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An overview of the impact of the tsunami on selected coastal fisheries resources in Sri Lanka and Indonesia

Funded by the people of
the Lao People's Democratic Republic

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AN OVERVIEW OF THE IMPACT OF THE TSUNAMI ON SELECTED COASTAL FISHERIES RESOURCES IN SRI LANKA AND INDONESIA

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
REGIONAL OFFICE FOR ASIA AND THE PACIFIC
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FOREWORD

The earthquake and tsunami of 26 December 2004 killed more than 300 000 people and devastated the livelihoods of many more. Fisheries and aquaculture were the sectors most severely hit by the disaster; many boats, fishing gear, ponds and support installations were destroyed or damaged.

Immediately after the tsunami, national and regional initiatives clearly identified an urgent need for comprehensive impact and needs assessment, prior to the planning and implementation of programmes aimed at rehabilitation of fisheries and aquaculture. Of particular importance to planning in the fisheries sector and the concept of “building back better” was how natural resources were impacted by the tsunami. Of particular concern was the possibility that during the relief stages fishing overcapacity might be created (through the provision of too many boats) with potential to negatively impact future fishery resources and the livelihoods of vulnerable communities.

The project “A rapid assessment of the status of the fisheries in tsunami affected areas of Indonesia and Sri Lanka (OSRO/RAS/504/LAO)”[1] aimed to provide technical advice to enhance knowledge of the impact of the tsunami on a limited number of affected inshore fisheries habitats and marine resources, and make this more accessible to policy decision-makers and for medium- to long-term sectoral planning in Indonesia and Sri Lanka.

This publication is the final report of that project and provides an interesting account of the status and trends in the fisheries resources of Sri Lanka and Nanggroe Aceh Darussalam Province (Indonesia) prior to and immediately after the tsunami. The main findings of the report indicate that overall, the impact of the tsunami on fisheries was more related to ongoing and new tsunami-related “human” factors, than the direct physical or biological effects of the disaster on resources and ecosystems. This report highlights the need for continued support to medium- to long-term initiatives for post-tsunami fisheries sector management to ensure sustainable use of resources through the involvement of affected communities.

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[1] Implemented with funding support through donations from the Laotian people, diplomatic corps, international organizations, entrepreneurs, traders, residential expatriates, local provincial authorities and donors from different sectors in Lao People’s Democratic Republic (Lao PDR).

CONTENTS

ABBREVIATIONS AND ACRONYMS

ADB	Asian Development Bank
APFIC	Asia Pacific Fishery Commission
BAPPENAS	National Development Planning Agency (Indonesia)
BOBP-IGO	Bay of Bengal Programme — intergovernmental organization
BRR	Rehabilitation and Reconstruction NAD-Nias Executing Agency
CCC	Coral Cay Conservation
CHARM	Community Hazard and Risk Management Program
CMFRI	Cochin Marine Fisheries Research Institute (India)
CMLRE	Centre for Marine Living Resources and Ecology, Annamalai University, Kochi (India)
CONSRN	Consortium to Restore Shattered Livelihoods in Tsunami-Devastated Nations (includes APFIC, BOBP-IGO, FAO, NACA, SEAFDEC and the WorldFish Center)
CORDIO	Coral Reef Degradation in the Indian Ocean
DKP	Dinas Kelautan Dan Perikanan (Provincial Fisheries Departments, Indonesia)
DMCR	Department of Marine and Coastal Resources (Thailand)
DOD	Department of Ocean Development (Integrated Coastal and Marine Area Management Project Directorate, Chennai, India)
FAO	Food and Agriculture Organization of the United Nations
FRP	Fibreglass re-informed plastic
GCRM	Global Coral Reef Monitoring Network
GDP	Gross Domestic Product
GNP	Gross National Product
ICSF	International Collective in Support of Fishworkers
IDP	Internally Displaced Persons
IGO	Intergovernmental Organization
IMR	Institute of Marine Research (Norway)
IUCN	The World Conservation Union
IWMI	International Water Management Institute (Sri Lanka)
JBIC	Japan Bank for International Cooperation
LIPI	Indonesian Institute of Science (Indonesia)
LIT	Line intercept transects
MENR	Ministry of Environment and Natural Resources (Sri Lanka)
MMAF	Ministry of Marine Affairs and Fisheries (Indonesia)
MOAC	Ministry of Agriculture and Cooperatives (Thailand)
MONRE	Ministry of Natural Resources and Environment (Thailand)
MSY	Maximum sustainable yield (tonnes/year)
NACA	Network of Aquaculture Centres in Asia-Pacific
NAD	Nanggroe Aceh Darussalam Province (Indonesia)
NARA	National Aquatic Resource Research and Development Agency (Sri Lanka)
NARESA	Natural Resources Energy and Science Authority (Sri Lanka)
NGO	Non-Governmental Organization

NIO-RC	National Institute of Oceanography (Kochi, India)
NORAMB	Royal Norwegian Embassy (in Colombo)
NRSA	National Remote Sensing Agency (Hyderabad, India)
OCHA	Office for the Coordination of Humanitarian Affairs (United Nations)
PRA	Participatory Rural Appraisal
RCO	Research Centre for Oceanography (LIPI, Indonesia)
ROI	Republic of Indonesia
RRG	Ramsar Reference Group
RRL	Regional Research Laboratory, Trivandrum (India)
SEAFDEC	Southeast Asian Fisheries Development Centre
SLSAC	Sri Lanka Sub Aqua Club (Sri Lanka)
SST	Sea surface temperatures
USAID	United States Agency for International Development
USGS	United States Geological Survey
WB	World Bank
WCS-IP	Wildlife Conservation Society Indonesian Programme
Kabupaten	District Government (Indonesia)
Kawasan Wisata	Government Marine Tourism Reserve (Indonesia)
Panglima Laut	"The leader in the fisherman community", has existed in the coastal areas of Aceh since the fourth century. A customary law that regulates fisheries and marine activities; it is presided over by an elected leader from the fishing community.

EXECUTIVE SUMMARY

The Asian 2004 tsunami was probably the worst natural disaster in human memory because of the numbers of people affected, its extent and complexity. Much has been written about its impact on human life, communities and livelihoods as the countries affected and the international community grapple with the enormous task of rebuilding. In this context, the fisheries sector has featured prominently as one of the sectors most affected by the disaster; most effort has focused on the human toll and losses in fishing capacity. This study was funded by contributions from the Laotian people, diplomatic corps, international organizations, entrepreneurs, traders, residential expatriates, local provincial authorities and donors from different sectors of Lao People's Democratic Republic (Lao PDR), as part of their tsunami assistance to the region. It focuses on the issue of whether fisheries resources were affected by the tsunami. The answer to this question is fundamental to efforts to recover fisheries livelihoods in the region.

Over 100 studies were assessed, including a range of anecdotal reports, rapid assessments and quantitative surveys and carried out participatory rural appraisals with fisherfolk in Indonesia and Sri Lanka, the two most impacted countries. Where available fisheries data was also examined. Assessment of impacts was made on fished resources as well as on the ecosystems that support them and how humans have responded in terms of fishing effort.

The available evidence shows that overall, impacts of the tsunami on fisheries are more related to ongoing and new tsunami-related "human" factors, rather than the physical or biological effects of the disaster on resources and ecosystems. That is, existing overexploitation trends had already brought many of the fisheries under severe stress before the tsunami. Evidence from participatory rural appraisals of fishing communities suggests that when the tsunami struck, some of these resources may have been driven down further. Greater impacts on livelihoods are now becoming apparent, with oversupply of boats and gear in some locations, increasing fuel prices and lower fish prices, added to pre-existing issues concerning illegal fishing methods and fishing by foreign vessels.

Some localized biological impacts were reported in Indonesia and Sri Lanka and in other tsunami-affected countries. Where fished resources and supporting ecosystems were in poor condition, almost all researchers concluded that the effects were part of pre-tsunami trends. This included direct damage to resources, plus decreased resilience to the tsunami resulting from chronic degradation and misuse of resources. Rehabilitation of fisheries therefore needs to focus not on the effects of the tsunami, but on addressing pre-existing trends in resource use and environmental damage, including building resilience against future shocks.

The main recommendations of this study are that:

1. Attempts at recovering fisheries resources should focus on management and issues that were present before the tsunami, including resource depletion and ecosystem degradation.
2. Attempts to restore resources and ecosystems should go a step further and ensure that building resilience against future disasters is included in all strategies.
3. In their present condition, fisheries in Aceh and Sri Lanka are not generally prepared to promote economic recovery. Governments should consider alternatives to fisheries for rebuilding livelihoods and their economies.
4. Recovery of fisheries will also need to address the new "human factors" that have arisen since the tsunami. These include problems of increased capacity, rising fuel prices, declining fish prices, problems with transportation, changes in fishing grounds, financing, illegal fishing and conflicts with other rehabilitation programmes.

5. There is an urgent need to address the pre-existing problems of weak institutions and enforcement in fisheries that have been exacerbated by the new problems arising post-tsunami. This will require increased capacity among institutions, including new skills to address conflicts among fisherfolk and industry, ensuring equitable and effective assistance to communities and innovative diversification of livelihoods.
6. Replacement of boats and gear in affected communities needs better scrutiny and management. Problems of oversupply, inappropriate beneficiaries, replacing traditional boats with larger, motorized vessels and poor vessel quality urgently need addressing.
7. The relationship between decreased or increased fishing effort after the tsunami and resulting changes in catch and catch/boat present an opportunity for further investigations on numbers of vessels for optimal yields.
8. The direct impacts on fisheries resources reported by fisherfolk (for example anchovies/lobster in Sri Lanka) merit further study.
9. Mechanisms for rebuilding fisheries livelihoods should remain flexible and able to adapt to lessons learned through regular monitoring of outcomes. This should include improved fisheries data management mechanisms and improved capacity in analysis.

1. INTRODUCTION

The 26 December 2004 Asian earthquake and tsunami is considered by many to be the worst natural disaster to occur in living memory. The sheer scale and complexity of damage to the countries of the Indian Ocean is without precedent. Estimates of the number of people killed or still missing range between 250 000 to almost 300 000, with more than 1 million people displaced and damage to infrastructure running into billions of dollars. It is estimated that a further 250 000 people in the region could be driven below the poverty line through loss of livelihoods in fisheries, tourism, trade, agriculture and artisanal or cottage industries (UNEP 2005), see also (ADB *et al.* 2005; FAO and MOAC 2005).

Concerns were quickly raised on the potential for damage to natural resources and ecosystems. Scientists, governments and non-government organizations (IGOs and NGOs) were concerned about the impact of the tsunami on ecosystem goods and services because of their crucial role in providing food and livelihoods for millions of people (UNEP and WCMC 2006; Wilkinson *et al.* 2006). These concerns focused mostly on damage to fisheries resources, aquaculture, forests (including mangroves) and coral reefs.

Indonesia and Sri Lanka had the greatest number of people affected by the disaster (Narayan *et al.* 2005; Pomeroy *et al.* 2005). Aceh Province was near the earthquake epicentre, with Simeulue Island within just a few kilometres and Sabang about 270 kilometres away. Although Sri Lanka was more than 2 100 kilometres distant it lay in direct line-of-sight with the epicentre and the energy of the tsunami was sufficient to cause major damage.

In Indonesia, damage was sustained as a result of the causative and subsequent earthquakes, and the tsunami itself. During the tsunami, waves accumulated water on land up to 30 m in depth. Between 170 000 and 220 000 people were killed, with the greatest damage recorded in the areas of Meulaboh, Banda Aceh, Aceh Besar and Aceh Jaya (Wilkinson *et al.* 2006). The total losses associated with fisheries including harbours, Ministry of Marine Affairs and Fisheries (MMAF) assets, aquaculture, boats, gear and production were estimated at approximately 4 752 billion rupiah,[2] of which 80 percent was attributed to losses in fishing production (BAPPENAS and International Donor Agency 2005).

In Sri Lanka over 31 000 people were killed, approximately 15 000 were injured (UNEP 2005) and 99 000 houses were destroyed (ADB *et al.* 2005). The districts most affected were those on the eastern and southern sides, although impacts extended around most of the coast with waves encircling the country. The estimated losses to fisheries were around US$297 million, including losses to assets and outputs (ADB *et al.* 2005).

In its Regional Strategic Framework for the rehabilitation of fisheries and aquaculture in tsunami-affected countries in Asia, the Consortium to Restore Shattered Livelihoods in Tsunami-Devastated Nations (CONSRN 2005d) focuses on “getting rehabilitation and development right” to avoid past mistakes and make a substantial improvement over the pre-tsunami situation in each country. The 2005 Rome Declaration on Fisheries and the Tsunami expressed concern over the risk of negative impacts from rehabilitation efforts if not appropriately designed and duly coordinated (FAO 2005). One of the greatest of these anticipated risks concerns the over-restoration of fishing capacity. The meeting also recognized that environmental degradation of critical habitats caused by the tsunami in affected coastal areas, such as coral reefs and mangroves, may continue to affect the productivity of inshore fishing grounds and the potential for aquaculture rehabilitation for some time.

The Blue Plan for rehabilitation and reconstruction in Aceh and Nias (ROI 2005) calls for the restoration and enhancement of fishing activities, largely in a bid to reactivate the local economy. At the same time,

[2] US$1 = 9 090 Rupiah (October 2007).

the plan calls for the restoration of "environmental supporting capacity" including the rehabilitation of coral reefs, mangroves and coastal vegetation (to form a protective green belt) and monitoring of environmental risks. At the sector level, the Ministry of Marine Affairs and Fisheries (MMAF) acknowledged that "there needs to be a strong attempt not to recreate poverty and unsustainable activities" in fisheries (MMAF 2005). In Sri Lanka, the strategy produced by the Ministry of Fisheries and Aquatic Resources (MFAR) recognizes an "opportunity for effecting necessary urgent improvements to create conditions for sustainable management and development of Sri Lanka's fisheries" and to improve the living conditions of fisherfolk (MFAR 2005).

The fisheries rehabilitation activities in Indonesia and Sri Lanka are focused on the restoration of fisheries capacity, which targets boats and to a lesser extent infrastructure and gear. Currently, there is a weak linkage between national and sectoral tsunami recovery policies, with national policies being slow to specifically acknowledge that resources may have been overexploited before the tsunami, or that they may have been damaged by it. This study reviews the available information for Indonesia and Sri Lanka, and other tsunami-affected countries, to determine whether and to what extent fished resources were affected by the tsunami. The extent to which ecosystems that support fisheries (such as coral reefs, mangroves, lagoons and coastal waters) may have been damaged and examine changes in fishing capacity is also reviewed. All of these factors may be concurrently and interactively influencing the status of fisheries resources in affected areas and thereby the basis of recovery of livelihoods and economies. Answering these questions is central to the formation of recovery policies because it identifies whether there are likely to be new drivers affecting resources under post-tsunami conditions.

2. APPROACH

Four different types of information were reviewed for this report. They were obtained from in-country sources, national and intergovernmental agencies operating in tsunami-affected areas and through interviews and meetings carried out as part of this work. The types of information are associated with varying levels of uncertainty, but were together taken to triangulate an overall assessment of whether fisheries resources have been significantly affected by the tsunami. It is important to note that although this study is focused primarily on the effects of the tsunami on fisheries resources in Indonesia and Sri Lanka, the authors felt obliged to review reports from other impacted countries to cover all relevant aspects. These were used to fill information gaps. The four sources of information were:

1. Rapid assessments undertaken soon after the disaster and over the past year, usually based on qualitative assessments;
2. Research cruises and surveys undertaken to collect quantitative data;
3. National data and statistics; and
4. Fisherfolk/community perceptions of changes in fished resources collected through participatory rural appraisals/interviews with fisherfolk, groups and key informants in Aceh and Sri Lanka.

3. STATUS OF FISHERIES RESOURCES AND ECOSYSTEMS

It is generally accepted that coastal fisheries resources in the tsunami-affected countries were severely depleted even before the tsunami struck in 2004 (CONSRN 2005c; Sugiyama *et al.* 2004; WorldFish 2005). Although data are patchy, it has been estimated that resources may have been fished down to somewhere between 5 and 30 percent of their unexploited levels (Silvestre *et al.* 2003). The main reasons identified for these conditions have included direct effects from serious overcapacity and overfishing (WorldFish 2005) as well as indirect effects arising from losses or damage to the ecosystems that support fisheries (UNEP 2005). Human activities have led to removal of mangroves, siltation and pollution and the degradation of coastal habitats, making them less productive (Silvestre *et al.* 2003; UNEP 2005). These losses were already contributing to poverty in the region through the reduced contribution of coastal fisheries to employment, export revenue, food security and social stability (World Bank 2004).

