes that will place as core goals the achievement of ecologically, socially and economically sustainable fisheries. Action must be undertaken by national and supra-national governments, international organisations as well as by the private sector and consumers.

International Policy Recommendations

Food and Agriculture Organization of the United Nations (FAO) and Member Governments

EJF recommends:

- All signatory governments to the FAO Code of Conduct for Responsible Fisheries (CCRF) integrate this voluntary code into national and regional shrimp fisheries management plans and report on actions taken in support of the Code's implementation.
- Governments share experiences in the implementation of the Code. Non-signatory governments should be encouraged to sign the Code and should be provided with assistance to enable them to meet the core provisions.
- The rapid implementation of the 'International Plan of Action for Management of Fishing Capacity' by 2005 and the 'International Plan of Action against Illegal, Unregulated and Unreported fishing' by 2004, in accordance with agreements reached at the World Summit on Sustainable Development in Johannesburg. Special focus should be given to reducing shrimping capacity and eliminating illegal shrimp fisheries.

ABOVE: *Illegal trawling for shrimp off the Indian coastline.*
© WPSI / Operation Kachhapa / WildAid

- The FAO be given sufficient support to continue national level capacity building, financial assistance and transfers of technical expertise in the pursuit of the above objectives.
- The adoption of an International Plan of Action on Bycatch Reduction under the auspices of the FAO.
- Enhanced commitment and support be given to develop and expand current UNEP/GEF/FAO projects on reducing the impacts of tropical shrimp trawling operations on living marine resources through the adoption of environmentally friendly techniques and practices.

World Trade Organisation and Member Governments

EJF recommends:

- The expeditious elimination of all detrimental fishing subsidies. These are trade-distorting and can have serious environmental and social repercussions.
- Continued collaboration between the WTO and Secretariats of Multilateral Environmental Agreements (MEAs). In particular, clarification of the relationship between WTO rules and MEAs is needed to ensure that such agreements are mutually supportive and that the primacy of pre-existing MEAs is recognised.
- The acknowledgement and approval by the WTO that trade-related measures may be necessary to achieve non-trade objectives – in this case the reduction of unsustainable shrimp production.

European Union

EJF calls for:

- Extensive, legally-binding changes to EU fisheries agreements that uphold European norms in foreign waters. Fundamentally, there should be a stringent set of standards for access agreements that prioritise ecological sustainability and the rights of local fishing communities. Thorough environmental impact assessments should be carried out prior to the initiation or renewal of any fisheries agreement that guarantee shrimp stocks and marine communities can endure further fishing pressure. Above all, no agreements should be signed without a) a long-term management plan for shrimp fisheries in place and b) independent affirmation that the coastal state (or third parties) has adequate capacity to enforce fisheries regulations. These measures would bring the EU in line with its international commitments as a signatory to both the FAO CCRF and the United Nations Convention of the Law of the Sea (UNCLOS).
- Cutbacks in EU fishing capacity, multi-annual frameworks for the conservation of resources and reductions of subsidies that support unsustainable Euro-

pean (shrimp) fisheries, as proposed in the current reforms of the Common Fisheries Policy (CFP).

- The rapid execution of proposed CFP reforms. If implementation is foreseen to take several years, destructive fishing practices such as shrimp trawling should, in the meantime, be constrained.
- The enforcement and independent monitoring of shrimp fishing practices, as well as increased scientific research on the impacts of shrimp trawling.
- The EU to resist pressure from pro-fishing states to grant further access agreements with developing nations and maintain current fishing subsidies.
- The full adoption of the FAO CCRF and implementation of its objectives in both national and overseas waters where EU fishing vessels operate.

ABOVE: *Artisanal fishermen.*

© Smailes / WildAid

National Governments

EJF calls for:

- Governments to demonstrate their political will to ratify and / or implement the plethora of international marine treaties signed over the last decade. These include: UNCLOS, the FAO CCRF and International Plans of Actions, the Convention on Biological Diversity (CBD), as well as the agreements reached at the World Summit on Sustainable Development (WSSD). All of these oblige states to adopt a precautionary approach to the exploitation of marine resources. In particular, national governments should urgently implement their commitments to maintain or restore depleted stocks by 2015 and eliminate destructive fishing practices by 2012 (as agreed at WSSD 2002) .

International Donor Community

EJF recommends:

- That the international donor community help support developing states adopt sound shrimp fisheries management plans and eradicate illegal, unregulated and unreported shrimp trawling. This can be done through capacity building and the transfer of technology. International donors should also stop financing shrimp boat building and initiate buyouts of shrimp trawling vessels.
- Coastal communities, regional fisheries management organisations and local NGOs should be empowered to become further engaged in the management of shrimp (and other fishing) fleets. Through community-based management schemes, local people should be given support to report unregulated or illegal trawling activities in artisanal fishing zones.
- Assistance should be offered to undertake much-needed research into alternative shrimp fishing methods.
- Support should be given to investigate the overall effects both foreign fishing fleets and export-oriented shrimp production are having on food security and rural livelihoods in the developing world.

Consumers and Retailers

EJF calls for:

- Consumers and retailers to only purchase shrimp proven to be from ecologically sustainable, economically viable and socially equitable shrimp fisheries. Retailers should provide consumers with shrimp products that have been independently certified as sustainable.

United Nations Agencies

At an intergovernmental level, the UN agencies have a principal role to play in co-ordinating marine conservation initiatives. To improve the management of (shrimp) fisheries, EJF endorses the establishment, by 2004, of:

- A regular process under the UN for global reporting and assessment of the state of the marine environment (as agreed at the WSSD 2002)
- An inter-agency co-ordination mechanism on ocean and coastal issues within the UN System (as proposed in the Reykjavik Declaration on Responsible Fisheries in the Marine Ecosystems 2001).

These two developments would help raise the profile of marine issues within the UN System, contributing to a reduction in unsustainable fishing practices. Greater dialogue between UN agencies and other intergovernmental, national and regional bodies concerned with shrimp fisheries management will also help to co-ordinate common goals. EJF applauds the work of the UNEP on enhancing the mutual supportiveness of MEAs and the WTO, and commends the advances the UNEP Economics and Trade Unit have made on fisheries subsidies reform.

Summary of Existing Policy Regime

United Nations Convention on the Law of the Sea and Living Marine Resources (UNCLOS)
This legally-binding Convention has been ratified by 130 nations and came into force in 1994. It is an international framework for the sustainable development of the oceans and contains explicit reference to states' obligations 1) to protect and preserve the marine environment and 2) to conserve and manage the living resources in their Exclusive Economic Zone (EEZ). However, many states have yet to fulfil these obligations[1].

The FAO Code of Conduct for Responsible Fisheries (CCRF) and International Plans of Action (IPOAs)
The FAO Code of Conduct has been signed by over 60 fishing nations and provides a framework for the sustainable management of (shrimp) fisheries[2]. However, it remains a voluntary code and many aspects have yet to be implemented. Besides the CCRF, the FAO have adopted four 'International Plans of Action' on pressing fisheries management issues; 1)Sharks, 2) Seabirds, 3) Illegal, Unregulated and Unreported Fishing and 4) Management of Fishing Capacity[3]. Agreements reached at the World Summit on Sustainable Development called for implementation of these latter 2 IPOAs by 2004 and 2005 respectively[4].

European Union
The EU's Common Fisheries Policy (CFP) is in the process of being reviewed by the European Commission, with final reforms to be negotiated by the end of 2002. Reforms centre on the over-arching objective of achieving 'responsible and sustainable fisheries and aquaculture activities that contribute to healthy marine ecosystems'[5]. Proposed reforms include the adoption of an ecosystem-based management approach, a reduction in fishing capacity, a multi-annual framework for the conservation of resources and a reduction of subsidies that maintain unsustainable fisheries. At the time of writing, it was declared that, following reforms, subsidies would only be used to support declines in fishing capacity and to improve the management and safety of fleets. One area of reform that needs further clarification is EU fisheries access agreements with developing countries; in 2002 there were few effective, legally binding proposals that addressed the sustainability of these agreements[6].

World Summit on Sustainable Development (WSSD) (Johannesburg 2002)
States agreed to maintain or restore depleted stocks by 2015 and eliminate destructive fishing practices by 2012 at the WSSD[4]. A regular process under the United Nations for global reporting and assessment of the state of the marine environment was also proposed. The outcomes of this Summit are not legally-binding.