The pre-tsunami fully or overexploited status of the region represents a dilemma for policy- and decision-makers. The fisheries sector was expected in many countries to contribute to an increase of GNP through an increase in total catches (Mous *et al.* 2005; NARA 2004).

3.1. Aceh, Indonesia

3.1.1. Fished resources in Aceh

Fisheries in Aceh Province have been mostly small-scale and traditional (Janssen 2005), though there were more motorized boats than in other parts of the country (Purnomohadi 2003). Levels of exploitation were higher on the east coast (the Malacca Strait) than on the western part of Sumatra. Fishing was focused on inshore demersal, and small to medium pelagic species. The fishing fleet consisted mostly of wooden boats 4 to 24 metres long that used trammel nets for shrimps, gillnets for fish and bottom set longlines for larger species. There were also small purse seiners (20 to 25 metres long) for small pelagic species. Most boats were "single-day" and operated in coastal waters, with only the purse seiners making extended trips of up to two weeks. Few locally registered vessels were active in deep sea fishing, and trawling was officially banned in 1980 (Dwiponggo *et al.* 1986; Janssen 2005). The main gear in use focused on nets, including trawl nets, seines, purse seines, gillnets, lift nets, cast nets and *muro-ami* (Tampubolon 2006).[3] Hook and line methods, hand collecting and spearing were also commonly used.

Based on fish density analysis, the potential yield of the Strait of Malacca for large pelagic fish is about 25 560 tonnes/year, and for small pelagic species about 124 840 tonnes/year (Purnomohadi 2003). Bailey *et al.* (1987) concluded that in most parts of western Indonesia (including Aceh), demersal stocks were already strongly exploited, while there may have been at that time room for expansion for pelagic species. Matthews *et al.* (1995 in Matthews and Ghofar 2006) analysing data on pelagic fisheries (1977–1992) off the west coast of Sumatra, suggested the MSY might have been reached and large increases in landings were unlikely (see also Merta *et al.* 1995). Dwiponggo *et al.* (1986) considered that trawled demersal species were being optimally exploited between 1977 and 1979. Martosubroto *et al.* (1996) re-examined demersal fisheries of the 1970s and recalculated a sustainable yield for Aceh using provincial data and field reports. This gave a sustainable yield of 8 000 tonnes/year, from which they concluded that the stocks were already beginning to be overfished.

Over the past ten years, around 90 percent of the landed catch has comprised finfish, about 8.4 percent crustaceans and 0.6 percent molluscs, with the remainder constituting "others" such as sea cucumbers and seaweeds. In 2003 these capture fisheries totalled around 134 000 tonnes, with a value of 863 billion rupiah (US$86 million) and accounted for 3 percent of the provincial GDP (CONSRN 2005a; Janssen 2005). The fisheries sector employed around 89 300 people, or 16 percent of the total coastal population of 558 641 in the disaster-affected areas of Aceh Province and Nias Island (CONSRN 2005a).

3.1.2. Fisheries ecosystems in Aceh

Aceh Province is bounded to the east by part of the Malacca Strait and to the west by the Indian Ocean (Purnomohadi 2003). Sumatra is 1 650 kilometres long and up to 350 kilometres wide; it has a mountain chain and associated volcanoes and is bordered to the east by a broad depositional lowland with extensive swamp areas. Off the west coast the Mentawai Islands constitute a "non-volcanic arc", consisting of uplifted and tilted areas with cliffed outer shores facing the predominant southwesterly swell transmitted across the Indonesian Ocean. The inner shores are typically lower and more indented, with embayments,

[3] Hauling a net across the ocean floor to trap fish.

and are fringed by mangroves. There are emerged coral reefs and beach ridges, especially on the outer shores and the possibility of continued tilting is supported by the disappearance of islets off the coast of Simeulue Isand even within the past century. The relatively high island of Nias (summit 886 metres) is encircled by emerged reef terraces. Coral reefs are rare along the central part of the southwest coast of Sumatra because of the large sediment yield from rivers draining the high hinterland, but to the south there are reef-fringed rocky promontories (Bird and Ongkosongo 1980).

The west coast is influenced by the presence of a pronounced thermocline between 100 to 125 metres, above which is a relatively homogenous mixed layer with temperatures of 28 to 29ºC — almost completely depleted in nutrients. In the Strait of Malacca, slightly higher surface temperatures of 28 to 30ºC occur during the south monsoon and lower temperatures of 26 to 27ºC during the north monsoon season. The southern shores of Sumatra receive a southwesterly ocean swell and relatively strong southeasterly wave action in the winter (Bird and Ongkosongo 1980).

3.1.3. Fisheries trends leading up to the tsunami

Landings of Aceh fisheries generally increased from 1976 for total finfish, crustaceans and molluscs, peaking at 111 000 tonnes in 1998 and then falling to 92 000 tonnes in 2002. This pattern was followed by a sharp increase to 134 000 tonnes in 2003. Finfish dominated landings, peaking at 126 000 tonnes in 2003 and falling to 103 000 tonnes in 2004 for reasons not yet understood. Crustacean landings peaked at 18 500 tonnes in 1995 and then fell to around 5 000 tonnes in 2001 to 2002, rising to 10 000 tonnes in 2004. Four long-lived demersal fish (Indian halibut, red snappers, groupers and barramundi) showed a sharp fall in landings in 2003 to 2004, before the tsunami, and have probably been overfished for several decades (Martosubroto *et al.* 1996; Mathews and Ghofar 2006). These authors also considered goatfish and shrimps likely to be overfished and called for more comprehensive studies of other species. Although Matthews and Ghofar (2006) consider the Aceh Fisheries Statistics to be of generally good quality, no assessment of reliability has been undertaken and there are scant biological data to aid in assessing the status of stocks.

The examination of the Aceh provincial fisheries statistics revealed several patterns that would tend to support a trend of increasing fishing pressure prior to the tsunami. The first pattern concerns total catch production in *kabupatens*. While some show steady or slowly increasing production between 1995 and 2005, several show clear declines at some time after 1988 (Figure 1). The two *kabupatens* that show the greatest declines are also those that had the greatest yearly production, namely Aceh Selatan and Aceh Utara. The second pattern shows significant declines in prawn catches, particularly after 1998, and in longer-lived demersal fish as identified by Martosubroto (*et al.* 1996) (Figure 2). Barramundi may have been in decline as early as 1997. Finally, there was an apparent overall trend in replacement of small, mostly individually-owned, dugout and plank-built boats with small and larger inboard powered boats from 1994 to 2002, beginning to increase again after that period (Figure 3). Overall the number of fishing boats declined over that period but catch efficiency increased (as catch/boat/year) (Figure 4). It is difficult to assess whether or by how much overall effort changed as standard conversion factors (between boat types) are unreliable, but estimated that that the overall number of boats declined by about 25 percent, while catch per boat increased by 75 to 100 percent. Over the same period total catch fluctuated, but did not show any consistent trend upwards or downwards, though there were different responses in different *kabupatens* and/or target species. This suggests that changes in catch per unit of effort occurred over the past decade, mirroring the number of boats deployed.

Figure 1: Catch production from 1994 to 2004 for *kabupatens* on the west and east coasts of Aceh Province

Data are from the Aceh Province Fisheries Statistics Yearbooks (1995–2005, see DKP 2005); there are missing data for some *kabupatens*, so trends cannot be discerned. Some *kabupatens* on both coasts showed steady or slowly increasing production over the period. They include Aceh Besar, Aceh Barat, Sabang and Pidie. For Aceh Selatan, Banda Aceh, Aceh Timur and Aceh Utara there are clear declines in catches.

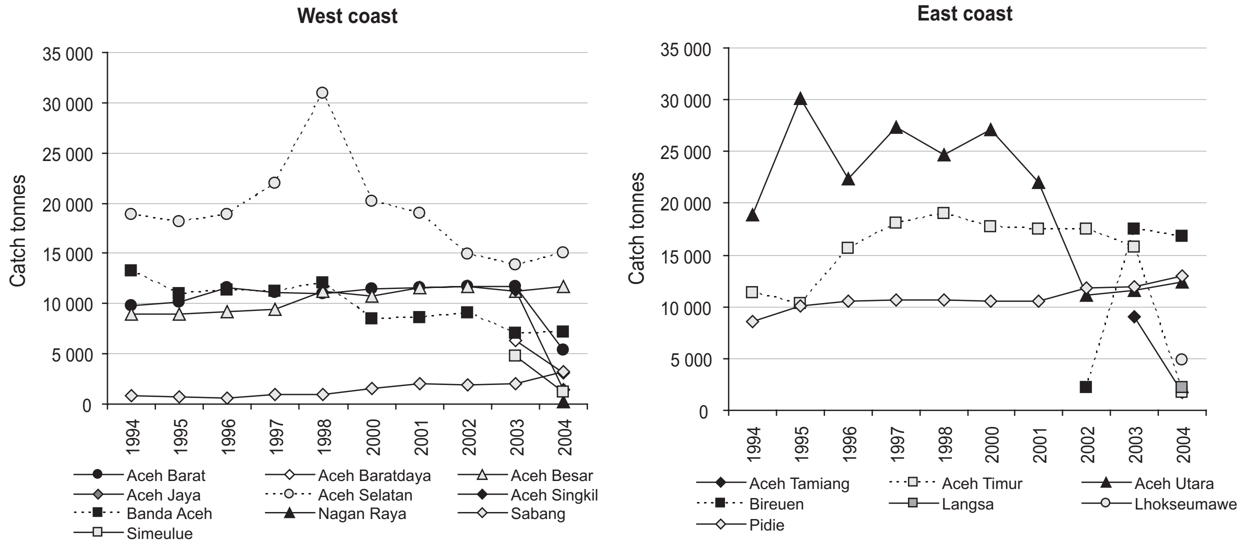


Figure 2: Catch production from 1994 to 2004 for crustaceans and selected demersal fish landed in Aceh Province

Data are from the Aceh Province Fisheries Statistics Yearbooks (1995–2005, see DKP 2005). Prawns showed a decline after a peak in 1995, while crabs and lobsters were either steady or increasing slowly. The picture for some demersal fish is more complex. All of the four groups shown below declined in 2004, but before that production of Indian halibut was increasing.

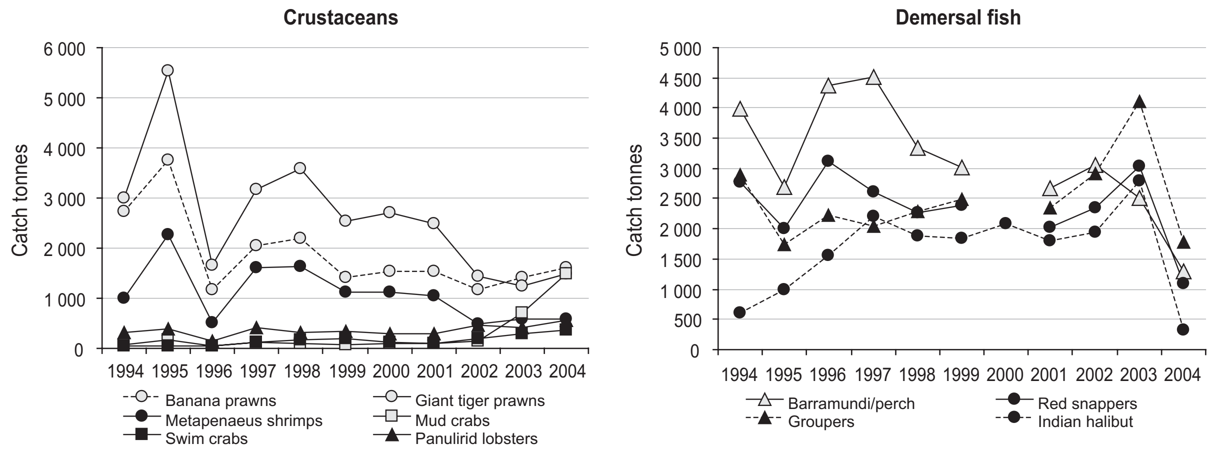


Figure 3: Numbers of fishing boats in use per year between 1994 and 2004 in Aceh fisheries

Data are from the Aceh Province Fisheries Statistics Yearbooks (1995–2005, see DKP 2005). The overall decrease in the total number of boats was due to changeover. There was a general increase in the numbers of boats with inboard engines and a general decline in the numbers of dugout, outboard and plank-built boats from 1994 to 2002. Between 2002 and 2004 some of these boats started to increase again. So did the total number of boats.

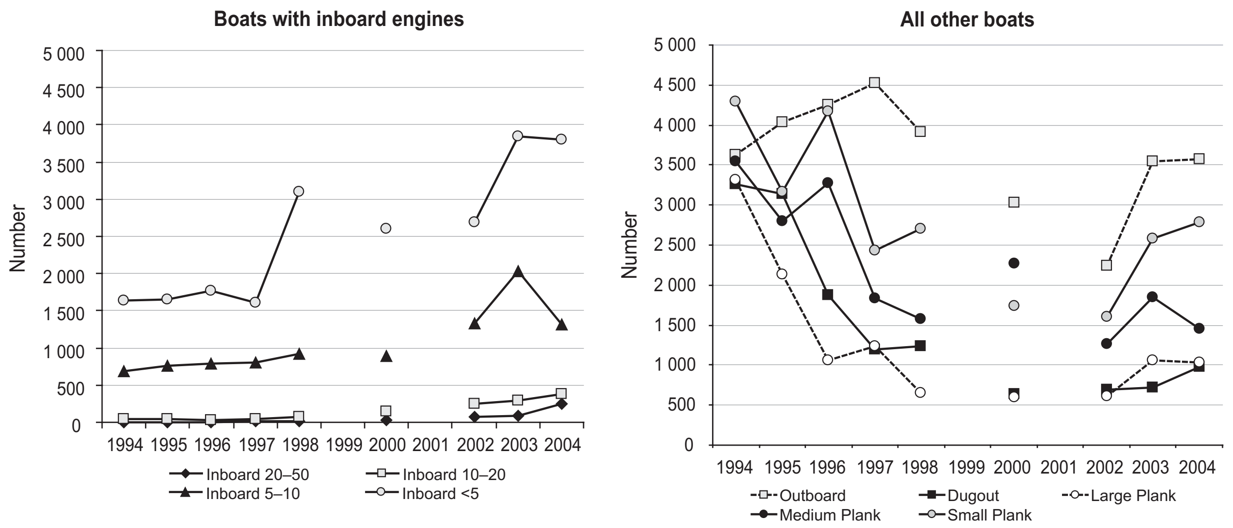
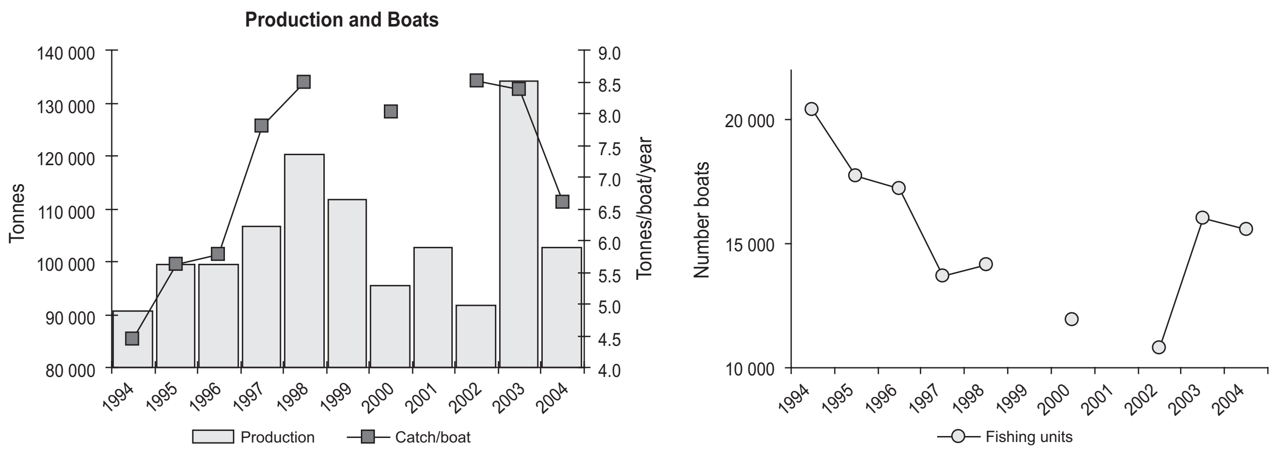


Figure 4: Relationship between yearly total catch production, total number of vessels in use and catch/vessel/year in Aceh, 1994–2004

Data are from the Aceh Province Fisheries Statistics Yearbooks (1995–2005, see DKP 2005). There was a general decrease then an increase in the overall number of boats from 1994 to 2004, but part of this was attributable to switching from many small boats to a smaller number of larger boats with inboard engines. Using only data on total number of boats (and not details of their capacity) the catch per boat (right axis) increases from 4.4 tonnes/boat/year in 1994 to 8.4 tonnes/boat/year in 1998. Between 2002 and 2004 catch per boat decreased while the number of boats increased and production fluctuated. The number of vessels and the catch per vessel are almost mirror images and the best catches over the past decade tended to occur when the total number of boats was below 15 000.