World Trade Organisation
The reduction of fishing subsidies was first considered by WTO Committee on Trade and Environment in 1996. Following a request from several fishing nations (including New Zealand, Chile and Australia) to address this issue further, a WTO negotiating group on WTO Rules was established in 2001[7,8]. The reduction of fishing subsidies has been subject to continued negotiations in 2002, with special consideration to be given to the needs and interests of developing countries[9].

The WTO has the potential to undermine existing Multilateral Environmental Agreements (MEAs) and national policies by prioritising the enforcement of free trade regulations above conservation measures. In 2001, the relationship between WTO rules and MEAs was identified as a key area demanding international clarification[9]. Negotiations begun in 2002 will start to resolve how these agreements might become more mutually supportive. Sustainable fisheries management is an integral part of both legally-binding MEAs (such as CBD and UNCLOS), as well as voluntary agreements (such as the FAO CCRF). One major issue under debate concerns the states' rights to regulate imports according to whether they are produced in an ecologically sustainable way. Advances have already been made in relation to the use of Turtle Excluder Devices (TEDs) in shrimp fisheries. The US has demanded that all shrimp imported into the US be caught by trawlers with TEDs, in accordance with US sea turtle legislation. This action was accepted by the WTO Appellate Body in 2001, proving there is scope for WTO members to implement similar multi-lateral import bans to achieve conservation objectives, provided they do not have protectionist motives (Apellate Body WT/DS58/AB/R)[10].

ABOVE: *As a global environmental resource, the protection of the oceans is an international responsibility.*

Many organisations and intergovernmental bodies are involved both directly and indirectly in the management of shrimp fisheries. However, to date, there is no co-ordination mechanism to ensure effective collaboration and communication between these bodies.

General Management and Technical Recommendations

To ensure the future sustainability of wild-caught shrimp production, EJF recommends the following course of action:

© Kip Evans/NOAA

1. Apply a precautionary Ecosystem-Based approach to the management of shrimp fisheries.

The ecological effects of fishing are complex and fiercely debated. As such, the regulation of many fisheries is based on incomplete knowledge of target stocks and their surrounding environments. In general, conventional fisheries management is 'trapped by the notion that fishing should be allowed everywhere, all the time, until we can prove that it is having a negative impact on stocks'[1]. Yet, in the case of shrimp fisheries, the target-stock may remain productive for many years. In the meantime, marine ecosystems and fish stocks undergo the devastating impacts of this exploitation, and may take many decades to recover. Consequently, it is vital to adopt a precautionary approach to management that, in the face of unknown consequences, only accepts shrimp trawling that is guaranteed to be sustainable from an *ecosystem* point of view. An Ecosystem-Based Management (EBM) approach has gained considerable support from marine ecologists, who have long doubted the logic behind traditional fisheries management's focus on target stocks alone[2]. It has also been advocated by the FAO[3], which acknowledges that continued trawling for shrimp at current levels of intensity is inherently unsustainable. In this precautionary context, the burden of proof should be placed on those who want to maximise shrimp fishing effort. While such restrictive tactics may face political opposition, in the long term this approach will help prevent the declining yields and collapsing stocks characteristic of past management failures. EBM will require a re-assessment of current fishing laws and practices, as well as the support of both national governments and international institutions.

2. Re-evaluate the long-term economic benefits derived from shrimp fisheries

Policy makers are often swayed more by economic than environmental outcomes of resource use. Environmental economic studies on the financial returns of different types of resource use have been pivotal in influencing many governments' policies on conservation and sustainable development[4]. Similar studies on shrimp fisheries, such as that underway in the Gulf of California, may help provide hard financial justifications for a precautionary approach to management[5].

3. Improve governance over natural resources and prioritise the needs of local communities in the management of shrimp fisheries

Many people are impacted by exploitative shrimp fisheries. A large number are found in the impoverished coastal communities of the developing world. They all too often have a weak political voice and few means to protect the marine resources on which they depend for food and employment. Their views need to be actively acknowledged through their formal inclusion in decisions relating to fishery regulations and their rights and needs should be reflected in shrimp fisheries management plans. This is especially important where foreign shrimp vessels are exploiting traditional fishing areas, with little or no financial compensation directly benefiting local communities or assuring sustainable national development. More broadly, any group of people, organisation or industry that has a stake in the health of marine environments should become involved in decision-making about shrimp fisheries, as part of an integrated coastal management system and as a means to improve transparency in governance over natural resources.

ABOVE: *A Turtle Excluder Device (TED). The hole in the net is where the trap door will be placed. The metal bars push the turtle towards the trap door through which it can escape. TEDs help some species of turtles to escape from shrimp trawl nets. However not all countries demand that shrimp trawlers use TEDs. Where TED legislation does exist, it is often unenforced, particularly in developing nations.*

FIGURE 12: *Total Bycatch = Bycatch Per Unit Effort x Fishing Effort.*

To decrease total bycatch of shrimp fisheries, one or both of the following factors need to be reduced[23]:

1. Bycatch Per Unit Effort. This can be reduced by:
technological changes (e.g. installation of Turtle Excluder Devices/Bycatch Reduction Devices)
operational changes (e.g. reduction of speed and duration of trawling)
training (e.g. to avoid areas of high bycatch)
management actions (e.g. setting of bycatch limits for individual vessels)

2. 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 eco-labelling schemes)
gear changes (e.g. use of passive fishing gear)

4. Prioritise further research on shrimp trawling

One of the main weaknesses of shrimp fisheries management is the lack of ecological information on which to base decisions. Leading scientists point out that, 'it is difficult to explain why there is virtually no scientific literature on the effects of trawling for shrimp in the Gulf of Mexico, one of the world's more heavily trawled areas, nor in the US Pacific, Latin American, African or Asian waters'[6]. Priorities include:

a) Research on how entire marine ecosystems (including benthic habitats) are affected by shrimp fishing pressure as, to date, most studies have focused only on commercial fish stocks and charismatic species.

b) The establishment of compulsory, independent bycatch monitoring programmes in order to record types, levels and rates of bycatch. This would also give scientists an indication of how the diversity and biomass of bycatch might be changing. Currently, this kind of data is scarce; in much of the developing world it is non-existent[7].

c) Research into effective means to reduce the impact of shrimp fisheries, both in terms of bycatch and benthic habitat disturbance.

d) Research into potential alternative methods to fish for shrimp, for example the use of passive/static fishing gears in place of trawlers.

However, the current lack of extensive scientific information should not be an excuse for inaction. The formal research and anecdotal evidence presented in this report already begin to confirm that shrimp trawling is having profound effects on ecosystem structure and function.

5. Reduce bycatch in shrimp fisheries to sustainable levels

Bycatch is one of the most unacceptable and ecologically disruptive impacts of shrimp trawling and its reduction is a management priority. While the utilisation of bycatch has been promoted as a solution in itself, EJF advises that reduction of bycatch is more ecologically appropriate.

One way to reduce total bycatch is by reducing Bycatch Per Unit Effort (BPUE) (see Figure 12). Bycatch reduction devices (BRDs) improve the selectivity of shrimp trawlers, so vessels catch more shrimp in proportion to other organisms. As such, they should be an integral part of shrimp fishery management. Yet, research and planning is required before they are introduced. Success depends on choosing the right type for the shrimp fishery in question.

Turtle Excluder Devices (TEDs) work specifically to exclude some larger bycatch species such as turtles, sharks and rays. In several shrimp fisheries they have worked effectively to reduce sea turtle mortality, and as such, their use should be widely advocated. Nevertheless, as with BRDs, they are not faultless, and should be utilised as part of a range of management tools.

Operational changes can also play a key role in reducing bycatch. For example, by training fishermen to trawl at slower speeds and for shorter periods, the survival rate for sea turtles is likely to increase considerably[8]. Furthermore, fishermen could be encouraged to avoid areas where high bycatch levels prevail. If voluntary measures are not effective, bycatch limits could be established, placing responsibility for bycatch reduction on individual vessels. Alternatively, through incentive schemes, management authorities could reward vessels with low bycatch records by giving them licences to access better shrimping areas. All these measures should be introduced as part of compulsory bycatch assessment and reduction plans[7]. EJF recommends that shrimp fishing fleets should only be granted permission to trawl following the adoption of such a plan.

ABOVE LEFT: *A green turtle* (Chelonia mydas).
© NOAA

ABOVE: *US shrimp trawlers protesting against TED legislation. Many shrimpers are concerned that TEDs allow shrimp to escape, thus lowering their catches.*
© Commander Grady Tuell, NOAA Corps

Bycatch Reduction Devices (BRDs) and Turtle Excluder Devices (TEDs)

There are a large variety of BRD designs, but on average they exclude only about a third of non-target species[9]. Many BRDs are designed specifically to exclude commercial species of finfish, as they naturally swim against the current and out through escape devices. This is beneficial, given that fish usually make up a large proportion of bycatch and have the highest rates of mortality once caught. Nevertheless, juvenile fish may still be vulnerable, as their lesser swimming ability may prevent them from escaping[10]. Furthermore, a reduction in total bycatch is harder to achieve, especially when the catch is diverse, as in tropical shrimp fisheries. This is because many bycatch species are about the same size as shrimp (for example seahorses) and respond in unpredictable ways to fishing gear. As such, in these fisheries, 'it is probably unrealistic to expect that bycatch could be eliminated entirely'[9]. BRDs are therefore most effective when used in conjunction with other management approaches. The same applies to the use of Turtle Excluder Devices. In some cases, TEDs may not be large enough to exclude all species of turtles. (However, in response to this, larger TEDs are being developed in the US)[8]. Moreover, in heavily-trawled areas, turtles may repeatedly pass through TEDs; they can be badly injured, and may even die following their escape. With both TEDs and BRDs, there are few estimates of how many bycatch organisms actually survive the escape process and are released in an unharmed state. This research is vital for any quantification of the long-term benefits of such mechanisms[11]. Aside from these technical difficulties, there has also been strong political opposition to the use of TEDs and BRDs. Shrimp trawl operators have claimed that TEDs do not work properly and cause a loss of shrimp catch[12]. Shrimpers often ignore TED legislation, especially where enforcement is weak, such as in developing nations. Educational programmes could encourage shrimp fishermen to comply with regulations by highlighting that BRDs and TEDs may benefit shrimpers. By reducing damage to shrimp caused by heavy bycatch, cutting the time spent sorting the catch, and decreasing general wear and tear of fishing gear, the use of these devices can actually be financially advantageous[13].

6. Reduce overall fishing effort of shrimp fisheries to sustainable levels

While reducing BPUE helps to solve the issue of bycatch reduction, it fails to address the problem of seabed disturbance or the over-exploitation of shrimp stocks themselves. Shrimp fishing effort needs to be strictly controlled as part of any shrimp fishery management plan. Fishing effort in many shrimp fisheries needs to be decreased by reducing the area trawled and/or frequency of trawling (see Figure 12). Regulatory bans can be effective in achieving these reductions. For example, temporal closures, such as those during spawning periods, can help to maintain stocks. Moreover, Marine Protected Areas (MPAs) (see below) have been proposed by scientists as one of the best ways to safeguard marine ecosystems from overfishing and benthic destruction. Other regulatory approaches decrease fishing effort by reducing numbers of boats, time spent fishing, or amount of stock caught. These can work successfully: a decrease in the number of 'boat days' in Australia's Northern Prawn Fishery from over 40,000 in the early 1980s to 18,300 in 1999 reduced the total amount of bycatch and discards by around 50%. Additionally, the area trawled decreased, lowering benthic impacts[10]. Another option to reduce fishing effort is to change the gear used for catching shrimp. The Australian Institute of Marine Science (AIMS) is conducting research into feasible alternatives to trawling. A method of shrimp capture such as trapping puts less pressure on shrimp stocks and surrounding ecosystems[14a].

Many of the management measures discussed above may lead to reductions in bycatch by increasing the costs of fishing. Some social scientists, such as Porter Hoagland of the Woods Hole Oceanographic Institution, believe that an alternative 'market-based' approach could be even more effective[14b]. Under this approach, management measures would be designed to maximise the long-term *economic* yields from fisheries. 'In many cases, this could lead to reductions in fishing effort and increases in biomass levels for both the target and bycatch stocks in excess of those associated with the biological maximum sustainable yield.' This could be done by either taxing fish or fishing effort, or through the creation of marketable property rights a) in fishing areas or b) of fishing quotas.

ABOVE: *Marine Protected Areas have been widely hailed as the key to preserving oceanic biodiversity and resources[19].*

© Kip Evans/NOAA

BELOW: *In conjunction with educational programmes, MPAs can help raise public awareness of the importance of marine conservation.*

© Smailes / WildAid

7. Establish and effectively manage Marine Protected Areas

Marine Protected Areas (MPAs) have been widely hailed as the key to preserving oceanic biodiversity and resources[15] and are considered to be effective fishery management tools. Scientist Callum Roberts maintains that 'marine reserves can help to overcome a key weakness of conventional fisheries management: its failure to account for ecological complexity'[2]. MPAs have no strict definition, ranging from multiple-use areas to 'no-fishing' zones. Reserves can protect a variety of sensitive habitats from shrimp trawling. Reefs, for example, have a very high ecological value, supporting biologically diverse and productive marine communities. Many deep water and near surface reefs have been damaged by shrimp trawling, and in some cases have been destroyed entirely[16]. Areas of submerged aquatic vegetation, such as seagrass beds, are also important habitats that need protection from shrimp trawlers[17].

In addition, MPAs provide shelter for over-exploited bycatch species that cannot endure high fishing pressure. From a commercial standpoint, MPAs allow a build up of fish biomass, and spread the benefits of this stock protection to surrounding fishing grounds through 'leakage'[2]. Protected areas can also potentially be used as 'control sites', which scientists could compare with heavily-trawled zones. This would further advance our understanding of the ecological impacts of shrimp trawling. Finally, in conjunction with educational programmes, MPAs can help raise public awareness of the importance of marine conservation. EJF calls for the establishment of fully protected marine reserves in a substantial fraction of every nation's shrimping grounds.

ABOVE: *Shrimp trawlers in Madagascar, where traditional fishing zones are being exploited by French and Japanese shrimping vessels flying the Malagasy flag.*
© FAO

8. Establish stronger mechanisms for the enforcement of shrimp fisheries regulations, particularly in relation to illegal 'pirate' fishing for shrimp

While stricter legislation may be needed to control the worst impacts of shrimp fisheries, equal priority should be given to the enforcement of legislation already in existence. Even well-equipped authorities in the US have difficulties upholding shrimp fisheries legislation, such as TED use or temporal closures. Compliance in developing countries is even harder to achieve and needs international support. In particular, greater protection of artisanal fishing zones is crucial if the livelihoods of local fishers are to be maintained. Equally concerning is the scale of Illegal, Unreported and Unregulated (IUU) fishing that takes place internationally; according to the FAO this takes up to 30% of the catch in some important fisheries[18]. Illegal trawling for shrimp by foreign vessels has been reported within the Exclusive Economic Zones (EEZs) of several African nations. The International Network for the Cooperation and Coordination of Fisheries-Related Monitoring, Control and Surveillance Activities has been set up to co-ordinate nations' efforts to reduce these abusive fishing practices[19]. EJF calls for widespread international support for such initiatives to help eradicate this modern form of piracy.

More generally, governments need to implement measures in accordance with international marine agreements. Agreements, such as the Oceans Chapter (17) of Agenda 21, The UN Convention on the Law of the Sea, and the FAO Code of Conduct for Responsible Fisheries have all been signed by many fishing nations in the last 10 years. They contain guidelines on how fisheries can be managed more sustainably, yet are undermined by a lack of binding commitment. Even those fishing accords signed in Johannesburg in 2002 by 180 countries, lack any true obligations[20]. Raising international resolve to implement and enforce global fishing agreements would be a significant step towards achieving sustainability in shrimp fisheries.

9. Support trade-related instruments that improve sustainability in shrimp fisheries

Most shrimp fisheries depend upon trade for their continuation. Trade mechanisms can therefore potentially help to redress unsustainable fishing activities. International trade is being distorted by public subsidies to the fisheries sector. In total, tens of billions of dollars a year are being spent on funding fisheries; this is equivalent to around 20-25% of the value of the landed fish catch world-wide[21]. Not only can these subsidies lead to unsustainable or inequitable practices they are essentially 'trade-distorting', giving assisted fisheries an unfair competitive advantage in the global marketplace. Subsidies have led to overfishing and the dependence of fleets on government support and public money. Without such subsidies, declining yields would lead to both reduced investment in fisheries and reduced fishing pressure[21]. However, some subsidies can play a positive role, for example those that help shrimp fishermen adopt more environmentally friendly practices (such as the installation of BRDs/TEDs).