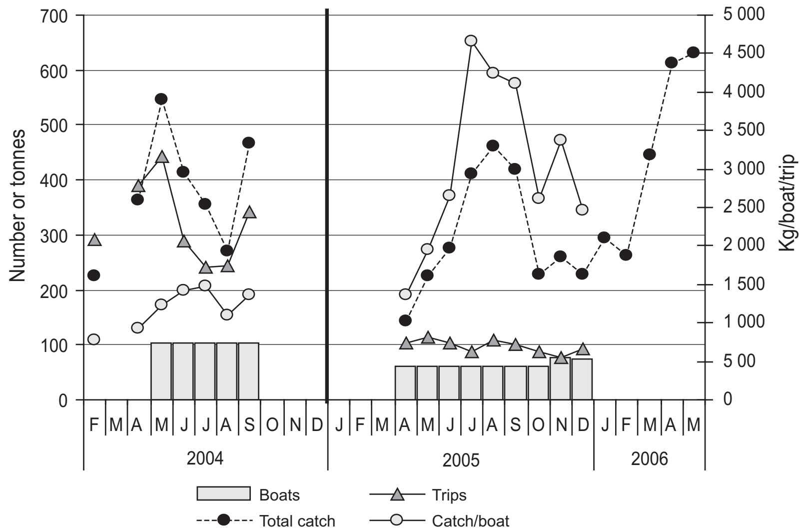


3.1.4. Aceh fisheries before and after the tsunami

Minimal provincial fisheries data are available for the period since the tsunami, but at Lampulo, Banda Aceh, it was possible to obtain some monthly data on catch, catch per boat, trips and number of boats between February 2004 and May 2006. These data show that catch per boat and total catch actually increased in 2005 and 2006 compared with 2004 (Figure 5). This is considered to be related to the reduced number of boats and fishing trips after the disaster.

Figure 5: Trends in purse seine landings at Lampulo, Banda Aceh from February 2004 to May 2006

Data are from Tampubolon (2006) and show that the number of boats and trips were reduced after the tsunami, but the total catch was back to within normal range by about May 2005. This was accompanied by far better catch rates per boat in 2005 compared with 2004.



3.2. Sri Lanka

3.2.1. Fished resources in Sri Lanka

The quantity and productivity of marine fish resources in Sri Lanka is driven by the presence of a narrow continental shelf and the lack of significant areas of upwelling (Joseph 1993). Between 1977 and 1980, acoustic surveys of coastal waters were undertaken[4] to estimate a potential yield of about 250 000 tonnes/year (170 000 tonnes pelagic, 80 000 tonnes demersal resources). At that time it was thought that the demersal resources had little potential for expansion and that the pelagic species mostly sustained the inshore fishery (Blindheim and Foyn 1980). Preliminary estimates of potential yield from the offshore/deep sea areas varied between 29 000 and almost 99 000 tonnes, which at that time indicated a scope for increasing production. These estimates of potential yield have not been updated since that time (Hersoug and Munkejord 2003); if regional analyses of trawl survey data for the APFIC states, including Sri Lanka are any guide, there has been substantive degradation and overfishing of coastal stocks (Sugiyama *et al.* 2004) since then.

Most of Sri Lanka's fisheries are small-scale with relatively recent increases in privately owned larger scale enterprises (BOBP 1984; Maldeniya and Amarasooriya 1998; Preston 1988). The main areas in which fisheries are focused are: (i) inland fisheries and aquaculture; (ii) coastal fisheries, including those in lagoons, swamps and estuaries and diverse activities and species; and (iii) offshore fisheries focusing on

4 Norwegian research vessel, *Dr Fridtjof Nansen*.

shark and tuna, mostly for the domestic market (IOTC 2004; Preston 1988). For purposes of data collection and management the most important fisheries are organized in the six groupings given in Table 1; for the purposes of this study, the most important of these will be the coastal fisheries focused on small and medium pelagic fish, demersal fish and crustaceans. The area defined as the coastal region comprises all 74 administrative divisions with a maritime boundary; it extends about 50 kilometres inland and contains about 23 percent of the islands, 65 610 km^2 of the land area and is home to one-quarter of the population (Joseph 2005).

Table 1: Summary of the most important Sri Lankan fisheries and their yields in the late 1980s (Preston 1988)

Fishery	Target species	Gear	Yield	Status
Small pelagic	Sardines, herrings, anchovies and mackerel	Beach seines, small-mesh gillnets	65 000 tonnes/year	Declining
Medium pelagic	Small tuna	Drift gillnetting and ring-netting	6 500–10 000 tonnes/year	
Large pelagic	Large tuna, pelagic sharks, billfish beyond continental shelf	Large-mesh drift gillnets and shark longlines	75 000 tonnes/year	Production growing
Demersal	Surgeon fish, jacks and trevallies, grunts and sweetlips, pony fish, emperors, snappers, groupers, sharks and rays	Trawling and line fishing	25 000 tonnes/year	Declining since 1980s when catch was around 40 000 tonnes/ year
Prawns	30 species, *Penaeus indicus, P. merguiensis, P. monodon, P. semisulcatus, Metapenaeus* spp. dominant		7 000 tonnes/year in 1994	Potential yield unknown, trends indicate no potential for increase
Lobsters	7 species		Up to 1 000 tonnes/ year	

According to the Department of Census and Statistics, fish contributes about 65 percent of the animal protein consumed in Sri Lanka. Total annual fish production in 1996 was 228 550 tonnes, around 65 percent of which was landed by coastal fisheries, 25 percent by offshore or deep sea fisheries and 10 percent by inland fisheries. By 1997 small pelagic fish contributed 70 percent of the catch from coastal waters with an estimated production of 152 752 tonnes (Samaranayake 2003). From 1999 to 2004, production of all commercial groups of marine fisheries climbed from 238 400 to 253 190 tonnes (NARA 2004). In 2003 coastal and offshore fishing produced 284 960 tonnes of fish providing 83 percent of the total quantity consumed in the country (CONSRN 2005b). Around 1 million people were dependent on fisheries and 250 000 people were employed in the sector (Sydnes and Normann 2003). The fishing industry contributed 2.6 percent to the GDP in 2003 in addition to foreign exchange earnings through exports of fish and marine products of 9.5 billion rupees[5] (CONSRN 2005b).

Demersal species included fish, squid, prawns, crabs and lobsters of around 215 species belonging to 55 families (Samaranayake 2003). The most common families were the emperors, snappers, jacks and trevallies, groupers, grunts, sweet lips and pony fish. The smaller short-lived species such as pony fish predominated in the north and northwest while the larger longer-lived species such as emperors, snappers and groupers were predominant in the other areas of the continental shelf. The demersal trawl catch rates in the northwest and north were higher than in other areas. Small pelagic species such as sardines, herrings, anchovies and mackerel in the inshore waters were exploited primarily by gillnets (80 percent of production, Samaranayake 2003).

[5] US$1.00 = 112.76 Rupees (October 2007).

Large pelagic fish such as tuna, marlin, sharks and billfish contributed about 30 000 tonnes to total annual production. The larger species, particularly skipjack, yellowfin and big-eye tuna, billfish and pelagic sharks were mainly exploited in offshore areas and oceanic ranges. The smaller tuna species such as frigate, bullet and eastern little tuna (mackerel tuna or *kawakawa*) and seerfish (Spanish mackerel) were concentrated on the continental shelf (Samaranayake 2003). In recent years, tuna fisheries in Sri Lanka have developed rapidly. By 1998 there were more than 3 000 boats engaged in tuna fishing, with 1 700 greater than 10 metres in length and operating in offshore areas, some into international waters. Fishing efforts through multiday operations jumped from 11 percent to 57 percent in just two years (1994–1996). The total production of large pelagic fish in 1998 was in the range of 100 000 to 110 000 tonnes, but evidenced a decreasing trend for the industrial longline fleet. All species of tuna together now contribute about 50 percent of the catch of large pelagics from both coastal and offshore fishing, with skipjack dominating catches (Maldeniya and Amarasooriya 1998).

Other commercially important resources consisted mainly of prawns, lobsters, crabs, squid, cuttlefish, bêche-de-mer, oysters and chanks. There were about 33 species of prawns — eight of importance mainly from the Palk Bay area, between Colombo and Udappu, off Mullaitivu and in Batticaloa. About five species of lobsters were present. Sea cucumbers were found primarily in the muddy bottom off the shores of the northwest coast at Palk Bay, Gulf of Mannar and Kalpitiya. Molluscs have in the past included edible oysters, window-pane oysters and pearl oysters, which dwindled in the 1970s, in addition to chanks which are now reviving and are collected for export from Palk Bay (Samaranayake 2003). Squid and cuttlefish came from the prawn grounds as incidental catch.

Ornamental fish have been a significant reef resource in Sri Lanka since 1980 (BOBP 1984) and may have good potential for co-management arrangements with communities. There is, however, a substantial gap in the available information on the species and numbers of specimens exported (Wilhelmsson *et al.* 2005); overexploitation of the resource is likely to have contributed to the declining trends in ornamental fish abundance. Haputhantri *et al.* (2002) interviewed 12 ornamental fish suppliers who said that there was a declining trend in marine ornamental fish abundance over the previous five years. Reasons quoted for the decline included: effects of coral bleaching in 1998; increasing numbers of ornamental fish collectors; destructive fishing/collecting practices, coral mining and pollution.

Although a range of estimates of MSY has been provided through trawl, acoustic and productivity surveys since the early 1970s, they differ significantly. Samaranayake (2003) reviewed the existing data and estimated an aggregate MSY for demersal, pelagic and large pelagic species of about 172 000 tonnes/year, while higher estimates of total production of up to 500 000 tonnes/year have been proposed (Sydnes and Normann 2003). The number of boats required to attain the MSY discussed by Samaranayake (2003) for different categories are: 2 715 for inboard motorized craft; 7 839 for outboard motor craft; and 22 146 for artisanal craft.

Fishing activities occurred all around Sri Lanka's coastline, with landings made at 12 fishery harbour centres, several large and small fishery anchorages and as many as 700 village-level fish landing sites. In 2003 the fishing fleet comprised 29 694 fishing craft including multiday boats (34–50 feet long) powered by inboard engines, 3.5 tonnes single-day boats powered by inboard engines, fibreglass re-inforced plastic (FRP) boats 18-23 feet long powered by outboard engines and traditional craft (dugouts and log craft some of which had outboard engines) (CONSRN 2005b).

3.2.2. Fisheries ecosystems in Sri Lanka

Sri Lanka and the southern tip of India stand on the same continental shelf and are separated by a shallow sea, the Palk Strait. There is a generally rocky continental shelf averaging 15 kilometres in width and 20 to 65 metres in depth, with the narrowest stretch at Kalpitiya, where the width is only 2.8 kilometres. The total area of the continental shelf is about 26 000 km^2, occupying about 11 percent of the EEZ and providing about 70 percent of the annual fish production (Samaranayake 2003). Within the coastal zone are diverse ecosystems including lagoons, estuaries, coral reefs, mangrove forests, sea-grass beds, salt marshes, beaches and dune systems (Samaranayake 2003). Coral reefs in Sri Lanka can be found along only 23 percent of the total shoreline and they are mostly fringing reefs. Barrier reefs are found in Vanakali and Silvathurai in the north and are rare.

The lagoons and estuaries of Sri Lanka are some of the country's most prominent natural features and cover some 160 000 hectares in total (UNEP and MENR 2005; NARESA 1991). The lagoons are complexes of other wetland systems and often contain marshes, mangrove areas, sea-grass beds and mud flats. These ecosystems are valuable for their fish, shrimp and other products. Those that open to the sea also provide nursery functions, supporting estuarine and coastal fisheries. About 90 percent of commercially important organisms captured in estuaries and lagoons arrive as migrants from the sea (NARESA 1991). They also have socio-economic importance as major settlement sites for urban and rural communities and provide natural harbours and anchorages. The health of lagoons and estuaries is heavily dependent on the interplay of freshwater flowing from the interior and influxes from the sea. Closed lagoons may be periodically opened naturally or by humans; diversions may reduce waterflow resulting in siltation and changes in salinity and ecology (UNEP and MENR 2005). For example, Negombo Lagoon's effective water area was reduced by 791 hectares between 1956 and 1981 due to high siltation rates (NARESA 1991).

Sri Lanka has short rivers with low sediment yield and maximum tidal amplitude of only about 75 centimetres, so there are few locations suitable for the development of extensive stands of mangrove vegetation. There are limited mangroves in Puttalam District, with over 2 000 hectares, and Batticaloa and Trincomalee Districts, each with over 1 000 hectares. Elsewhere, mangroves occur only along the fringes of brackish-water lagoons, estuaries and inlets (UNEP and MENR 2005).

With the ongoing support of several international NGOs (e.g. IUCN) there are now several programmes aimed at protecting coastal ecosystems and resilience in the country such as a wetland sanctuary in Kalametiya (Bambaradeniya *et al.* 2006); others are in the pipeline, such as a turtle refuge at Rekawa (Sandun *et al.* 2006).

3.2.3. Trends in district fisheries pre- and post-tsunami

Marine fish production in the districts of Galle, Hambantota and Kalutara increased steadily from 1990 to 2000, tripling in that period and peaking at over 34 000 tonnes in Hambantota (Maldeniya and Jayamanne 2006) (Figure 6). This was followed by a decline to around 17 500 to 22 000 tonnes per district in 2004 and then a steep drop back to or below 1990 levels after the tsunami (6 220 to 11 560 tonnes). Almost 80 percent of the marine fish catch in these districts consisted of large pelagic species, with shore seine varieties contributing over 21 percent (demersal finfish and non-finfish prawns, lobsters and others). After the tsunami the contribution of shore seine varieties declined by up to 20 percent (Maldeniya and Jayamanne 2006).

A different picture emerges for Ampara and Batticaloa Districts. Data on total fish production are recorded by the district offices for a number of fisheries (FI) divisions. According to these data, annual catches in Batticaloa were increasing from 2001 to 2004, from a yearly total of about 4 200 to 7 600 tonnes (Figure 7). After the tsunami, the monthly catches at Ampara fell to nearly zero and increased by March 2005, but remained lower than the equivalent months in 2004. In Batticaloa after a lower catch in January 2005, catches were subsequently within the normal range seen from 2001 to 2004.

Landings' data for small pelagic species in seven districts using NARA's Small Pelagic Fisheries Database were examined (see examples in Figure 8). Chilaw, Kalmunai, Kalutara, Matara, Negombo, Tangalle and Trincomalee Districts had data from 2000 to early 2006. Five of the seven districts showed an overall trend of declining landings of small pelagic species from 2000 to 2004, with two districts (Kalutara and Chilaw) remaining relatively steady over the same period. In two of the districts showing an overall

Figure 6: Catch production of marine fisheries in three tsunami-affected districts in Sri Lanka (Maldeniya and Jayamanne 2006). Data are from MFAR, the red line marks the tsunami

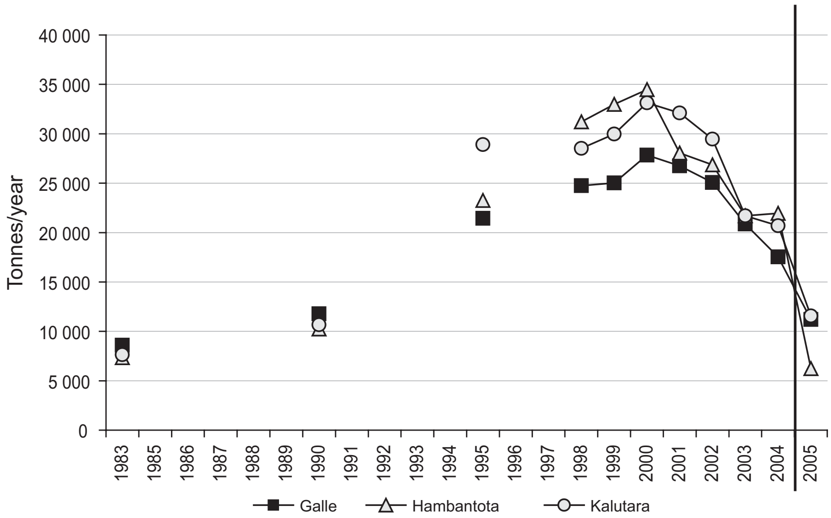
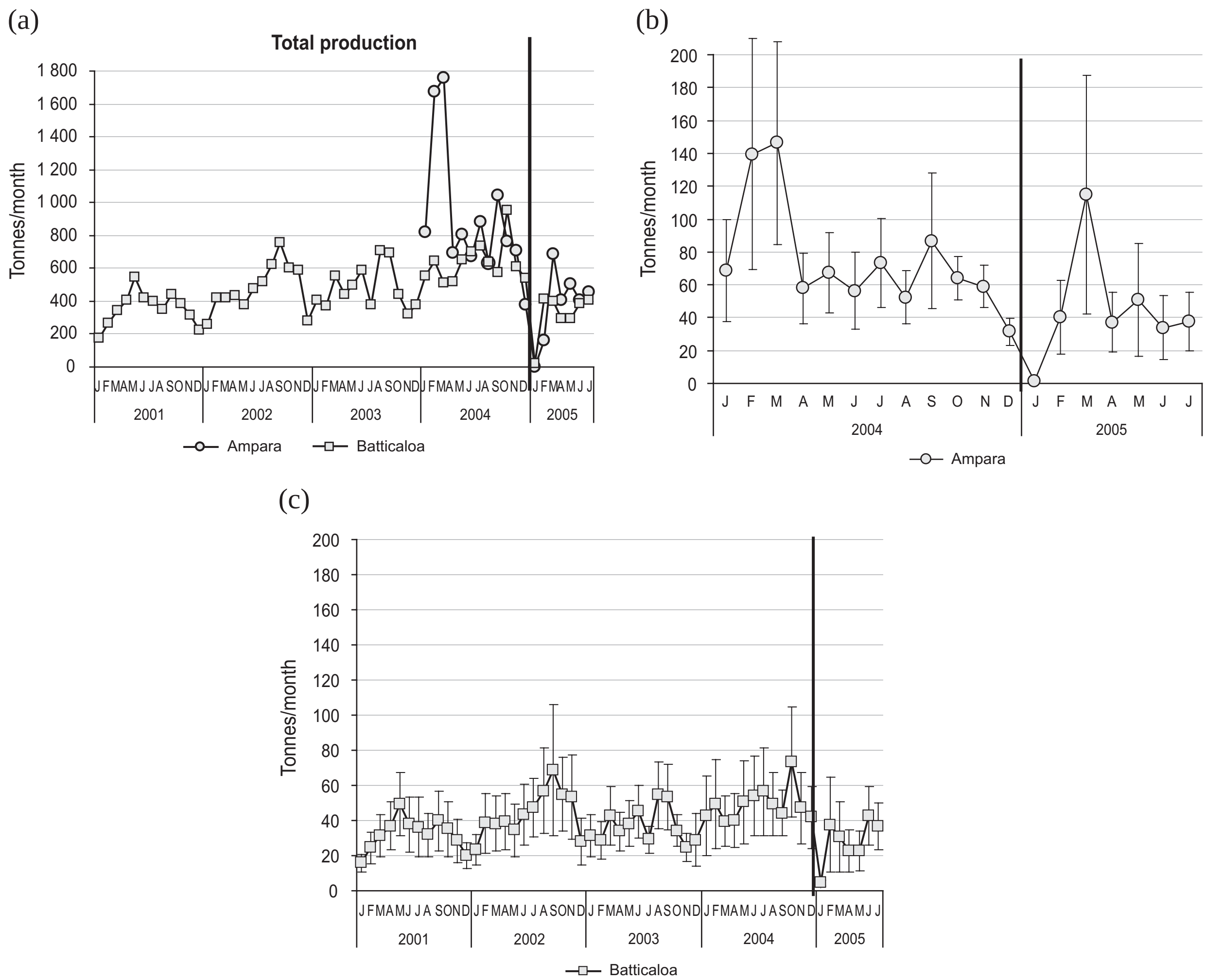


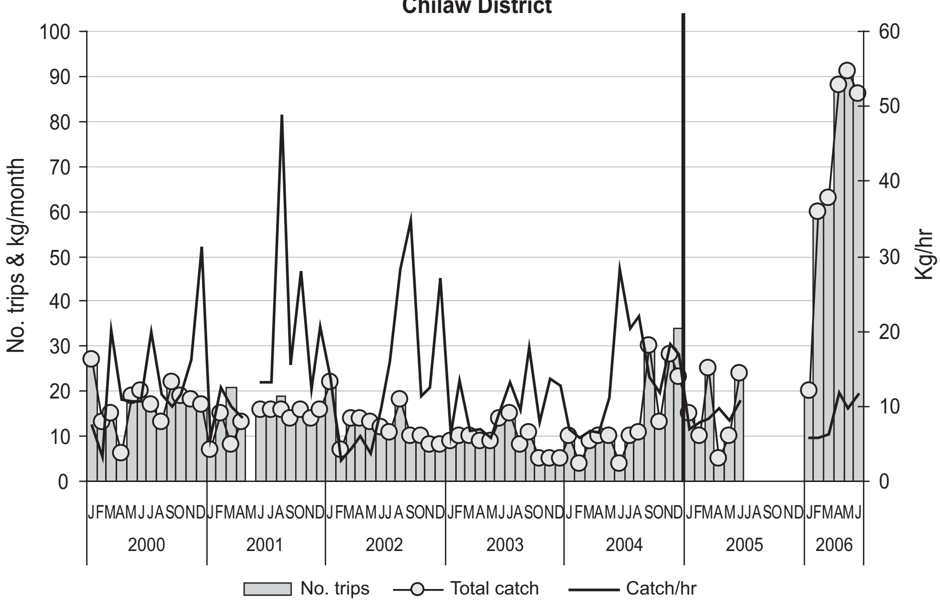
Figure 7: Landed catches in Ampara and Batticaloa Districts. Data are from district administrations; the red line is the tsunami. (a) is total production per month and (b&c) is average production across all FI divisions +/-SE



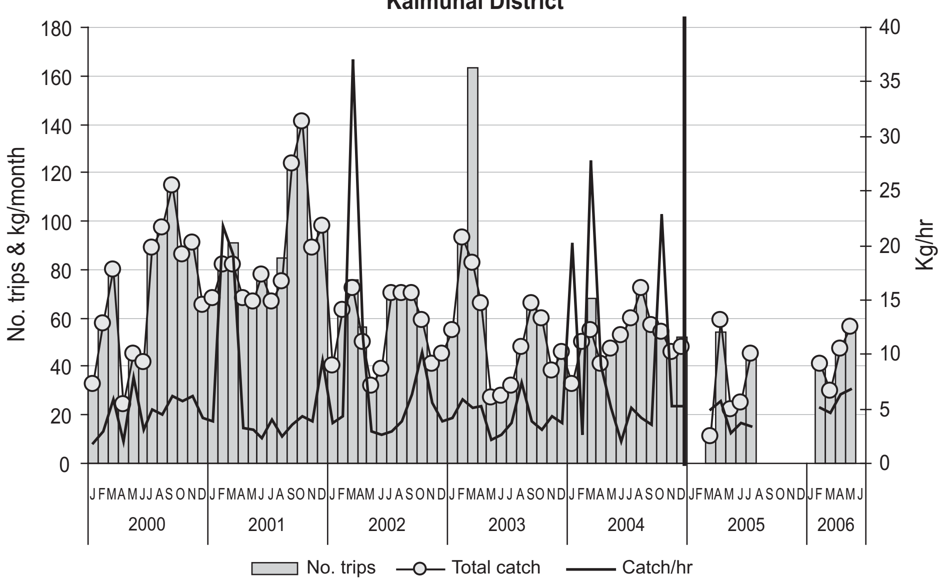
decline in catches, the pattern was more complex. For Matara and Trincomalee, catches increased in 2000 and 2001, dropping abruptly in November and December of that year. Between 2002 and 2006 catches remained low and steady. Responses to the tsunami were very different in the seven districts. In Chilaw (Figure 8a), catches were greater in 2006 than at any time back to 2000. In Tangalle and Kalmunai (Figure 8b), catches were significantly lower after the tsunami and by May–June 2006 had not recovered to pre-tsunami levels. In all of the remaining districts, catches quickly recovered to pre-tsunami levels, including normal seasonal fluctuations (Figure 8c).

Figure 8: Landings per month of small pelagic fisheries in (a) Chilaw, (b) Kalmunai and (c) Kalutara. Data are from NARA's Small Pelagic Fisheries Database. The red line is the tsunami

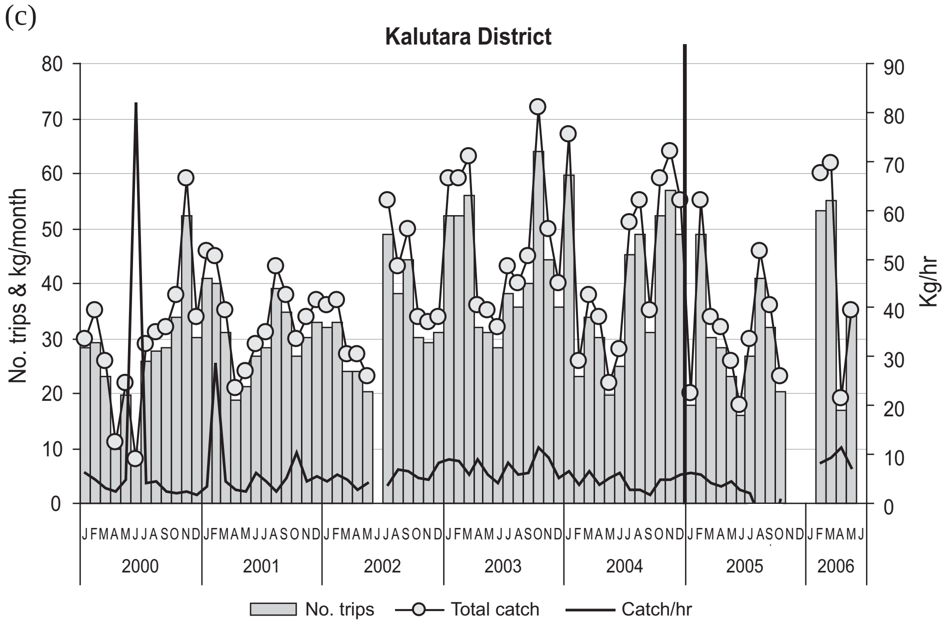
(a)



(b)



(c)



Figures 6, 7 and 8 cover different time frames and provide different information on the overall behaviour of the district fisheries and how they responded to the tsunami. The yearly data give a good picture of how the fisheries were behaving over longer time frames before the tsunami. The monthly catch data show significant seasonal patterns that tend to repeat over the years and different responses to the tsunami. The highlights are:

- Total catches declined from about 2000 in Galle, Hambantota and Kalutara, while catches of pelagic species declined in Kalmunai, Tangalle and Negombo.
- Total catches in Batticaloa increased from 2001.
- All districts showed a drop in total and pelagic catches following the tsunami (either in monthly or yearly data).
- Monthly total catches in Batticaloa quickly rebounded after February/March 2005 so that catches were back in the normal range for that time of year. At Ampara catches rebounded but not back to the monthly equivalent levels of 2004.
- For small pelagic species one district showed an increase in catches after the tsunami, two districts had lower catches a year after the tsunami, while four districts showed no difference in catches and a continuation of long-term trends within a few months of the tsunami.

4. MODE OF ACTION OF THE TSUNAMI ON NATURAL RESOURCES

Initial reaction to the tsunami by the international community was that it had a large potential to damage coastal and nearshore ecosystems and resources. At small spatial scales, tsunamis were considered to have the potential to directly affect fish by displacing or washing them ashore as occurs in storms (Walsh 1983). Locals reported many small fish washed ashore at Palau Weh (Allen 2005b).

Post-tsunami, environmental damage was expected to be extensive with potentially irreversible destruction of benthic reef habitats (coral mortality, alterations in physical structure), as well as immediate loss of living coastal resources such as fish, lobsters and crabs (IUCN 2005c; Wilson *et al.* 2006). This was expected to have serious implications for fisheries, though it was unlikely that the pelagic environment had been severely affected (IUCN 2005c). Declines in the abundance of fish following extensive depletion of hard coral are common (Booth *et al.* 2002; Jones *et al.* 2004) though there can be a significant time lag between the loss of habitat and a reduction in fish numbers. Pratchett *et al.* (2006) detected no change four months after bleaching in the abundance of obligate corallivorous fishes, despite a 90 percent decline in coral cover. They suggested that it may take longer than this for the fish to starve or relocate. It should be noted therefore that a low abundance of fish immediately after the tsunami could be the result of conditions prevailing before the waves hit.

A range of mechanisms on how tsunamis could affect coastal resources and ecosystems and the factors that can modify their effects has been identified (Table 2). The direct mechanisms that can damage resources and ecosystems include wave action, smothering by sedimentation and land-based debris, mechanical damage by land-based debris and uplift/submergence. Waves can also directly dislodge attached benthic organisms and move mobile organisms significant distances inland. In rapid assessments in Sri Lanka, many species of nearshore and estuarine fish populations were subjected to mass mortality and washed into inland areas. Freshwater fish species inhabiting low-saline lagoons were reported to have died due to increased salinity (IUCN 2005a). Wave action was specifically found to dislodge, break and move corals. Sediments washed off the land smothered corals and there were many cases of corals being covered by land-based materials swept from damaged settlements. Allen (2005a) suggested that the debris picked up by the waves increased their destructive nature. Corals in Simeulue Island were lifted 2 metres out of the water and completely lost, while on the other side of the island they were submerged by the same amount (ICRI 2005; Phongsuwan and Tun 2005; IUCN 2005e; IUCN *et al.* 2005; LIPI 2006).

Table 2: Summary of the main mechanisms that can lead to damage to coastal resources and ecosystems and the modifiers that can increase or decrease effects

Direct mechanisms	Modifiers	Feedback effects
1. Wave action	1. Distance from the earthquake epicentre	1. Changes in nearshore water characteristics (nutrients, primary production)
2. Smothering with sediments	2. Inlets allowing funnelling further inland	2. Changes in water currents
3. Smothering with land-based debris (e.g. plastics)	3. Headlands refracting waves and wave interference patterns	3. Previous damage to ecosystems
4. Mechanical damage by land-based debris (e.g. logs, building materials)	4. Presence, extent and gradient of continental slope	4. Pollution and sedimentation
5. Uplifting or submergence	5. Shoreline elevation 6. Presence and health of vegetation including mangroves 7. Presence and health of coral reefs 8. Spurs and grooves 9. Presence of dunes 10. Coastal land use (sediments more available, barriers removed, effect of buildings etc.)	5. Changes in fishing effort

The direct effects of waves, sediments and mechanical damage were patchy and their intensity and extent were modified by a range of factors (Table 2). Most agree that distance from the earthquake epicentre, the presence of inlets and headlands, the presence, extent and gradient of the continental slope, shoreline elevation, the presence of dunes and other vegetation, and density of habitation and infrastructure seem to explain most of the variation (Gibbons *et al.* 2005; ICRI 2005; UNEP and WCMC 2006). In particular, tsunami waves were considered extremely sensitive to details of nearshore and coastal topography

(Gibbons *et al.* 2005; Rudi and Fadli 2005). Narayan *et al.* (2005) reported that in India the width of the continental shelf played a major role in the pattern of tsunami damage (less width = more damage) and that wave reflection and interference from Sri Lanka and Maldives created areas of wave doubling and cancelling, explaining the highly patchy nature of damage.

After the initial impacts of tsunami waves, more medium- to long-term feedback effects can lead to further damage to nearshore resources and their environments. Changes in nearshore water characteristics, including temperature and nutrients could be expected to lead to algal blooms or anoxia events because new sources of nutrients have been mobilized. Changes in topography caused by sediments being deposited, or eroded, including the opening of normally closed lagoons in Sri Lanka could be expected to alter water currents. Previous damage to ecosystems was expected to leave them more vulnerable to tsunami damage and less likely to recover. New sources of pollution from damaged sewage and drainage systems could impose new stresses on ecosystems recently affected by the tsunami. Finally, feedback damage might include changes in fishing effort and other human uses of resources and ecosystems. Temporary reduction in fishing caused by loss of boats and fisherfolk, increases resulting from emergency fishing and sudden possibly permanent changes in fishing practices prompted by the introduction of new gear and new boats from donors were all expected to play a role.

According to Campbell *et al.* (2006) the damage by the tsunami is very different to that observed following large storms. Cyclone damage to reefs is also patchy (Woodley *et al.* 1981) but it is unusual for shallow reefs to escape damage over large scales (Hughes and Connell 1999). Baird *et al.* (2005) hypothesized that in cyclones, energy is concentrated near the surface and diminishes with depth, while for tsunami waves the entire water column is in motion. They suggested that for corals the initial run-down of the tsunami, along with the first wave of the tsunami train, excavated unconsolidated substrata from around the bases of unattached colonies, making them susceptible to displacement when inundated by the subsequent waves.