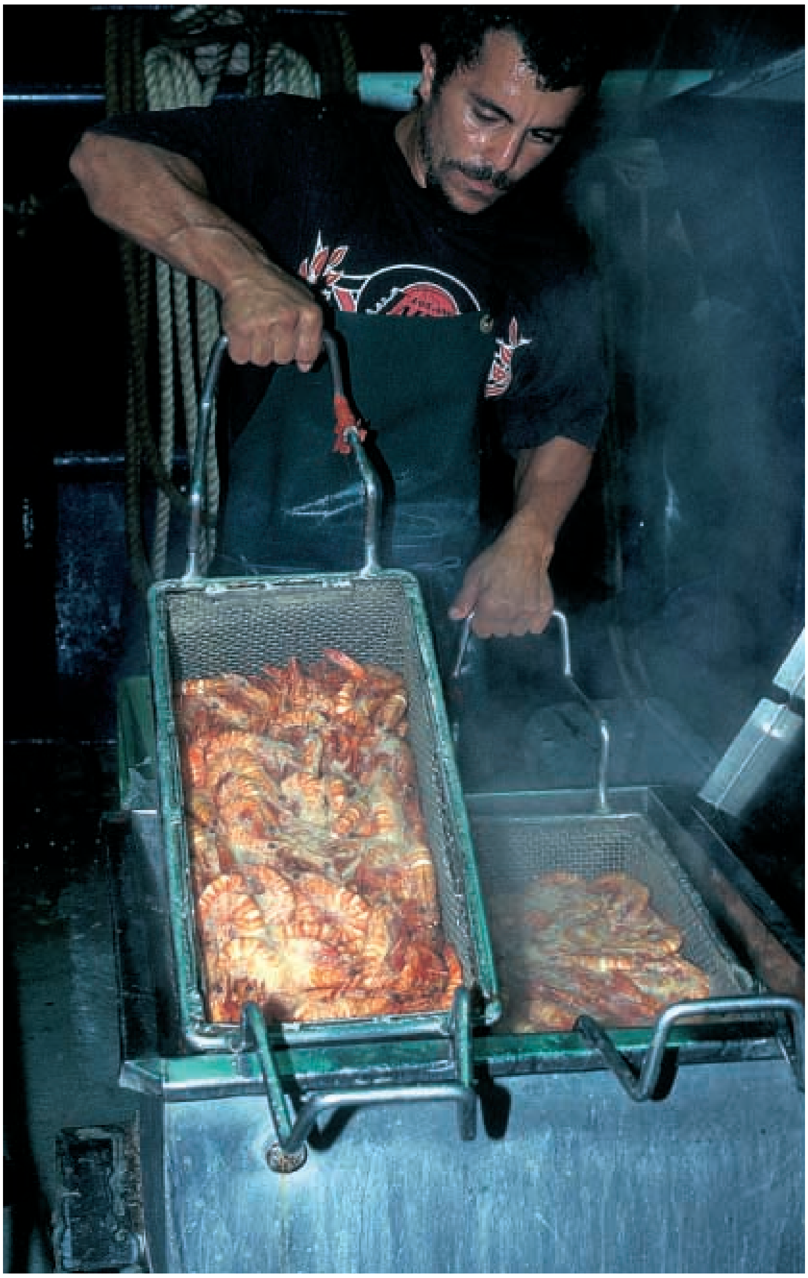
10. Raise consumer awareness and establish 'eco-labelling' schemes for shrimp products

EJF believes that educating the public and key national/international organisations about the exploitation of marine environments is essential if shrimp fisheries are to be become more sustainable. Many people still think that the oceans are inexhaustible, and that its resources will be constantly renewed regardless of how much pressure they are put under. In fact, scientists argue that overfishing poses a greater threat to ocean biodiversity than either global warming or pollution[22]. Consumers should be made to think about the ecological and social costs that were incurred to catch the shrimp they buy.

Certification is a market-driven voluntary technique that seeks to inform consumers as to the environmental sustainability of a product whilst also providing a desirable premium for sustainable producers. Successful certification demands a transparent procedure in which consumers and retailers have confidence that the product is produced responsibly. Fundamentally, there has to be sufficient economic incentive to encourage producers to adopt sustainable production methods. Certification requires an independent monitoring programme, in which observers should be given unrestricted access to shrimp fisheries. Eco-labelling will act as a starting point in raising consumer awareness about shrimp production and enabling positive consumer choice in favour of sustainability.

RIGHT: *Consumers should be made to think about the ecological and social costs that were incurred to catch the shrimp they buy.*

© Michael Aw



REFERENCES

Introduction
1 FAO 2002b. *Globefish Commodity Update: Shrimp*. Food and Agriculture Organisation of the United Nations, Rome.
2 McQuaid, J. 1997. Trawling into trouble. *The Times-Picayune.* [http://www.pulitzer.org/year/1997/public-service/works/5-1/]
3 Bauer, R. 2002. *The general biology of caridean and penaeid shrimps* [http://www.ucs.louisiana.edu/~rtb6933/shrimp/index.html]
4 De Groot, S. 1984. The impact of bottom trawling on benthic fauna of the North Sea. *Ocean Management* Vol 9 pp177-190.
5 Holmes, B. 1996. Blue revolutionaries. *Science*. 7th December 1996.
6 Carlton, J. 1998. Apostrophe to the Ocean. *Conservation Biology* Vol.12 (6) pp1165-1167.
7 New Scientist 1997. Death on the Ocean Floor. *New Scientist* 14th June, 1997.
8 Roberts, C. 1997. Ecological advice for the global fisheries crisis. *Tree*. Vol. 12 (1) pp35-38.
9 Meffe, G. 1998. *Scientists speak on bottom trawling*. American Ocean Alliance [http://www.americanoceans.org/fish/trawlpack13.htm#gary]
10 FAO 1999. *Report of the workshop of national co-ordinators of the UNEP/GEF/FAO project on reducing the impact of tropical shrimp trawling fisheries on living marine resources through the adoption of environmentally friendly techniques and practices* Fisheries report no.605, Food and Agriculture Organisation of the United Nations, Rome.
11 Clucas, I and Teutscher, F. (eds) 1999. *Report and Proceedings of the FAO/DFID Consultation on bycatch utilisation in tropical fisheries*. Beijing China, 21-28 September 1998, University of Greenwich, UK.

Shrimp fisheries
1 FAO 2000. *State of world fisheries and aquaculture*. Food and Agriculture Organisation of the United Nations, Rome.
2 FAO 2002b. *Globefish Commodity Update: Shrimp*. Food and Agriculture Organisation of the United Nations, Rome.
3 McQuaid, J. 1997. Trawling into trouble. *The Times-Picayune.* [http://www.pulitzer.org/year/1997/public-service/works/5-1/]
4 Alverson, D. *et al.* 1996. *A global assessment of fisheries bycatch and discards*. FAO Fisheries technical paper 339, Food and Agriculture Organisation of the United Nations, Rome.
5 Njock, J. 2001. National report on reducing the impacts of tropical shrimp trawling fisheries on living marine resources through the adoption of environmentally friendly techniques and practices in Cameroon. *Tropical shrimp fisheries and their impacts on living resources.* Food and Agriculture Organisation of the United Nations, Rome.
6 Ross Robertson, Smithsonian Tropical Research Institute: personal communication. 2002.
7 Clucas, I and Teutscher, F. (eds) 1999. *Report and Proceedings of the FAO/DFID Consultation on bycatch utilisation in tropical fisheries*. Beijing China, 21-28 September 1998, University of Greenwich, UK.
8 McQuaid, J. 1997. Farm-raised imports take over. *The Times-Picayune.* [http://www.pulitzer.org/year/1997/public-service/works/5-2/]
9 NORMAC 2002b. *Bycatch Action Plan 2001.* Northern Prawn Fishery Management and Advisory Committee, Australia.
10 Hall, M. *et al.* 2000. By-catch: problems and solutions. *Marine Pollution Bulletin* Vol. 41 (1-6) pp204-219.
11 Watling, L. and Norse, E. 1998b. Disturbance of the Seabed by Mobile Fishing Gear: A Comparison to Forest Clearcutting. *Conservation Biology*, Vol 12(6) pp1180-1197.
12 Blaber, S. *et al.* 2000. Effects of fishing on the structure and functioning of estuarine and nearshore ecosystems. *ICES Journal of Marine Science* 57 pp590-602.
13 Stephan, C. *et al.* 2000. *Evaluating fishing gear impacts to submerged aquatic vegetation and determining mitigation strategies*. ASMFC Habitat Management Series #5, ASMFC, Washington DC
14 WWF Australia. 2002. Scraping the bottom: Seafloor trawling in the Great Barrier Reef World Heritage Area, WWF Australia, Sydney.
15 NORMAC 2002a. *Bycatch Action Plan 2001 Background Paper*. Northern Prawn Fishery Management and Advisory Committee, Australia.
16 Broadhurst, M. 2000. Modifications to reduce bycatch in prawn trawls: A review and framework for development. *Reviews in fish biology and fisheries* Vol. 10 pp27-60.
17 Stobutzki, I. *et al.* 2001. Bycatch diversity and variation in tropical Australian penaied fishery: the implications for monitoring. *Fisheries Research* 53 pp283-301.
18 Bauer, R. 2002. *The general biology of caridean and penaeid shrimps* [http://www.ucs.louisiana.edu/~rtb6933/shrimp/index.html]
19 FAO 1999. *Report of the workshop of national co-ordinators of the UNEP/GEF/FAO project on reducing the impact of tropical shrimp trawling fisheries on living marine resources through the adoption of environmentally friendly techniques and practices* Fisheries report no.605, Food and Agriculture Organisation of the United Nations, Rome.
20 Gribble, N. 2001. A model of the ecosystem and associated penaied prawn community in the far northern Great Barrier Reef in Wolanski, E. (ed) *Oceanographic Processes of Coral Reefs: Physical and Biological Links in the Great Barrier Reef*. CRC Press, Boca Raton, Florida, USA; 356 pp.
21 Serge Garcia, Food and Agriculture Organisation of the United Nations: personal communication. 2002.
22 John Everett, Food and Agriculture Organisation of the United Nations: personal communication. 2002.
23 Rahman, M. 2001. The impact of shrimp trawling fisheries on living marine resources of Bangladesh. *Tropical shrimp fisheries and their impacts on living resources*. Food and Agriculture Organisation of the United Nations, Rome.