5. REPORTED EFFECTS OF THE TSUNAMI ON FISHERIES RESOURCES

Reports of the actual impacts of the tsunami on fisheries resources are few, with most studies being undertaken on sensitive ecosystems such as coral reefs and mangroves by conservation groups and organizations. Because these ecosystems and others in coastal areas are the support systems for fished resources, the effects of the tsunami on them were reviewed to determine whether effects on the fisheries resources could be demonstrated over the longer term.

Most of the reports of significant or extensive damage due to the tsunami came from initial rapid assessments (Chavanich *et al.* 2005; CORDIO and IUCN 2005; Kulkarini 2005) and focused on coral reefs. This is not surprising because *a priori* rapid assessments are designed to detect damage and quickly zero in on the worst affected areas. More formal quantitative assessments of impacts are usually more objective and focus on detecting changes in abundance, cover and diversity compared with pre-impacted conditions. They usually include damaged and undamaged sites in a logical framework designed to estimate geographic extent. Both types of studies were included in this review, but it appears that evidence from quantitative surveys are likely to give a more accurate picture of the real extent of impacts of the tsunami on fisheries resources. Further, because the review focussed on information from Aceh and Sri Lanka, the two hardest hit areas, it is fair to assume that the findings of this review findings cover the worst cases of impacts, which therefore could be generalized to imply lesser effects in surrounding countries.

The overwhelming evidence available in the studies reviewed suggests that the tsunami had relatively minor impacts on fisheries resources and the ecosystems on which they depend. There were cases, described hereunder, in which effects were measured, but these were localized and of little significance from a local, provincial, national or regional fisheries perspective. Of far more importance is one message that is repeated in many of the studies. Ongoing anthropogenic impacts and misuse of resources already firmly entrenched throughout the region prior to the tsunami are far more important in determining the status of resources than the effects of the tsunami or any other rare natural disturbances. As Foster *et al.* (2006) put it, "sedimentation (exacerbated by the tsunami), overfishing, and the use of destructive fishing methods may represent a greater threat to Aceh's reef ecosystems than the immediate impacts of the earthquakes and tsunami". The sections that follow review the evidence covering effects on fished resources, the ecosystems that support them, interactive effects and changes in fishing effort that accompanied the tsunami.

5.1. Effects on fisheries resources reported in other studies

5.1.1. Pelagic species

In Aceh, LIPI (2006) and LIPI and IMR (2006) reported that the total catch of pelagic fish, species composition and size distribution declined in Aceh from 2003 to 2005. This study concluded that the changes observed were unlikely to be due to the tsunami. A similar result was reported from Maldives where a study of fisherfolk's perceptions was undertaken on the effects of the tsunami on bait fish (mostly sprats, anchovies, silversides, but including reef-associated cardinal fish and fusiliers) for the pole-and-line fishery. Surveys were undertaken in three atolls: Laamu and Thaa with high impacts and Baa with medium impacts, with additional information collected from fisherfolk landing their catches in Malé fish markets (Gunn *et al.* 2005). Although five respondents reported negative impacts on bait fish resources, the majority (122) from the three outer atolls reported that bait fishing was average or good (January to February 2005), concluding that it was similar or better than the period immediately before the tsunami. In Malé, 68 respondents landing primarily from Kaafu Atoll (nearby) reported that bait fishing was poor, but most attributed this to normal seasonal effects — relating this to post-tsunami increases in turbidity and perceived habitat damage, and normal seasonal effects (Gunn *et al.* 2005).

5.1.2. Trawled species — evidence from research cruises

A research cruise undertaken by LIPI, the Research Centre for Oceanography and IMR, the Institute of Marine Research, Norway in 2005 concluded that demersal fisheries have been in decline since 1980 (LIPI and IMR 2006). They did not report specific impacts of the tsunami on demersal species, but warned that alterations to the benthic substratum (tsunami deposits and habitat damage) could lead to long-term impacts on demersal fish through changes in the benthos (their food).

Surveys carried out on demersal fish along the Andaman Coast of Thailand over seven cruises on *Pramong IV* in 2004 and 2005 showed an increase in catch per unit of effort (CPUE) and stock densities after the tsunami (LIPI and IMR 2006). CPUE increased from 35.2 kg/hour in 2004 to 42.7 kg/hour in 2005, while stock densities increased from 345 to 430 kg/km^2 over the same period. The differences were reported to be significant for total catches (of demersal fish), cephalopods and crabs (Figure 9), but varied according to sites within the area surveyed. Off western Phang-nga and Phuket Provinces, abundances of marine fish decreased to one-third of levels before the tsunami, while in Phang-nga Bay, abundances of cephalopods and shrimps were higher after the tsunami (LIPI and IMR 2006).

Two research cruises were undertaken off Kedah and Penang by the Fisheries Resource Branch of the Malaysian Fisheries Research Institute (Ahmad *et al.* 2005a, b) (Table 3). The purpose of the surveys was to undertake post-tsunami trawls in areas that had been sampled before the tsunami to identify any changes in the density and/or composition of fish and invertebrate catches in tsunami-affected areas. The catch results were also examined to determine whether there might be differential effects on fisheries stocks according to depth (<30 metres, >30 metres), habitat preference (demersal or pelagic) or trophic level (omnivores, mid-level carnivores or high-level carnivores).

Figure 9: Stock biomass of major fished groups in 2004 and after the tsunami in 2005 as surveyed in the *Pramong IV* cruises off Thailand's Andarman Coast

Data are overall results from LIPI and IMR (2006) and are converted from percent of catch contributed by each group to kg/km^2.

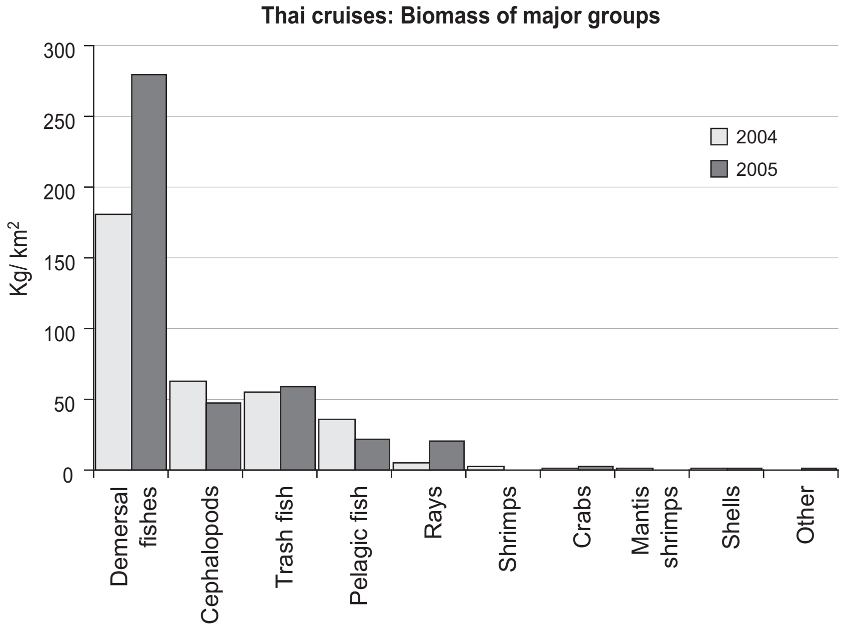


Table 3: Summary of trawl results obtained by Ahmad *et al.* 2005a, b in Malaysia off Kedah and Penang. Trawls were carried out pre- and post-tsunami to examine changes in density, diversity, and trophic level of resources in varying water depths and were separated by habitat preference (demersal and pelagic species)

Survey	Trawls	Pre-tsunami	Post-tsunami	Results	Conclusions
Kedah	45	Feb 2004	Feb 2005, May 2005	Temporary increase in density, diversity and trophic level, especially demersal species and pelagic invertebrates 2 months after the tsunami; Return to approx. normal after 5 months. Catch data less variable post-tsunami.	Effect of tsunami on resources appears low. Decreased fishing effort may be more important.
Penang	36	July-Aug 2000	Jun 2005	No significant changes in density and diversity. Increase in trophic level. Catch data more variable after tsunami.	Effects of tsunami not clear. May have been an increase in trophic level, but this may be attributed to fishing.

At Kedah, there appeared to be a temporary increase in density and diversity of up to 286 percent for fished species, including demersal fish and demersal and pelagic invertebrates. This occurred two months after the tsunami, but returned to "normal" levels when five months had elapsed. Off Penang, although some changes were observed, they were statistically not significant. In both studies, the authors concluded that the impacts of the tsunami on fished resources were probably low and that changes in fishing pressure were likely to be more significant.

Researchers from Kochi, India at the Cochin University of Science and Technology, NIO-RC, Annamalai University and the Centre for Marine Living Resources and Ecology (CMLRE) and Cochin Marine Fisheries Research Institute (CMFRI), undertook a research cruise aboard the *FORV Sagar Sampada*, followed by additional studies in January 2005. Their purpose was to carry out detailed investigations on the impacts of the tsunami on the benthic communities, sedimentation, water chemistry and productivity patterns of the coastal waters off Kerala, Tamil Nadu and Andhra coasts and the Andaman Sea (Sampath 2005). Using baseline data from previous cruises, results were reported separately for the cruise tracks surveyed.

Along the Kochi–Chennai track the team found no significant effects on the major groups of benthic organisms in samples taken between 30 and 100 metres depth. There were similarly no observed effects on demersal fishery catches, nor any sign of algal or zooplankton blooms. On the Andaman–Chennai track the team found high levels of sedimentation, nutrients and dissolved oxygen which they implied promoted phytoplankton production in the nearshore waters of Viper Island and Minnie Bay, where the tsunami waves were high.

5.1.3. Reef fish

In a detailed study that included coral reef fish in Aceh, Campbell *et al.* (2006) found no clear evidence of disturbance to the reef fish assemblages of northern Aceh. Further they concluded that because they detected no major change in benthic habitats it would be highly unlikely that reef fish would be adversely affected by the tsunami in indirect ways. Campbell *et al.* (2006) suggested that these results be treated cautiously because data from before the tsunami were generally lacking. They found that the overall abundance of fish was high at a site where damage to corals was most pronounced, compared to another where there was very little damage to corals.

In another study in Aceh, low abundance and small mean size of the ten primary food fish families was attributed not to the tsunami, but to overfishing. Evidence of destructive fishing practices was common. Overfishing can lead to an imbalanced ecosystem in which the lack of herbivorous fish allows fleshy algae to overgrow corals and dominate the coral reef (Foster *et al.* 2006).

In Sri Lanka rapid assessments of the impacts on coral reef fish put the damage due to the tsunami at relatively high levels. Loss of small reef fish was noted in four out of six locations across the affected parts of the country, in association with significant damage to reefs. In Dutch Bay where reef damage was considered extreme, fish life was reduced drastically (NARA *et al.* 2005; Rajasuriya 2005). The main groups affected were damsel fish, butterfly fish, wrasses and surgeon fish.

5.2. Fisherfolk’s perceptions: PRAs in Aceh and Sri Lanka

An important part of this study was consultation through participatory rural appraisals (PRAs) of affected fishing communities in Aceh and Sri Lanka to determine the status of fisheries, fisheries resources and ecosystems. This work was undertaken in Indonesia (Aceh) and Sri Lanka by teams of national consultants between March and July 2006. The aim of the PRAs was to discuss fisheries resources and fishing pre- and post-tsunami to identify: (i) status and trends prior to the tsunami; (ii) the impacts of the tsunami; and (iii) gather people’s opinions on how their fisheries should be managed in the future. These studies were focused on the *perceptions* of fisherfolk and others involved in fisheries, acknowledging that they are likely to have significant anecdotal knowledge of their resources and fishing behaviour. Fishing communities are also those that are most directly affected by any changes resulting from the tsunami and will be part of management strategies that may follow. It should be noted, however, that the PRA assessments were carried out in post-emergency conditions in both countries and results may be influenced by the trauma experienced by communities and the limited capacity of facilitators.

Communities and fisherfolk groups were approached through structured focus group discussions and key informant interviews. In Aceh, at least six focus group discussions involving six to 12 people and five key informant interviews were carried out in each of the eight sites (Aceh Jaya, Pidie, Lhokseumawe, Idi, Langsa, Aceh Barat, Aceh Besar and Banda Aceh) (Tampubolon *et al.* 2006). The surveys undertaken in Aceh are incomplete and have not been fully analysed for all sites.

In Sri Lanka surveys were undertaken at 11 sites within the tsunami-affected districts of Galle and Hambantota, with additional information collected at three sites in Kalutara (Maldeniya and Jayamanne 2006). Although 12 coastal districts in the country were affected, the studies focused on Galle and Hambantota because of the importance of fisheries on the economy of the districts, the presence of many fisherfolk and fisheries and the magnitude of impact on the resources and habitats. Kalutara District, also heavily impacted, was included to provide information on the important beach seine fishery. The sites selected were: Galle – Balapitiya, Maduganga Estuary, Ambalangoda, Rathgama Lagoon, Galle Harbour and Galle Dewata; Hambantota – Mawella Lagoon, Unakuruwa, Rekawa Lagoon, Kahandamodera and Kirinda; and Kalutara – Payagala, Beruwala and Maggona. In each area all (fisheries) cooperative societies and environmental organizations were interviewed, but community members involved in the group meetings were sampled and not selected by any specific criteria. Approximately 25 to 100 people participated in each meeting. Additional environmental assessments were made by the survey team at each site.

The information obtained through these meetings focused on: (i) historical maps of major fisheries and ecosystems with key events; (ii) identification of the impacts on fisheries and ecosystems; (iii) fisheries seasonal calendars and impacts of key events; (iv) identification of direct and indirect impacts by key events; and (v) community perceptions on mitigation. The main fisheries examined in the study were defined by a combination of habitat, gear and species identifiers and included demersal, lagoon, small and medium pelagic and beach seine fisheries; as well as the crustacean and chank fisheries. The ecosystems examined included estuaries, lagoons, mangroves, coral reefs, shallow seas and sandy and turtle-nesting beaches (Maldeniya and Jayamanne 2006).

5.2.1. Results of the PRAs for Aceh

Overall, the size of animals and species composition of catches remained the same after the tsunami at all sites (Table 4). Fisherfolk did, however, report an increase in prawns at Aceh Jaya, particularly in areas from which mangroves had been lost. Overfishing was reported at all sites, which at Aceh Jaya concerned lobsters. It is not clear whether this refers to general overfishing, or overfishing as a result of the tsunami (e.g. emergency fishing). At most sites, participants noted that catches had declined as a result of the tsunami at five of the eight sites and that fishing grounds were now located further offshore. It is not clear whether the greater distance to fishing grounds was thought to be a result of changes in the grounds themselves or overfishing. At Aceh Jaya human populations close to fisheries landing sites were smaller than pre-tsunami levels. Boat ownership declined as a result of the tsunami at five sites, but actually increased at Pidie. At one site (Idi) boats provided by donors after the tsunami were considered inappropriate and could not be used for fishing. Participants reported some environmental damage, including a loss of between 100- and 300-metre strips of coastal land and loss of mangroves at Aceh Jaya. At Aceh Besar, fisherfolk reported that damage to the mouth of the river impeded their access to the sea. Most participants reported that they thought that catches had declined in their area compared with five years previously (including non-tsunami declines). Pidie was an exception: Fisherfolk reported an increase in catches over the last five years, with a decline since the tsunami.

Table 4: Summary of main PRA results from 8 sites surveyed in Aceh Province

Data are from Tampubolon et al. (2006) with ⬄ No change; ⇧ Increased; ⇩ Decreased; ● Greatly decreased.

	Aceh Jaya	Pidie	Lhokse-umawe	Idi	Langsa	Aceh Barat	Aceh Besar	Banda Aceh
Impacts of the tsunami								
Size	⬄	⬄	⬄	⬄	⬄	⬄	⬄	⬄
Species	⬄	⬄	⬄	⬄	⬄	⬄	⬄	⬄
Abundance	⇧ prawns							
Overfishing	Lobster	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Catches		⇩	⇩ Purse seine	⇩	●	⇩	⇩	⇩
Fishing grounds	⬄	Further		Further		Further	Further	Further
Boat ownership	⇩	⇧	⇧	⇩	⬄	⇩	⇩	⇩
Role of women	⬄	⬄	⬄	⬄	⬄	⬄	⬄	⬄
Role of children	⬄	⬄	⬄	⬄	⬄	⬄	⬄	⬄
Environmental change	100–300 m coastal land lost; mangroves lost				⬄		Damage to river mouth	
Other changes not related to the tsunami								
Catches compared with 5 years ago	⇩	⇧	⇩	⇩	●	⇩	⇩	⇩*

* This decline appears to refer to three years ago instead of five.