Bycatch
1 Serge Garcia, Food and Agriculture Organisation of the United Nations: personal communication. 2002.
2 Alverson, D. *et al.* 1996. *A global assessment of fisheries bycatch and discards*. FAO Fisheries technical paper 339, Food and Agriculture Organisation of the United Nations, Rome. [http://www.fao.org/DOCREP/003/T4890E/T4890E00.HTM]
3 Hall, M. *et al.* 2001. Chapter 116: Bycatch: Problems and solutions in Sheppard, C. (ed) *Seas at the Millennium: An Environmental Evaluation.* Elsevier Science, Ltd.
4 Marcano, L. 2001. Revision de la pesca de arrastre en Venezuela. *Tropical shrimp fisheries and their impacts on living resources.* Food and Agriculture Organisation of the United Nations, Rome.
5 Indonesian Fisheries DG. 2001. Reducing the impact of tropical shrimp trawling fisheries on living marine resources through the adoption of environmentally friendly techniques and practices in the Arafura Sea, Indonesia. *Tropical shrimp fisheries and their impacts on living resources*. Food and Agriculture Organisation of the United Nations, Rome.
6 Salini, J. *et al.* 2000. Assessment and benefits of damage reduction in prawns due to use of different bycatch reduction devices in the Gulf of Carpentaria, Australia. *Fisheries Research*, 45 pp1-8.
7 Ye, Y. *et al.* 2000. Bycatch and discards of the Kuwait shrimp fishery. *Fisheries Research*, 45 pp9-19.
8 WWF Australia. 2002. Scraping the bottom: Seafloor trawling in the Great Barrier Reef World Heritage Area, WWF Australia, Sydney.
9 Clucas, I and Teutscher, F. (eds) 1999. *Report and Proceedings of the FAO/DFID Consultation on bycatch utilisation in tropical fisheries*. Beijing China, 21-28 September 1998, University of Greenwich, UK.
10 Andrew, N.L., and J.G. Pepperell. 1992. The by-catch of shrimp trawl fisheries. In: Margaret Barnes, A.D. Ansell, and R.N. Gibson, eds. *Oceanography and Marine Biology Annual Review*. Vol. 30. UCL Press, United Kingdom. pp527-565.
11 Stobutzki, I. *et al.* 2001. Bycatch diversity and variation in tropical Australian penaeid fishery: the implications for monitoring. *Fisheries Research* 53 pp283-301.
12 Hill, B. and Wassenberg, T. 2000 The probable fate of discards from prawn trawlers fishing near coral reefs study in the northern Great Barrier Reef, Australia. *Fisheries Research* Vol. 48, no.3, pp277-286 (10).
13 Clucas, I. 1997. *A study of the options for utilisation of bycatch and discards from marine capture fisheries*. Food and Agriculture Organisation of the United Nations, Rome.
14 Stobutzki, I. *et al.* 2001. Bycatch diversity and variation in tropical Australian penaeid fishery: the implications for monitoring. *Fisheries Research* 53 pp283-301.

Ecological impacts
1 Poiner, I. *et al.* 1998. *Final Report on Effects of Trawling in the Far Northern Section of the Great Barrier Reef*. CSIRO, Division of Marine Research, Cleveland, Australia.
2 O'Riordan, B. 1994. Tangled webs of chaos adrift. *New Scientist* 20th August 1994.
3 Stobutzki, I. *et al.* 2001. Bycatch diversity and variation in tropical Australian penaied fishery: the implications for monitoring. *Fisheries Research* 53 pp283-301.
4 Stobutzki, I. *et al.* 2000. *Ecological sustainability of bycatch and biodiversity in prawn trawl fisheries*. FRDC Final report 96/257, 512 pp.
5 Serge Garcia, Food and Agriculture Organisation of the United Nations: personal communication.2002.
6 Milton, D. 2001. Assessing the susceptibility to fishing of populations of rare trawl bycatch: sea snakes caught by Australia's Northern Prawn Fishery. *Biological Conservation*. 101 pp281-290.
7 Pauly and Christensen, 1995 cited in Garcia-Caudillo, J. *et al.* 2000. Performance of a bycatch reduction device in the shrimp fishery of the Gulf of California, Mexico. *Biological Conservation* 92 pp199-205.
8 Roberts, C. 1997. Ecological advice for the global fisheries crisis. *Tree*. Vol. 12 (1) pp35-38
9a Garcia-Caudillo, J. *et al.* 2000. Performance of a bycatch reduction device in the shrimp fishery of the Gulf of California, Mexico. *Biological Conservation* 92 pp199-205.
9b Sainsbury, K. 1998. The ecological basis of multispecies fisheries and management of a demersal fishery in tropical Australia, in J. A. Gulland (ed.), *Fish population dynamics*, 2nd edition. Wiley, New York.
10 Alverson, D. *et al.* 1996. *A global assessment of fisheries bycatch and discards*. FAO Fisheries technical paper 339, Food and Agriculture Organisation of the United Nations, Rome.
11 Amanda Vincent, Project Seahorse: personal communication. 2002.
12 FAO 2001a. *Tropical shrimp fisheries and their impacts on living resources.* Food and Agriculture Organisation of the United Nations, Rome.
13 Rahman, M. 2001. The impact of shrimp trawling fisheries on living marine resources of Bangladesh. *Tropical shrimp fisheries and their impacts on living resources*. Food and Agriculture Organisation of the United Nations, Rome.
14 Broadhurst, M. 2000. Modifications to reduce bycatch in prawn trawls: A review and framework for development. *Reviews in fish biology and fisheries* Vol. 10 pp27-60.
15 McQuaid, J. 1997. Trawling into trouble. *The Times-Picayune.* [http://www.pulitzer.org/year/1997/public-service/works/5-1/]
16 Hall, M. *et al.* 2000. By-catch: problems and solutions. *Marine Pollution Bulletin* Vol. 41 (1-6) pp204-219.
17 Reed, J. 2002. *NOAA's 'Ocean Explorer'* [http://oceanexplorer.noaa.gov/explorations/02sab/background/corals/corals.html]
18 Hill, B. and Wassenberg, T. 2000 The probable fate of discards from prawn trawlers fishing near coral reefs study in the northern Great Barrier Reef, Australia. *Fisheries Research* Vol. 48, no.3, pp277-286 (10).
19 Garthe, S *et al.* 1996. Amounts of discards by commercial fisheries and their significance as food for seabirds in the North Sea. *Inter-Research Marine Ecology Progress Series*, MEPS 136:1-11.
20 Fertl, D. and Leatherwood, S. 1997. Cetacean Interactions with Trawls: A Preliminary Review. *J. Northw. Atl. Fish. Sci.*, Vol.22: 219-248.
21 Ibarra, I. 2002. Porpoise's fate hinges on enforcement. *Arizona Daily Star.* [http://www.azstarnet.com/border/21105SONORANSEAPRESERVE2fvei.html]

Impacts on seahorses
1 Project Seahorse 2002. [www.seahorse.mcgill.ca/]
2a Amanda Vincent, Project Seahorse: personal communication. 2002.
2b Egan, L. 2002. Seahorses given protection status by UN body. *World Environment News*. [www.planetark.org]
3 Lourie, S., Vincent, A. and Hall, H. 1999. *Seahorses: An identification guide to the world's species and their conservation*. Project Seahorse, Canada.
4 Heather Hall, Project Seahorse/London Zoological Society: personal communication. 2002.
5 WWF Australia. 2002. Scraping the bottom: Seafloor trawling in the Great Barrier Reef World Heritage Area, WWF Australia, Sydney.

Impacts on sea turtles
1 Marine Conservation Society. 2001. *Marine Turtle Factfile*, MCS, UK. [www.mcsuk.org/Turtles/factfile/factfile.htm]
2 MTSG. 1995. A Global Strategy for the Conservation of Marine Turtles. Prepared by the IUCN/SSC Marine Turtle Specialist Group. 24 pp.
3 Dayton, P. *et al.* 1995. Environmental Effects of Marine Fishing. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 5, pp205-32.
4 Hall, M. *et al.* 2000. By-catch: problems and solutions. *Marine Pollution Bulletin* Vol. 41 (1-6) pp204-219.
5 Marine Conservation Society. 2001. *Turtle Facts: Leatherback Turtle*, MCS, UK. [www.mcsuk.org/Turtles/factfile/leatherback.htm]
6 Poiner, I. and Harris, A. 1996. Incidental Capture, Direct Mortality and Delayed Mortality of Sea Turtles in Australia's Northern Prawn Fishery. *Marine Biology* 125: 813-825.
7 Oravetz, C. 1999. Reducing Incidental Catch in Fisheries, in Eckert, K.L., K.A. Bjorndal, F. A. Abreu-Grobois, and M. Donnelly (eds). *Research and Management Techniques for the Conservation of Sea Turtles*. IUCN/SSC Marine Turtle Specialist Group Publication No. 4.
8 Marine Conservation Society. 2001. *Turtle Facts: Kemp's ridley turtle*, MCS, UK. [www.mcsuk.org/Turtles/factfile/kempsridley.htm]
9 Crouse, D. 1999. Guest Editorial: The WTO Shrimp/Turtle Case. Marine Turtle Newsletter 83:1-3.
10 HSUS (1997) *Report of investigation into violations of Turtle Excluder Device regulations by Texas shrimp fishermen.* Humane Society of the US in co-operation with Sea Turtle Restoration Project of Earth Island Institute Washington, US.
11 Marydele Donnelly, Ocean Conservancy: personal communication. 2002.
12 US Environmental Protection Agency Federal Register. 2001. *Sea turtle conservation; shrimp trawling requirements*. EPA [http://www.epa.gov/fedrgstr/EPA-SPECIES/2001/December/Day-20/e31275.htm]
13 Kocherry, T. 2000. Indian Fisheries over the past 50 years. Part 1: The impact of mechanised fishing on coastal fisheries. *Kachhapa* 2. [http://www.kachhapa.org/newsletter/pdf/kachhapa2.pdf]
14 Patnaik, S and Kar, C. 1999. *Status and conservation of sea turtles in Orissa, India*. 2nd ASEAN Symposium and Workshop on Sea Turtle Biology and Conservation (July 15-17,1999 Kota Kinabalau, Sabah, Malaysia).
15 WPSI / Operation Kachhapa / WildAid. 2001. Video footage from Orissa, India.
16 Shanker K. 1999. It's turtle time in Orissa again. *Kachhapa* 1 January 1999.
17 Shanker, K. and Wright, B. 2000. Editorial: Operation Kachhapa: new problems, new solutions? *Kachhapa* 2. January 2000. [http://www.kachhapa.org/newsletter/pdf/kachhapa2.pdf]

Socio-economic impacts
1 Blaber, S. *et al.* 1997. *Effects of trawl design on bycatch and benthos in prawn and fisheries.* FRDC Final Report 93/179:190, Australia.
2 FAO 2001a. *Tropical shrimp fisheries and their impacts on living resources.* Food and Agriculture Organisation of the United Nations, Rome.

3a Diamond, S. *et al*. 2000. Population effects of shrimp trawl bycatch on Atlantic croaker. *Canadian Journal of Fish. Aquat. Sci*. 57 pp 2010-2021.
3b Oceanic Resource Foundation 1998. International Year of the Ocean. *Currents* (Spring Issue).
4 (Tillman, 1992 cited in Alverson, D. *et al.* 1996. *A global assessment of fisheries bycatch and discards*. FAO Fisheries technical paper 339, Food and Agriculture Organisation of the United Nations, Rome.
5 Hansen, K. 2002. *A farewell to Greenland's wildlife.* Gads Forlag, Denmark.
6 Berghahn, R. and Purps, M. 1998. Impact of discard mortality in crangon fisheries on year-class strength of North Sea flatfish species. *J Sea Res*, Vol 40 (1-2).
7 Revill, A. *et al*. 1999. *Economic consequences of discarding in the Crangon fisheries* (The ECODISC Project). Final Report, July, 1999 (EC DGXIV 97/SE/025), DML (University of Newcastle).
8 Rahman, M. 2001. The impact of shrimp trawling fisheries on living marine resources of Bangladesh. *Tropical shrimp fisheries and their impacts on living resources*. Food and Agriculture Organisation of the United Nations, Rome.
9 O'Dickson, J. 2001. Shrimp trawl fisheries in the Philippines. *Tropical shrimp fisheries and their impacts on living resources.* Food and Agriculture Organisation of the United Nations, Rome.
10 Marcano, L. 2001. Revision de la pesca de arrastre en Venezuela. *Tropical shrimp fisheries and their impacts on living resources.* Food and Agriculture Organisation of the United Nations, Rome.
11 Njock, J. 2001. National report on reducing the impacts of tropical shrimp trawling fisheries on living marine resources through the adoption of environmentally friendly techniques and practices in Cameroon. *Tropical shrimp fisheries and their impacts on living resources.* Food and Agriculture Organisation of the United Nations, Rome.
12 Kaiser, M. 2000. Fishing-gear restrictions and conservation of benthic habitat complexity. *Conservation Biology* Vol 14 (5) pp1512 — 1525.
13 Ogbonna, J. 2001. Reducing the impact of tropical shrimp trawling fisheries on the living marine resources through the adoption of environmentally friendly techniques and practices in Nigeria. *Tropical shrimp fisheries and their impacts on living resources*. Food and Agriculture Organisation of the United Nations, Rome.
14 Ceaser, M. 2002. *Venezuela's embattled small fishermen*. BBC news 17th June 2002 [http://news.bbc.co.uk/1/hi/sci/tech/2032009.stm]

Bycatch utilisation
1 Hall, M. *et al*. 2000. By-catch: problems and solutions. *Marine Pollution Bulletin* Vol. 41 (1-6) pp204-219.
2 Clucas, I. 1997. *A study of the options for utilisation of bycatch and discards from marine capture fisheries*. Food and Agriculture Organisation of the United Nations, Rome.
3 Serge Garcia, Food and Agriculture Organisation of the United Nations: personal communication. 2002.
4 Clucas, I and Teutscher, F. (eds) 1999. *Report and Proceedings of the FAO/DFID Consultation on bycatch utilisation in tropical fisheries*. Beijing China, 21-28 September 1998, University of Greenwich, UK.
5 EJF. 2002. *Smash & Grab: Conflict, Corruption and Human Rights Abuses in the Shrimp Farming Industry.* Environmental Justice Foundation, London, UK.
6 Naylor, R. *et al*. 2000. Effect of aquaculture on world fish supplies. Nature. Vol. 405, 29 June 2000.