Participants in the PRAs made recommendations on strategies for recovery and management of their fisheries. The main recommendations made across all of the sites were:

- There must be regulation and enforcement (especially of gear and fishing areas) or five years from now there will be “dangerous” levels of overfishing and/or a decline in incomes from fishing;
- Trawling should be stopped because of effects on fisheries resources, particularly by boats from North Sumatra and Thailand;
- There should be better facilities (ice, cold storage) to support export;
- There should be assistance in the form of training for fisherfolk;
- There should be financial assistance to fisherfolk;
- Mangroves should be rehabilitated; and
- The role of women should be improved, especially in processing and fisheries management.

5.2.2. Results of PRAs for Sri Lanka

Participants of the PRA surveys held in Sri Lanka identified a wide range of changes in their local fisheries and ecosystems (Table 5), some of which were confirmed by analyses of historical catch data (Section 5.1) and site assessments undertaken by the team. During the PRA fisherfolk identified cases in which there were declines in catches of pelagic, reef and lagoon fish, particularly in Galle and Hambantota.

Table 5: Summary of main PRA and assessment results from 14 sites surveyed in Sri Lanka

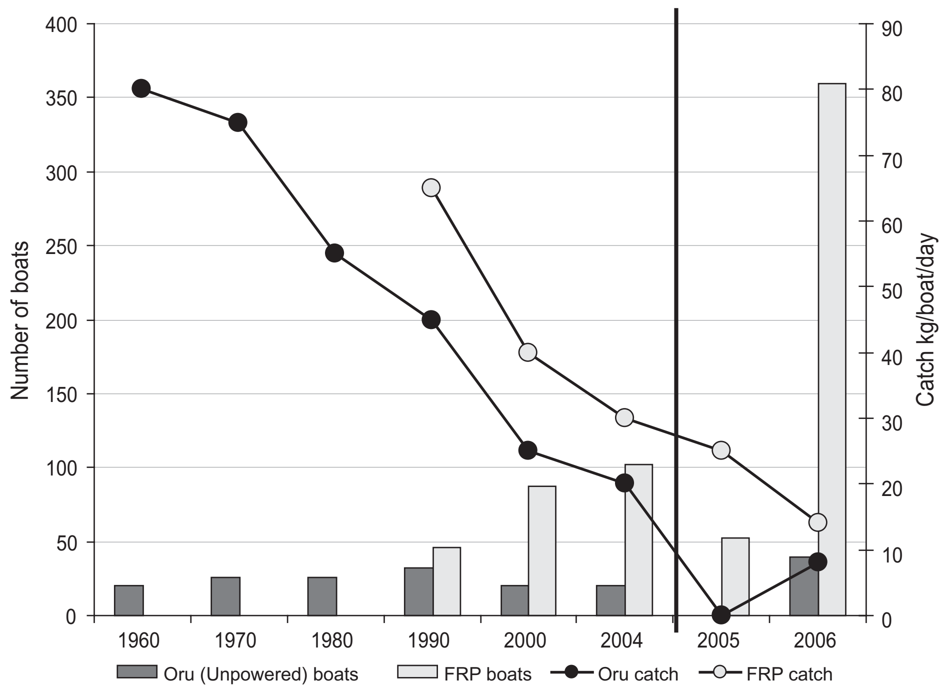
Data are from Maldeniya and Jayamanne (2006) and include PRA results (⊙) and assessments made by the team (■). ⇔ No change; ⇧ Increased; ⇩ Decreased.

	Galle	Hambantota	Kalutara
Impacts of the tsunami on fisheries (PRA only)			
Beach seine	⇔ But debris obstructs fishing	⇔ But debris obstructs fishing	⇩ Anchovies
Small pelagic	⇩ Trenched sardine	⇩ Trenched sardine ⇧ Hilsa	
Medium pelagic	⇩ Frigate tuna	⇩ Frigate tuna	
Reef fishing	⇩ Seer fish, ornamentals ⇧ Large demersal	⇩ Large demersal, chanks	
Lagoon fishing	⇧⇩ Initial increase in prawns, followed by decline	⇧⇩ Initial increase in prawns, followed by decline ⇩ Lobsters	
Crustaceans	⇔ But catches down due to loss of gear	⇔ But catches down due to loss of gear.	
Fish landings/harbours	Debris	Debris	Debris
Boat ownership	⇧ 77–315% oversupply	⇧ 50–275% oversupply	⇩ 55% replacement
Impacts of the tsunami on ecosystems (⊙ PRA and ■ team assessments)			
Beaches/dunes	⊙ Erosion	⊙ Dunes damaged ■ Dunes damaged where previously disturbed. Vegetated dunes minor damage now recovering.	⊙■ Erosion
Mangroves	⊙■ Minor	■ Frontline trees severely damaged.	
Sea-grasses	■ Minor	■ Minor	
Lagoons/estuaries/bars	⊙■ Debris, pollution, encroachment ⊙ Poor water exchange ⊙ Opening of bars ■ Closure of bars	⊙ Debris, sedimentation ⊙■ Opening of bars. One converted from fresh to brackish, now reverting.	⊙ Debris
Reefs	■ Low–extreme	■ High–extreme	■ Yes. Has recovered naturally
Rehabilitation?	⊙ Beaches	⊙ Ad hoc work has been done on mangroves, beach vegetation.	⊙■ Beaches

It is not always entirely clear from the results whether the changes were thought to be effects on populations of the target species, or whether they were related to reduced effort after boats and gear were lost. In the beach seine and crustacean fisheries in Galle and Hambantota it was clear that fisherfolk thought that there were no changes in the stocks and that catches were down because of debris hampering fishing or the lack of gear. Interestingly, for lagoon fisheries, people in two districts reported a temporary increase in shrimps which was then followed by a decline. This compares with the findings in Aceh (Aceh Jaya) where a similar increase in prawns was observed in areas where mangroves had been removed. In Galle and Hambantota, participants reported a serious oversupply of boats and in some cases, replacements of traditional boats with motorized craft. Impacts on fisheries ecosystems included effects in all major habitats, ranging from erosion, loss of mangroves, problems with debris and pollution and changes in lagoons brought on by altered physical conditions (water flow, sedimentation, opening or closing of sand bars).

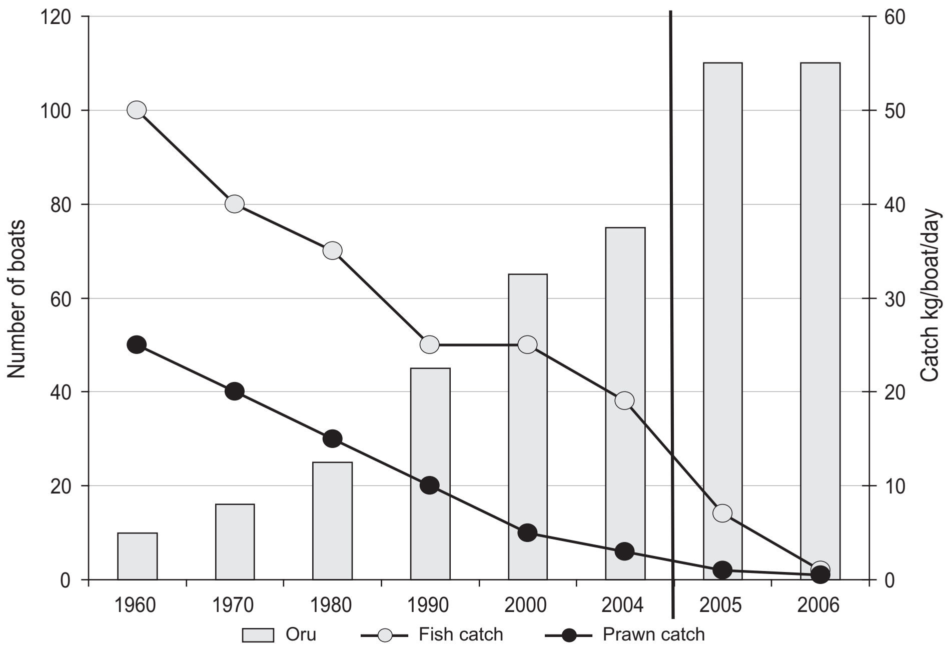
Galle: The small pelagic fishery shows an influx in FRP boats from the 1990s, with non-motorized traditional craft (Oru) being in use before and since that time (Figure 10). Catches by both types of boat show a steady decline since the 1960s (Oru) and 1990s (FRP). For traditional boats, catches dropped from 80 kg/boat/day in the 1960s to 20 kg/boat/day in 2004 and zero in 2005 after all of the boats were wiped out by the tsunami. In 2006 their catch rates rebounded to about 8 kg/boat/day. For FRP boats catches fell from around 65 kg/boat/day to around 12 kg, but there was no change in the trajectory of this line resulting from the tsunami. This could be related to the way boats were replaced, as most of the lost traditional boats were replaced with FRP boats. The medium pelagic fishery saw a decline in unpowered boats and a slow increase in ring-net boats, with a gradual increase overall between the 1960s and 2005. In 2006, the number of FRP boats increased dramatically, with more than 1 000 boats added to the fleet by 2006 (Maldeniya and Jayamanne 2006). At the same time, the catch per boat per year declined for unpowered craft and increased for FRP and ring-net boats. After the tsunami, catches by powered boats decreased significantly, while those for unpowered boats increased slightly. The beach seine fishery in Galle showed a decline in catches between the 1990s and 2006, with the trend continuing unchanged around the time of the tsunami. Despite the fact that all boats were lost, they were fully replaced in 2005 (Maldeniya and Jayamanne 2006). Data on lagoon finfish and shrimp fisheries are limited, but show decreasing effort for prawns and increasing effort for finfish. Boats were not seriously affected by the tsunami but debris in the lagoons is hindering fishing. There is an indication of declining catches for finfish and prawns.

Figure 10: PRA results for the small pelagic fishery at Dewata, Gallle, showing changes in numbers of traditional unpowered and FRP boats, and the catch over time. The red line is the tsunami



Hambantota: The long-term trends and responses of fisheries to the tsunami in Hambantota showed similar trends to those seen in Galle. The small pelagic fishery in this district has witnessed a change in boat types from traditional unpowered and then powered boats to FRP boats which were introduced in the 1980s. Many boats were lost to the tsunami, but in 2006 they had been replaced and there was an increase in FRP boats of 49 percent. Catches by all boat types show a declining trend since the 1960s for traditional boats and almost since the time of introduction of FRP boats. Catches to date in 2006 are still low, despite more boats. In medium pelagic fisheries, 28-foot-inboard day boats have been replaced gradually by FRP boats since the 1970s. Most of the FRP boats were lost during the tsunami, but have now been replaced; there are now many more boats than before the tsunami. Over the same period, in Kalametiya, catch rates declined from around 250 kg/boat/day (28-foot boats) and 100 kg/boat/day (FRP boats) in the 1970s to 20 and 10 kg/boat/day by mid-2006. A similar pattern was seen in Mawella where gillnet catches of 1 500 kg/boat/day in 2000 declined to about 250 kg/boat/day in mid-2006. The beach seine fishery has witnessed a decline in catches since the 1960s, with very low catches in 2000. Only one boat remains in operation after all of the others were lost in the tsunami. None of the boats have been replaced and fishing is severely restricted by the debris in shallow waters. The Rekawa Lagoon fishery had a steady increase in the number of boats between the 1960s and 2004. None of the boats were damaged by the tsunami, but the number of boats increased by 44 percent subsequently. Catches of fish and prawns have been declining in the lagoon fishery since the 1960s, a trend which continued after the tsunami (Maldeniya and Jayamanne 2006).

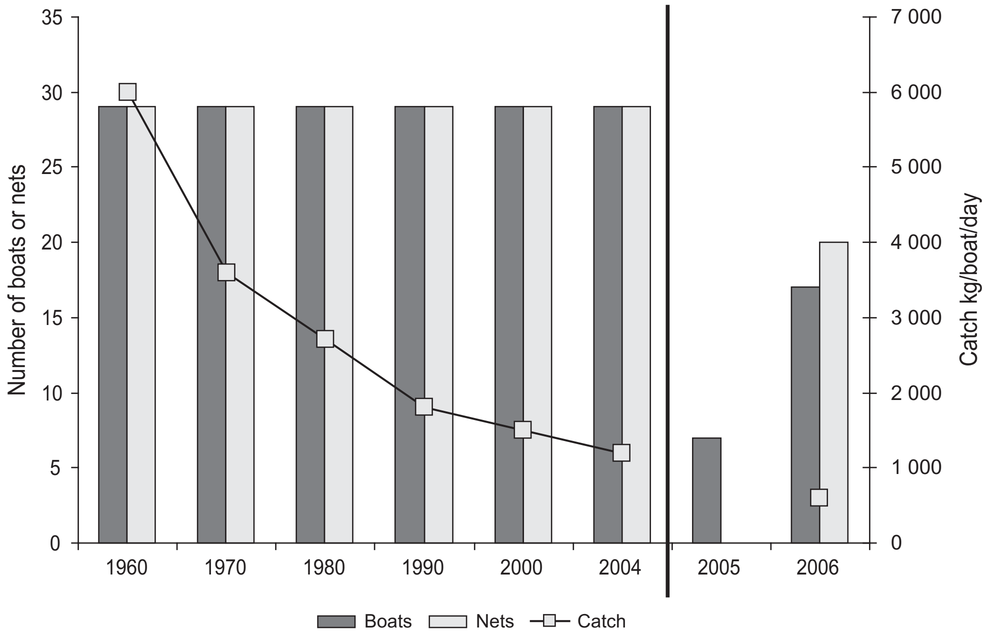
Figure 11: PRA results for the lagoon fishery at Rekawa, Hambantota, showing changes in numbers of traditional unpowered boats (Oru), and catches over time. The red line is the tsunami



Kalutara: The beach seine fishery in Kalutara (catch/boat/day) has been declining since the 1960s dropping from almost 6 000 kg/day to just over 1 000 kg/day (Figure 12). This declined further after the tsunami, probably because of losses of boats and gear.

Maldeniya and Jayamanne (2006) concluded that coastal fisheries had declining catch rates for a long time before the tsunami and were in trouble before it struck. Most of the coastal fisheries resources have been overexploited or exploited to their maximum. Further, productivity may be declining due to damage to the coastal ecosystems and destructive fishing methods in use.

Figure 12: PRA results for the beach seine fishery at Kalutara, showing changes in numbers of boats, nets and the catch over time. The red line is the tsunami



5.2.3. Outcomes of PRAs and National Workshops

Through the PRA process, followed by national workshops held in Aceh and Sri Lanka (MMAF 2006; NARA 2006), participants identified issues related to tsunami impacts and recommendations for addressing tsunami and non-tsunami impacts on fisheries ecosystems. The most important of these included:

Fisheries

- Long-term trends of declining catches are evident in Aceh and Sri Lanka and overfishing is recognized as a problem by communities;
- Problems with relief delivery (oversupply of boats, wrong beneficiaries, poor quality boats, unethical practices, beach seining and diving have been overlooked). As a result, there has been a change in the number of fisherfolk, boats and/or gear which has led to increased fishing capacity in some locations;
- Reduced access to fishing grounds (Sri Lanka) and changes in location of grounds (Aceh). This is related to the establishment of sanctuaries, uncleared debris, coastal protection structures, encroachment by housing and other commercial activities;
- Weak institutions and enforcement are leading to unenforceable management arrangements, conflicts among fisherfolk and industry and questions of “who comes first: local or foreign fisherfolk?” There is a clear need for improved capacity and better fisheries information on which to base management;
- There is a need to diversify fisheries livelihoods and promote alternative livelihoods. There is a lack of skills for alternative (non-fisheries) livelihoods;
- Lower fish prices and increasing fuel prices are affecting fishing, including the distance fisherfolk can travel to fishing grounds;
- Continuing use of destructive fishing methods;
- Support for women’s livelihoods is lacking;
- There is increased fishing effort on some resources (chank).

Ecosystems

- Strategies and policies are needed to reduce vulnerability and improve resilience. This includes strengthening of cooperation for the rehabilitation of ecosystems (including beaches);
- Develop standardized methods to identify needs for rehabilitation;
- Mapping to identify areas for conservation and sustainable management;
- Develop guidelines on the "correct" balance of species in ecological zones, protection requirements and support of natural regeneration;
- Develop guidelines on green belts to provide protection to coastal communities;
- Develop sustainable livelihoods and increased earnings for coastal communities;
- Improve environmental awareness.

Workshop participants suggested a range of actions that could be taken to address these issues. In Sri Lanka, some of the recommendations centred on *increasing* fish production and use of remote sensing technology and better boat design to increase catch efficiency, while at the same time promoting better fisheries management. Other recommendations focused on reducing fuel use through promoting use of the sail, maximizing income through value-adding and providing training for alternative livelihoods, particularly for women. Participants suggested that problems with reduced access to fishing grounds would be best addressed through better coordination among agencies (referring to the establishment of sanctuaries and coastal protection) and better planning.