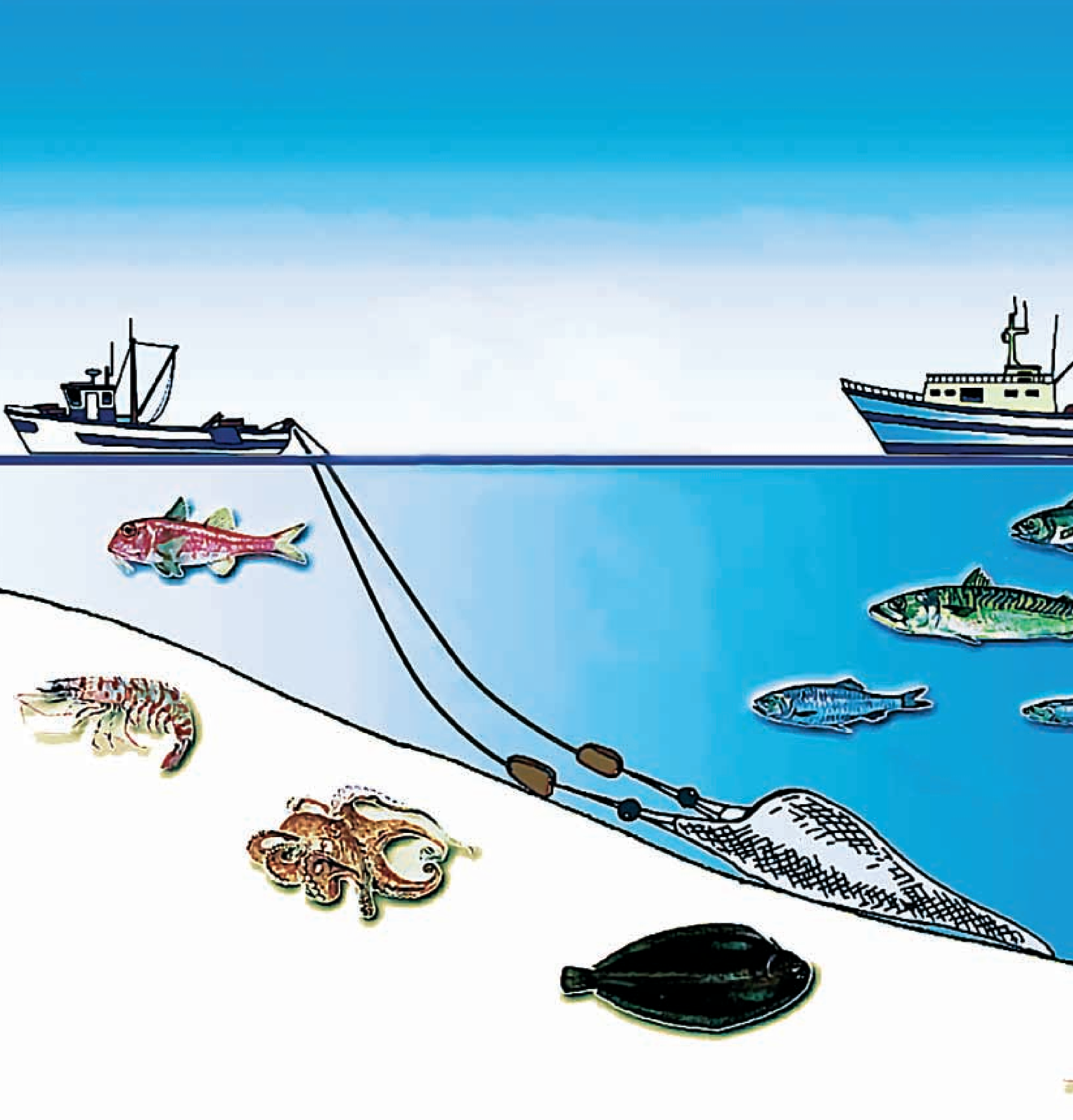
Foreign-owned shrimp trawling fleets
1 FAO 2002a. *Fighting the fish pirates*. Food and Agriculture Organisation of the United Nations, Rome. [http://www.fao.org/english/newsroom/news/2002/3500-en.html]
2 Kulmiye, A. 2001. Militia vs. Trawlers: Who is the Villain? *The East African* (Monday 9th July 2001) [http://www.nationaudio.com/News/EastAfrican/16072001/Features/Features.html]
3 FAO 2001b. *The State of Food Insecurity in the World.* Food and Agriculture Organisation of the United Nations, Rome.
4 Megapesca. 2000. Illegal fishing in West Africa [http://www.megapesca.com/aerial_survey_wafrica.htm]
5 Earth Report (TVE) 2002. *A fish too far*. 29 August 2002, Television Trust for the Environment [http://www.tve.org/earthreport/archive/doc.cfm?aid=799]
6 Pearce, F. 2002. Heading into troubled waters. *The Independent,* 31 August, 2002.
7 UNEP 2001. *Economic Reforms, Trade Liberalization and the Environment* [www.unep.ch/etu/doha/pdfs/papers/synthesisround2.pdf]
8 WWF 1999. *Underwriting Overfishing.* Issue Summary No.1 9/99, WWF Endangered Sea Campaign, Washington DC.
9 Randrianasoavina, F. 2001. Distant Voices. *Lines.* No 5. 13 October 2001.
10 Tollervey, A. 2002. Can the tide turn for African fisheries? *Developments: The International Development Magazine.* [http://www.developments.org.uk/data/issue18/dev-fisheries.htm]
11 Intrafish. 2002a. 'France urged to broker EU-Morocco deal'. [http://www.intrafish.com/]
12 European Commission. 2002a. *Commission welcomes renewal of EU/Senegal fisheries protocol* [http://europa.eu.int/comm/fisheries/news_corner/press/inf02_16_en.htm]
13 De Vries, H. 1996. *The Fight for Fish: Towards Fair Fisheries Agreement*. Eurostep, [http://www.oneworld.org/eurostep/fishppa2.htm]
14 IRIN. 2002. Angola: WWF concerned about EU fisheries deal. *IRINnews.org* [http://www.irinnews.org/print.asp?ReportID=30353]

Impacts on benthic environments
1 Rahman, M. 2001. The impact of shrimp trawling fisheries on living marine resources of Bangladesh. *Tropical shrimp fisheries and their impacts on living resources*. Food and Agriculture Organisation of the United Nations, Rome.
2 Stephan, C. *et al*. 2000. *Evaluating fishing gear impacts to submerged aquatic vegetation and determining mitigation strategies*. ASMFC Habitat Management Series #5, ASMFC, Washington DC
3 Poiner, I. *et al*. 1998. *Final Report on Effects of Trawling in the Far Northern Section of the Great Barrier Reef*. CSIRO, Division of Marine Research, Cleveland, Australia.
4 Pitcher, C. 1997. Status of inter-reefal benthos in the GBR World Heritage area. In: Wachenfeld *et al*. (eds) *State of the Great Barrier Reef World Heritage Area Workshop Proceedings*, Townsville, Queensland, Australia.
5 WWF Australia. 2002. Scraping the bottom: Seafloor trawling in the Great Barrier Reef World Heritage Area, WWF Australia, Sydney.
6 Jennings, S. and Kaiser, M. 1998. The effects of fishing on marine ecosystems. *Advances in Marine Biology*, 34: 201-352.
7 Watling, L. and Norse, E. 1998b. Disturbance of the Seabed by Mobile Fishing Gear: A Comparison to Forest Clearcutting. *Conservation Biology*, Vol 12(6) pp1180-1197.
8 Drew and Larsen 1994 cited in Stephan, C. *et al*. 2000. *Evaluating fishing gear impacts to submerged aquatic vegetation and determining mitigation strategies*. ASMFC Habitat Management Series #5, ASMFC, Washington DC.
9 Auster, P. 1998. *Scientists speak on bottom trawling*. American Ocean Alliance [http://www.americanoceans.org/fish/trawlpack13.htm#gary]
10 Roberts, C. and Hawkins, J. 1999. Extinction risk in the sea. *Tree*. Vol. 14(6) pp241-246
11 Talbot, F. 2001. Will the Great Barrier Reef Survive Human Impact? in Wolanski, E. (ed) *Oceanographic Processes of Coral Reefs: Physical and Biological Links in the Great Barrier Reef*, p331-48, CRC Press.
12a Elliott Norse, Marine Conservation Biology Institute: personal communication. 2002.
12b FAO 1999. *Report of the workshop of national co-ordinators of the UNEP/GEF/FAO project on reducing the impact of tropical shrimp trawling fisheries on living marine resources through the adoption of environmentally friendly techniques and practices* Fisheries report no.605, Food and Agriculture Organisation of the United Nations, Rome.
13 Roberts, C. 1997. Ecological advice for the global fisheries crisis. *Tree*. Vol. 12 (1) pp35-38
14 Indonesian Fisheries DG. 2001. Reducing the impact of tropical shrimp trawling fisheries on living marine resources through the adoption of environmentally friendly techniques and practices in the Arafura Sea, Indonesia. *Tropical shrimp fisheries and their impacts on living resources*. Food and Agriculture Organisation of the United Nations, Rome.
15 Dayton, P. *et al*. 1995. Environmental Effects of Marine Fishing. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 5, pp205-32.
16 Kaiser, M. 2000. Fishing-gear restrictions and conservation of benthic habitat complexity. *Conservation Biology* Vol 14 (5) pp1512 – 1525.
17 National Research Council (USA) (2002) *Effects of trawling and dredging on seafloor habitat*, Prepublication draft, National Academy Press, Washington D.C.
18 Hansen, K. 2002. *A farewell to Greenland's wildlife.* Gads Forlag, Denmark.
19 Meyer, D. *et al*. 1999. Effects of live-bait shrimp trawling on seagrass beds and fish bycatch in Tampa Bay, Florida. *Fish Bulletin* Vol. 97(1) pp193-199.
20 Hall-Spencer, J. 2002. Our very own coral reef crisis. *Marine Conservation*. September, 2002. The Marine Conservation Society.
21 Donofrio, J. 2002. American Oceans Campaign Press Release: *National Academy of Sciences releases report on trawling impacts; environmental and fishing groups join in support of Ocean Habitat Protection Act*. American Oceans Campaign [www.americanoceans.org/issues/presses21.htm]
22 Reed, J. 2002. *NOAA's 'Ocean Explorer'* [http://oceanexplorer.noaa.gov/explorations/02sab/background/corals/corals.html]
23 Watling, L. 2002. *Deep Sea Corals* [http://oceanexplorer.noaa.gov/explorations/deepeast01/background/corals/corals.html]
24 JNCC. 2001. *Habitat Action Plan: Sabellaria spinulosa reefs*. Joint Nature Conservation Committee. [http://www.ukbap.org.uk/asp/UKPlans.asp?UKListID=38]
25 Ceaser, M. 2002. *Venezuela's embattled small fishermen*. BBC news 17th June 2002 [http://news.bbc.co.uk/1/hi/sci/tech/2032009.stm]
26 Mark Fonseca, National Oceanic & Atmospheric Administration: personal communication. 2002.

Conclusion
1 FAO 2000. *State of world fisheries and aquaculture*. Food and Agriculture Organisation of the United Nations, Rome.
2 Watling, L. and Norse, E. 1998b. Disturbance of the Seabed by Mobile Fishing Gear: A Comparison to Forest Clearcutting. *Conservation Biology*, Vol 12(6) pp1180-1197.
3 McQuaid, J. 1997. Leadership can save our fisheries. *The Times-Picayune* [http://www.pulitzer.org/year/1997/public-service/works/8-4/]
4 Natural Resources Institute. 2001. *Fisheries*. [http://www.nri.org/work/fisheries.htm]
5 Clark, J. 1998. *Coastal Seas: The conservation challenge.* Blackwell Science, Oxford.

International Policy Recommendations
1 UNCLOS. 2001. [http://www.oceanlaw.net/texts/losc.htm] United Nations Convention on the Law of the Sea]
2 FAO. 2002. Code of Conduct for Responsible Fisheries. [http://www.fao.org/fi/agreem/codecond/ficonde.asp]
3 FAO.2002. International Plans of Action. [http://www.fao.org/fi/ipa/ipae.asp]
4 World Summit on Sustainable Development. 2002. Plan of Implementation. [http://www.johannesburgsummit.org/html/documents/summit_docs/2309_planfinal.pdf]
5 European Commission. 2002. Reforming the Common Fisheries Policy [http://europa.eu.int/comm/fisheries/reform/index_en.htm]
6 WWF. 2002. CFP Reform: WWF Briefing and analysis on the first package of proposals. [www.panda.org]
7 Bridges Weekly Trade News Digest. 2002. Rules Negotiations 'Friends of Fish' Call for Altering Subsidies Disciplines. Bridges Weekly Trade News Digest. 7 May 2002.
8 UNEP. 2002. Fisheries subsidies and trade liberalization. UNEP Briefs on Economics, Trade and Sustainable Development, United Nations Environment Programme.
9 WTO. 2002. The Doha Declaration explained. [http://www.wto.org/wto/english/tratop_e/dda_e/dohaexplained_e.htm]
10 World Trade Organisation Apellate Body WT/DS58/AB/R.

General Management and Technical Recommendations
1 Ballantine, W. 1995. The New Zealand experience with 'no-take' marine reserves, in Roberts, C. *et al* (eds) *Review of the use of marine fishery reserves in the U.S. Southeastern Atlantic,* NOAA Technical Memorandum NMFS-SEFSC-376.
2 Roberts, C. 1997. Ecological advice for the global fisheries crisis. *Tree*. Vol. 12 (1) pp35-38.
3 FAO 2000. *State of world fisheries and aquaculture*. Food and Agriculture Organisation of the United Nations, Rome.
4 Hodgson G. and Dixon, J. 2000. El Nido Revisited: Ecotourism, Logging and Fisheries in Cesar, H. (ed.) *Collected Essays on the Economics of Coral Reefs*. CORDIO, Kalmar University, Kalmar, Sweden.
5 Conservation International. 2002. Policy and Economics. [http://www.conservation.org/xp/CIWEB/programs/policy_economics/policy_economics.xml]
6 Watling, L. and Norse, E. 1998b. Disturbance of the Seabed by Mobile Fishing Gear: A Comparison to Forest Clearcutting. *Conservation Biology*, Vol 12(6) pp1180-1197.
7 Dobrzynski, T. 2002. *Oceans at risk: Wasted catch and the destruction of ocean life*. Oceana, Washington.
8 Marydele Donnelly, Ocean Conservancy: personal communication. 2002.
9 Stobutzki, I. *et al*. 2001. Bycatch diversity and variation in tropical Australian penaeid fishery: the implications for monitoring. *Fisheries Research* 53 pp283-301.
10 NORMAC 2002b. *Bycatch Action Plan 2001*. Northern Prawn Fishery Management and Advisory Committee, Australia.
11 Broadhurst, M. 2000. Modifications to reduce bycatch in prawn trawls: A review and framework for development. *Reviews in fish biology and fisheries* Vol. 10 pp27-60.
12 McQuaid, J. 1997a. Shrimpers, regulators often at loggerheads. *The Times-Picayune* [http://www.pulitzer.org/year/1997/public-service/works/5-1/]
13 Salini, J. *et al*. 2000. Assessment and benefits of damage reduction in prawns due to use of different bycatch reduction devices in the Gulf of Carpentaria, Australia. *Fisheries Research*, 45 pp1-8.
14a The Wilderness Society. 2000. *Reef Breakthrough – Research into Alternatives to Trawling* [http://www.wilderness.org.au/member/tws/projects/Reef/traprsrch.html]
14b Porter Hoagland, Woods Hole Oceanographic Institution: personal communication. 2002.
15 WCPA. 2002. *Key Issues - Marine Protected Areas*. World Commission on Protected Areas. [http://wcpa.iucn.org/biome/marine/marine.html]
16 JNCC. 2001. *Habitat Action Plan: Sabellaria spinulosa reefs*. Joint Nature Conservation Committee. [http://www.ukbap.org.uk/asp/UKPlans.asp?UKListID=38]
17 Stephan, C. *et al*. 2000. *Evaluating fishing gear impacts to submerged aquatic vegetation and determining mitigation strategies*. ASMFC Habitat Management Series #5, ASMFC, Washington DC
18 FAO 2002a. *Fighting the fish pirates*. Food and Agriculture Organisation of the United Nations, Rome. [http://www.fao.org/english/newsroom/news/2002/3500-en.html]
19 International Network for the Cooperation and Coordination of Fisheries-Related Monitoring, Control and Surveillance Activities. 2002. [http://swr.ucsd.edu/enf/mcs/mcs.htm]
20 Pearce, F. 2002. Heading into troubled waters. *The Independent*. Saturday, 31st August 2002.
21 WWF 1999. *Underwriting Overfishing.* Issue Summary No.1 9/99, WWF Endangered Sea Campaign, Washington DC.
22 Safina, C. 1999. *Song for a blue ocean*. Henry Holt and co. US.
23 Hall, M. *et al*. 2000. By-catch: problems and solutions. *Marine Pollution Bulletin* Vol. 41 (1-6) pp204-219.
24 Earle, S. in Martin, G. 2002. Fishing Out The World's Oceans: Marine scientists worry that little is being done to stop global crisis. .*San Francisco Chronicle* Monday, April 15, 2002.



Environmental
Justice
Foundation
Charitable
Trust
Registered charity no. 1088 128

5 St Peter's St, London N1 8JD, UK
tel: 44 (0) 20 7359 0440
fax: 44 (0) 20 7359 7123
info@ejfoundation.org
www.ejfoundation.org