In Indonesia, participants highlighted a range of actions including better stock assessments, improving livelihoods through better safety, facilities and diversification into post-harvest processing, aquaculture and land-based livelihoods and improving the aid delivery process. They also suggested that weak institutions would need to be strengthened to deal with the complex issues that have arisen since the tsunami, including conflicts among fisherfolk and industry and, in some areas, increased fishing capacity.

5.3. Effects on fisheries-related habitats

In addition to providing a wide range of services to humans (e.g. nutrient cycling, flood control, protection) (Chong 2005), coastal ecosystems provide the critical habitats that support the wide range of fished species found in Aceh and Sri Lanka. Loss or serious damage to these habitats could be expected to lead to declines in resources either in the short or longer term.

Fisheries habitats are here defined as those zones that provide significant ecosystem support to either fished resources or to fisherfolk themselves. In terms of tsunami-affected areas, fisheries habitats include coral reefs and other rocky or soft-sediment nearshore areas, sea-grass areas, coastal lagoons, estuaries and mangroves. Beaches are an integral part of the coastal lagoon systems of Sri Lanka, and in many countries provide sites for fisherfolk to maintain and store boats, clean fish, market their products, service nets and carry out other fishing-related tasks. For the purposes of this study, the review will focus on habitats for fished resources rather than on services provided to fisherfolk.

5.3.1. Coral reefs

Most of the work that has been carried out in tsunami-affected areas on habitats of direct concern for fisheries resources has centred on coral reefs and is reviewed and summarized by Wilkinson *et al.* (2006). Coral reefs, considered fragile, can be slow to recover and can provide significant fisheries habitats and/or livelihoods. In Aceh and Sri Lanka coral reefs would only contribute direct habitat support for a small part of the overall marine catches which are more focused on pelagic, trawled and offshore species. An initial assessment of damage by the Indonesian Government was that there was 30 percent damage to 97 250 hectares of coral reef in north Sumatra at a net loss of US$332.4 million. There was, however, little baseline information on the status of coral reefs in the area on which to base this estimate (ICRI 2005) and concerns over coral reef damage (LIPI and IMR 2006) are based on general condition, but not deviation from pre-tsunami conditions. There were a few cases of spectacular damage, particularly near the epicentre on Simeulue Island, with cases of uplift and submergence (Foster *et al.* 2006; LIPI 2006). On other reefs there was substantial mechanical damage, mainly due to debris and sediments washed off the land. According to ICRI (2005) tsunami damage was additional to considerable prior damage from human activities, especially destructive fishing (including fishing with explosives).

A study using data from before and after the tsunami detected no changes in the shallow coral assemblage on Pulau Weh in Aceh (Baird *et al.* 2005), despite an estimated run-up height of 5 metres at this location (USGS 2005). In this study there was no detected change in shallow water coral assemblages between March 2003 and April 2005, with the exception of one site smothered by sediment. This was supported by the findings of Rudi and Fadli (2005) who also reported generally good reef conditions and attributed degradation of coral reefs at Weh Island to human activities such as illegal fishing. Reef conditions in Aceh varied widely within the province and were clearly correlated with management regimes. Coral cover was high, and the cover of algae and rubble low at Kawasan Wisata and Panglima Laut sites (under management). In contrast, coral cover was low and the cover of algae and rubble was high at open access sites. Baird *et al.* (2005) and Campbell *et al.* (2006) described the damage to reefs in Aceh as occasionally spectacular, but surprisingly limited, given the proximity of their sites to the epicentre of the earthquake.

In Sri Lanka, information on damage to coral reefs is limited. Rapid assessments of the impacts on corals put damage due to the tsunami at relatively high levels (NARA *et al.* 2005; Rajasuriya 2005), describing it as “widespread” (CORDIO and IUCN 2005) and “patchy” (UNEP and MENR 2005). In one location on the southwest coast, zero impacts were recorded for coral reefs, while for most other locations the impacts were reported as medium or high. The greatest impacts were reported from Dutch Bay where reef damage was considered extreme.

According to ICRI (2005) the overall damage to the coral reefs of the region was site dependent and heavily influenced by local environmental conditions such as water depth (shallow reefs most affected), damage to land and coastal morphology (e.g. the presence of channels between islands which focused wave energy). Baird *et al.* (2005) also found that direct damage in Aceh was dependent on habitat, being largely restricted to corals growing in unconsolidated substrata. The picture from the majority of the other reports from the Indian Ocean (Brown 2005; Comley *et al.* 2005; Gunn *et al.* 2005; Satapoomin *et al.* 2006) is that the damage caused to coral reefs by the earthquake and tsunami was rarely of ecological significance. Even in northern Aceh close to the epicentre, tsunami damage was trivial when compared with that caused by chronic anthropogenic impact.

Site assessments undertaken by NARA staff in Sri Lanka as part of this study, and the opinions of fisherfolk during the PRAs, showed that damage to reef ecosystems did occur, but was site specific in effects (Table 5) (Maldeniya and Jayamanne 2006). Damage to coral reefs was recorded at all three districts surveyed, but Kalutara has already recovered naturally. At Galle and Hambantota, damage ranged from low to extreme, with some areas subject to very localized damage and others, such as Unawatuna damaged over a broad area. Most of the damage reported occurred through smothering by sediments or debris, and the shifting of coral rubble.

The main lessons learned on impacts to coral reefs were:

- Most damage to the corals was caused by sediment and coral rubble thrown about by the waves, and smothering debris washed off the land;
- Damage to reefs was greatest in Indonesia, Thailand, the Andaman and Nicobar Islands and Sri Lanka. There was little damage in countries further away from the source due to decreased tsunami wave energy and height;

- Most of the coral reefs of the region escaped serious damage and will naturally recover in five to ten years, assuming reduced harmful anthropogenic activity;
- A few coral reefs were significantly damaged and may take many years to recover and then possibly not to the previous structure;
- Tsunamis have unique mode of action not shared with other forms of disturbance such as cyclones making their impacts more patchy and not devastating to large areas;
- Ongoing human threats to coral reefs were far more damaging to coral reefs than the tsunami. Coral cover in the Pulau Weh Marine Reserve and in areas under traditional fisheries management (Panglima Laut) had much better coral condition than at open access sites likely to be subject to destructive fishing practices (Baird *et al.* 2005; Campbell *et al.* 2006); and
- Throughout the Indian Ocean, healthy coral reefs were better able to withstand the force of the tsunami and may have offered increased protection to adjacent coastal areas (IUCN 2005b; CORDIO and IUCN 2005; Marris 2005).

5.3.2. Mangroves and sea-grasses

CORDIO and IUCN have carried out extensive work on damage to mangrove forests, particularly in Sri Lanka, because of their reported mitigation of the effects of the tsunami on human communities. Mangrove forests are considered highly threatened and provide services to humans (Dahdouh-Guebas *et al.* 2005; Danielsen *et al.* 2005; IUCN 2005d; Kulkarini 2005), including breeding, spawning, hatching and nursery grounds for marine and pelagic species, and livelihoods for human communities. Further, it is now being debated whether mangroves may have mitigated impacts of the tsunami on human life and property (Kathiresan and Rajendran 2005; Kerr *et al.* 2006). Answering this question has significance not only for humans and the mangrove habitats themselves, but also for fisheries habitats (coastal lagoons, nearshore areas, estuaries, etc.) that might have been buffered from damage either directly or through decreased land-based pollution. In areas with maximum tsunami intensity, it is thought that little could have prevented catastrophic coastal destruction. Further away, areas with coastal tree vegetation may have been less damaged. Modelling suggests that tree vegetation may shield coastlines by reducing wave amplitude and energy (Massel *et al.* 1999 in Danielsen *et al.* 2005) and that 30 trees/100 m^2 in a 100-metre-wide belt may reduce the maximum tsunami flow pressure by more than 90 percent (Hiraishi and Harada 2003).

Whilst there is little published information on the effects of the tsunami on mangrove habitats in Indonesia, Wilkinson *et al.* (2006) reported that in Aceh entire forests were destroyed. In Sri Lanka, IUCN (2005e) investigated damage to mangroves in Batticaloa where the tsunami wave was about 6 metres high at the shore and penetrated up to 1 kilometre inland, across a complex mixed vegetated and settled landscape. This complex environment evidently absorbed and dissipated much tsunami energy so that although coconut palms close to the sea were damaged, the lagoon was affected negligibly.

Sea-grass beds were also largely unaffected. There were cases in which beds of sea-grasses were damaged either in channel areas where currents were concentrated, or in areas smothered by sediments (Wilkinson *et al.* 2006). In Thailand, less than 5 percent of sea-grass beds were affected and those smothered by sediments or eroded by the currents and waves are expected to recover within a year (ICRI 2005; Phongsuwan and Tun 2005). Damage to sea-grass beds in Sri Lanka was also minor (UNEP and MENR 2005). Localized damage to sea-grasses was greatest in Yao Yai Island in Phang-nga Province of Thailand where 10 percent of the sea-grass areas was destroyed (ICRI 2005).

5.3.3. Coastal water quality

A few studies have focused on changes in nearshore water quality and characteristics, with most of them reporting little change from pre-tsunami conditions. In some cases reports of elevated nutrients, pollution and turbidity were reported soon after the tsunami, but there was no follow up to determine the longevity of the effects. Only one study was carried out off Aceh, and several off the coast of India. It was not possible to find studies carried out in other affected countries, particularly Sri Lanka.

Soon after the tsunami, general physical and chemical water properties in Aceh were found to be similar to pre-tsunami baseline levels and within national standards for pollution, including faecal coliforms (LIPI 2006). This study does not give details on the variables measured, their locations or values and contradicts some findings of increased sedimentation and turbidity over coral reefs (Baird *et al.* 2005) and that visible from satellite photos of other nearshore areas (UNEP 2006). In July–August 2005, LIPI and IMR carried out oceanographic studies to find indications of tsunami impacts, including changes in ecosystems and productivity (LIPI and IMR 2006). They examined oceanographic conditions, nutrients, pollution and the chemical properties of seawater. The researchers concluded that there were no indications of anomalous chemical conditions in the areas surveyed and that concentrations of dissolved oxygen, phosphates, nitrates and silicates were normal. They also found that there was little impact through pollution — concentrations met Indonesian standards.

Additional information on possible impacts on water quality comes from India, where several studies were undertaken including water quality sampling and satellite analysis. On the Chennai coast, the Adyar and Cooum rivers are polluted by sewage and are normally closed for most of the year because of accretion across the river mouths. DOD (2005) reported that the tsunami opened them temporarily, flushing polluted waters and sludge into nearshore areas. They anticipated that this may have had a significant but temporary impact on coastal waters and biota. Indicator bacteria (including *E. coli*, faecal coliforms and *Salmonella*) normally found within 3 kilometres of the coast, were found 10 kilometres out to sea. A study of impacts on biological resources by Annamalai University (DOD 2005) found effects on water quality in the mouths of estuaries and their backwaters, and in the coastal waters between 5 to 10 kilometres offshore. Nutrient levels, especially nitrogen, increased in several rivers and in the coastal waters 0.5 to 1 kilometre offshore. A phytoplankton bloom (*Lauderia borealis*) was recorded only in the coastal waters off Chennai and not in any other area investigated. Effects on zooplankton populations were also recorded, but these were patchy. The Regional Research Laboratory (RRL) sampled water quality off Kerala and Tamil Nadu, reporting decreased nutrients, productivity and phytoplankton, effects on fish catches and evidence of the transport of sediments offshore (DOD 2005).

An analysis of Oceansat OCM Data by NRSA, Hyderabad (DOD 2005) revealed that sea surface temperatures (SST) of Andaman and Nicobar coastal waters dropped by around 1 C on the day of the tsunami. NRSA also recorded an increase in turbidity in coastal waters between Chennai and Nellore, along the Andhra and Tamil Nadu coasts and the Andaman Islands. In addition to an increase in suspended sediments, highly turbid waters increased their range from 15 kilometres offshore and 50 metres depth as far as 45 kilometres offshore and 1 000 m depth off the Chennai coast. Impacts on coastal chlorophyll concentration included a threefold increase between 25 and 31 December 2004. Although these effects were reported as temporary, DOD (2005) suggested again that effects could be significant on marine organisms. They did not, however, give any indication of how long the effects on SST and turbidity lasted in the areas observed, or any information on actual impacts on marine organisms. Applied Analysis Inc. (2005) carried out preliminary analyses of ICONOS images acquired three days after the tsunami over Porto Novo, India. They found that inland waters were heavily impacted by suspended minerals, with effects extending approximately two kilometres offshore. At the same time, chlorophyll concentrations were variable inland and elevated in a band about three kilometres offshore. No information was given on the longevity of these effects or an update on their current status.

5.3.4. Other coastal habitats

Beaches, coastal dunes, lagoons, mudflats, soft sediment areas and estuaries play a significant role in fisheries in most of the tsunami-affected countries (Sydnes and Normann 2003; Salagrama 2006). In Sri Lanka, for example, there are 45 major brackish-water lagoons and estuaries, with a total water area of

158 000 hectares; the total area covered by mangrove swamps, mudflats and salt marshes is approximately 71 000 hectares. There has been no estimate of impacts on resources in Sri Lanka's unique beach "Stick Fishery" and the resources fished from the closed coastal lagoons.

There are some anecdotal reports of effects for shallow subtidal areas. In a study of tsunami deposits around Aceh, LIPI (2006) identified a layer of tsunami sediments, between 5 and 22 centimetres thick, in 75 percent of samples in coastal marine habitats. In shallow areas, the deposits comprised sand and pebbles, while in deeper areas silts and muds were recorded. Despite the potential, at least in the short term, for tsunami deposits to smother benthic communities, LIPI (2006) reported that seven months after the tsunami benthic communities showed no clear indications of impact. In India, Salagrama (2006) reported that fisherfolk on the Coromandel Coast complained that the fishing grounds had changed, with an increase in depth at the traditional grounds and changes in water currents and tidal patterns near the shore. They reported that many species, particularly shrimp, had been "relocated" by the tsunami and the fisherfolk had to seek new fishing grounds.

Lagoons were temporarily affected by the tsunami in Sri Lanka in many places, inducing changes in the biota of lagoonal and wetland ecosystems as salt and marine sand had intruded and drainage channels had been changed (IWMI 2005). Observers generally concluded, however, that most lagoons have more or less recovered ecologically since the tsunami, except to the extent that they had accumulated sand, debris and litter (e.g. IUCN 2005e; MENR 2005).

5.4. Changes in fishing effort

Part of the potential for impact on fisheries resources caused indirectly by the tsunami comes in the form of changes in fishing effort. Changes in fishing effort may operate simultaneously in both directions. An increase in effort may occur if people turn to fishing and/or collecting to meet their immediate needs in times of emergency. Emergency fishing may occur during times of war, famine, displacement and natural disasters. Decreases in fishing effort can and did occur. They are associated with loss of fisherfolk, boats and other fishing infrastructure (wharves, ice plants etc.), and in some cases may be attributable to psychological reasons.

5.4.1. Losses of fisherfolk, fishing gear, boats and infrastructure

The fishing effort was severely affected by the tsunami in Aceh Province and many of the eastern and southern districts of Sri Lanka. It was estimated that in Aceh around 10 to 12 percent of the fisherfolk in the province were killed by the tsunami, with the greatest losses recorded in those districts closest to the northwest tip (Matthews and Ghofar 2006; NACA *et al.* 2005; Sykuri and *et al.* 2005) (Figure 13). Fisherfolk mortality was greatest in Aceh Besar (around 33 percent) and was unexpectedly low on Sabang Island and Simeulue where local topography is thought to have protected harbours and the population in general (Matthews and Ghofar 2006).

In terms of fishing boats, around 50 percent of boats with either an inboard or outboard engine were lost or damaged during the tsunami in Aceh Province. This figure was around 30 percent for sailboats. Matthews and Ghofar (2006) did note some inconsistencies in the Sykuri *et al.* (2005) data, with considerably more lost boats than the original number in some cases, but the picture is generally clear and damage extends throughout the province (Figure 14).

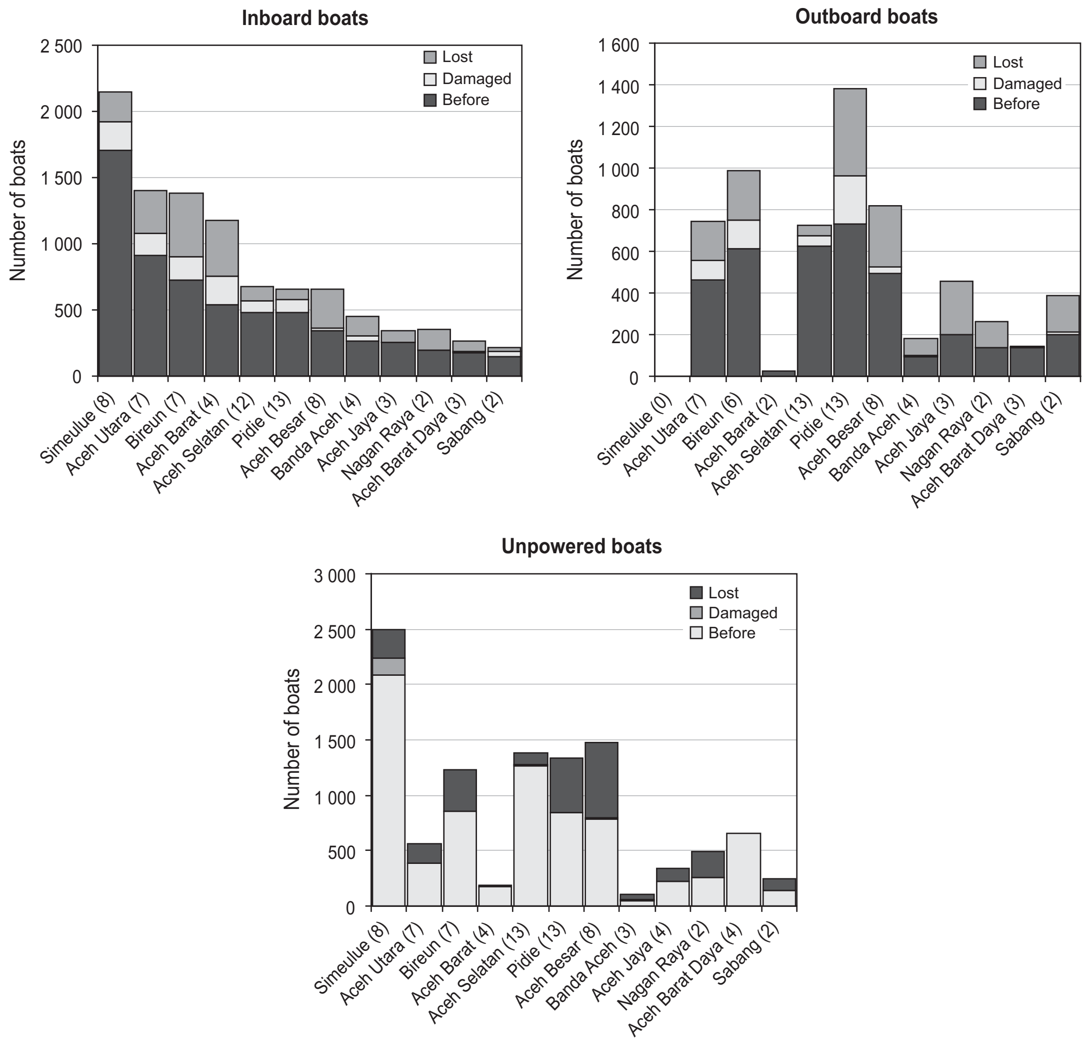
It has been estimated that around three-quarters of the fishing gear in Aceh's tsunami-hit areas were lost or severely damaged by the tsunami (Janssen 2005). This translates to the loss of around 20 000 units of fishing gear (out of 26 000 recorded in 2003) and an estimated financial loss of US$18 million. Although Janssen discussed the loss of gear in terms of financial damage, in terms of capacity for fishing, the loss/damage to gear may be highly significant because most vessels are equipped with several sets of nets and other gear, which may be used depending on season, type of fish and fishing method. There is no information currently on rates of replacement of lost nets, lines and other equipment.

Figure 13: Numbers of fisherfolk lost in Aceh Province, Indonesia

Pie data are derived from Sykuri *et al.* (March 2005) and show the proportion of fisherfolk lost (red) in each district. Values are based on estimates made during assessments of 78 subdistricts across 12 districts in the province. Values in parentheses after each district name show the number of subdistricts assessed. Data for Banda Aceh and Aceh Utara are added from Matthews and Ghofar (2006). The background map is from HIC and shows affected villages in red.

Figure 14: Summary of losses and damage to fishing boats in Aceh Province, Indonesia

Data are derived from Sykuri *et al.* (March 2005) and show losses and damage to 3 types of fishing craft. Values are based on estimates made during assessments of 78 subdistricts across 12 districts in the province. Values in parentheses after each district name show the number of subdistricts assessed. Bars are ranked in order of total number of inboard boats per district.



Significant losses of fisheries-related infrastructure were also recorded throughout Aceh Province, including drying facilities, fish aggregating devices, meeting halls, landing sites and piers, ice plants and fuel stations (Sykuri *et al.* 2005) (Table 6).

Table 6: Summary of losses of fisheries infrastructure in Aceh Province, Indonesia

Data are derived from Sykuri *et al.* (March 2005) and show losses based on estimates made during assessments of *n* = 78 subdistricts across 12 districts in the province.

Infrastructure	# Lost	*n* Subdistricts
Drying facilities	1 076	64
FADs	167	64
Meeting halls	73	60
Landing sites	52	53
Landing piers	23	50
Ice plants	20	43
Fuel stations	8	42

In Sri Lanka 4 870 fisherfolk were lost and 136 were still reported as missing in April 2006 (MFAR 2006). Added to this is the displacement of another 60 000 fisherfolk, with over 16 430 homes lost and a further 13 300 damaged (MFAR 2006).

More than 10 973 boats (37 percent) were lost and 4 411 (15 percent) damaged by the tsunami (Ministry of Fisheries estimates of January 2005 in CONSRN 2005b). Data on losses in fishing gear appear to be available only for six of the 14 affected districts with 10 994 units of gear lost. This figure is likely to be a serious underestimate as there are no figures for some of the most severely affected districts.

5.4.2. Repair, replacement and expansion of the fishing fleet

In Aceh, the Panglima Laut carried out a detailed assessment of the number of boats repaired and replaced in the province (Janssen 2005). They reported around 1 600 boats replaced and 224 repaired by the end of September 2005. They came from an uncoordinated mix of individuals and organizations and focused on 7–11-metre-long boats. Although they were the most commonly used size in Aceh, and many were lost or damaged, they were being replaced preferentially because of their affordable price and simple design (Janssen 2005). The distribution of boats across districts has also been uneven, with the four districts closest to Banda Aceh accounting for 40 percent of boat losses, but receiving 75 percent of all boats distributed or repaired (Janssen 2005). Bireuen, Lhokseumawe, Aceh Barat Daya, Aceh Selatan, Simeulue and Nias have received comparatively little in terms of boat support (BRR 2005). Further, Matthews and Ghofar (2006) reported anecdotal information for Aceh that suggests that around 40 percent of the boats built by NGOs since the tsunami are unsafe and unused. In other cases, donors provided boats, but not engines or gear. The Rehabilitation and Reconstruction NAD-Nias Executing Agency (BRR) estimated that only 600 of the total of 4 000 boats to be provided will have a complete set of gear (Janssen 2005).

Savins and Lee (2005) reported a range of problems with the boats being supplied to Aceh that tended to reduce the capacity for fishing. They reported that boats were being constructed poorly, at the lowest budget, to increase output numbers; they were being distributed to non-fisherfolk, reducing assistance to real fisherfolk and their families.

The major parties involved in fishery rehabilitation in Aceh (DKP, BRR, FAO, ADB and Panglima Laut) are only now focusing on the construction of larger boats. At the community level, a focus on larger vessels is criticized by the Panglima Laut and fisherfolk as many are still waiting for the replacement of the small boats. In 2004, however, a total of 638 boats of 10 metres or more in length were recorded in the Provincial Fisheries Statistics Yearbook. According to the Panglima Laut assessment a total of 802 larger boats (>12 metres) are planned for replacement, which may signal a significant potential for increase in the fishing fleet.

5.4.3. Emergency fishing or fishing avoidance?

There is little evidence, anecdotal or otherwise, of emergency fishing after the tsunami in either Aceh or Sri Lanka. In Sri Lanka it appears that the price of fish plummeted immediately after the tsunami, despite the decreased supply. According to Mr Leslie Joseph (Fisheries Consultant), people avoided eating marine products for fear that they may have been feeding on corpses. There are no figures on the number of fisherfolk that would have simply suspended fishing activities while they attended to recovery of their families, homes and communities. In terms of fisheries ecosystems, environmental considerations were neglected in Sri Lanka regarding decisions on the location of resettlement camps, new construction and the sourcing of building timber, where there had been losses of forests, including mangroves (UNEP and MENR 2005). There may also be some evidence of recent increases in illegal fishing in Sri Lanka at Rumassala Marine Sanctuary. Fish abundances were found to be similar to surrounding unprotected areas, but recent blast fishing craters were seen (IUCN *et al.* 2005).

In Kanyakumari, India, Salagrama (2006) reported that the tsunami had engendered a "fear psychosis" among fisherfolk about fishing in the sea, reducing their willingness to go fishing and restricting them to perceived "safer" nearshore waters (see also Miller 2005). One of the fears being faced by fisherfolk related to the well-being of their families while they were away.

5.4.4. Overall effect on the fishing effort

Government data suggest that at least 50 percent less fishing effort was expended in Aceh waters after the tsunami, compared with pre-tsunami levels. The greatest losses in fishing boats were of the larger, more powerful craft; this might mean that effort was even lower and that some recovery of normally heavily fished stocks might be expected. A range of factors has, however, been identified that suggests there is still a risk to the sustainability and livelihoods of fisherfolk in the region. The reasons quoted by CONSRN (2005c) and WorldFish (2005) include:

1. The catching power of new boats and fishing gear is likely to be higher than those they replaced;
2. Without sufficient options, new people may take up fishing as a livelihood facilitated by the availability of new boats and gear or resume destructive fishing practices;
3. Widespread damage to coastal habitats such as mangroves (and deforestation to support rebuilding efforts) may affect the sustainability of key fisheries resources.

There is now evidence that the number of boats has indeed exceeded pre-tsunami levels in some areas of Aceh and Sri Lanka (see Sections 3 and 5.3 of this study). The additional lessons learned as a result of data collected from landings and fisherfolk at the same time are:

4. In areas where effort was reduced in the form of boats and trips (e.g. Lampulo, Banda Aceh) total catches recovered and efficiency improved, exceeding pre-tsunami levels;
5. New fishing techniques are being introduced in affected areas, such as the antenna trawl reported in PRAs in Aceh; and
6. Where boats and/or gear were oversupplied, catches continued to decline and/or were lower than pre-tsunami levels.

6. CONCLUSIONS

Environmental change occurs at two extremes: (1) slow and incremental (e.g. fishing pressure, pollution) and (2) catastrophic (e.g. tsunamis and other natural disasters). It would appear that humans are very good at responding to catastrophic change but are more accepting of incremental change. This would explain how according to Adger *et al.* (2005) resilience can be eroded gradually and go unrecognized or be thought unimportant. The lessons learned of increased impacts from the tsunami in chronically impacted and degraded ecosystems should be taken as an alert for future management.

The evidence from the sources reviewed shows strongly that although there are localized cases of clear impact caused directly by the tsunami, most of the fished resources and their supporting ecosystems were not severely impacted by the tsunami but had already been in decline. Such pre-existing trends were acknowledged in the two national workshops run as part of this project in Indonesia and Sri Lanka (MMAF 2006; NARA 2006) though for Indonesia, there was a consensus among participants that there may still be some resources not yet fully exploited in Aceh. Overall, the current condition of resources is the result of these same trends and/or interactive effects resulting from reduced environmental resilience. In this study Maldeniya and Jayamanne (2006), Tampubolon *et al.* (2006) and others undertaken elsewhere (e.g. India, Salagrama 2006) fisherfolk agreed that declines in fish catches after the tsunami were generally a continuation of existing trends. This observation is generally supported by the scientific studies reviewed. It should be noted, however, that the fisherfolk of the Coromandel Coast were quite clear that the tsunami did influence fisheries resources, as their catches had never been as bad as they were in 2005, particularly during peak fishing seasons. In Aceh and Sri Lanka it was found that fisherfolk generally blamed the loss of boats and gear for this decline, though in some cases they seemed to suggest that abundance of some species had declined after the tsunami. An examination of historical catch data in Sri Lanka showed that declines occurred in all coastal fisheries and often extended back decades. Catch data and the fisherfolk in both countries indicate that catch rates continued to decline after the tsunami. In fact the main post-tsunami issues for the fishing communities raised in both countries were related not to declining catches but to “human factors” such as the rising fuel and falling fish prices.

It is also possible that the long-term effects of the tsunami could include some positive changes in resources, though information is generally lacking at this stage. Salagrama (2006) suggested that the “vigorous churning” of the waters in the Bay of Bengal from the tsunami contributed to an upwelling from the nutrient-rich benthic strata to the upper layers, and enhanced primary productivity which might be reflected further down the food chain as an increase in fish production over the coming years. In this study, there was evidence from the PRAs that prawn numbers increased in a damaged mangrove in Aceh Jaya in Indonesia and increased temporarily in Galle and Hambantota in Sri Lanka. *Hilsa* numbers were also increased in Hambantota.

The important lessons learned on fisheries, fished resources and their ecosystems are:

- Fisheries resources and ecosystems have generally not been significantly impacted by the tsunami, though there are some local cases of effects. The fisheries resources of Indonesia and Sri Lanka can be expected to recover naturally from the impacts of the tsunami, provided that the fishing effort is kept within sustainable limits and other stresses on ecosystems and resources are managed.
- Fisheries resources were already severely depleted and declining prior to the tsunami due to unsustainable practices and environmental degradation. Further, overfishing is recognized as a problem by communities. Programmes for rebuilding fisheries livelihoods need to address the pre-tsunami situation (MFAR 2005; MMAF 2006; NARA 2006; Stobutzki and Hall 2005).
- In Indonesia and Sri Lanka fisheries resources in tsunami-affected areas have been under stress since well before the tsunami and may not be in a condition to promote local economic and livelihood recovery. In fact the pre-tsunami “stagnation” of fisheries perceived by the Government of Indonesia, an issue to be addressed in its master plan for recovery ROI (2005), may be a sign that the health of resources needs to be investigated.
- Most changes in catches since the tsunami appear to be due to human factors, including increases in boats, fisherfolk and gear; increases in fuel price leading to shorter fishing trips and concentration of effort; problems with transportation; financing issues; lower fish prices; changes in grounds, sometimes related to sanctuaries and debris; illegal fishing methods; and fishing by foreign vessels.
- The problems now arising in fisheries after the tsunami have highlighted issues of weak institutions and enforcement, raising issues of the need for better human capacity, facilities, funding and information needed for effective fisheries management.
- The effects of the tsunami have precipitated new divisions in industry and conflicts between the management agencies and industry. This has raised issues of “who comes first?” (local vs foreign fisherfolk) and conflicts among local fisherfolk, some of which are related to the post-tsunami reconstruction efforts.
- The tsunami has highlighted the need to rehabilitate fisherfolk livelihoods though diversification into new areas and improving safety and facilities. This could include improving post-harvest processing and cold storage/ice facilities, promotion of aquaculture and land-based livelihoods, safety at sea and transport to markets.

- It is apparent that as a result of the well-meaning efforts of donors, fishing capacity has been increased at some locations in Aceh and Sri Lanka, taking numbers of boats and efficiency of gear well above pre-tsunami levels. This situation can be expected to further exacerbate sustainability problems for fisheries resources and already appears to be happening in Lampulo, Banda Aceh.
- The impacts of the tsunami on effort appear to have had flow-on effects on catches. Where effort was reduced, total catches recovered and efficiency improved, exceeding pre-tsunami levels. Where boats and/or gear were oversupplied catches continued to decline and/or declined further to lower than pre-tsunami levels.
- In CONSRN's (2005d) Regional Strategic Framework for rehabilitation of fisheries and aquaculture strategic element 3 is concerned with restoring the natural environment. The focus of this element needs to shift to alleviating pre-existing human impacts and pressures on marine ecosystems rather than the direct effects of the tsunami. Habitat restoration should focus on approaches that harness the natural recovery power of ecosystems and resources, with artificial restoration (such as transplantation) used only in critical areas.
- Recovery of fished resources and ecosystems needs to focus on restoring resilience as well as outputs of interest to humans.
- Because both the resources themselves and their supporting ecosystems are under stress, an adaptive management approach is needed for planning and implementing recovery. As pointed out by IUCN (2005f) complexity and uncertainty make it impossible to accurately predict outcomes.
- The fisheries data being collected in Aceh Province and Sri Lanka are invaluable for determining how resources and fisherfolk are faring post-tsunami compared with earlier times. They are, however, often poorly organized, missing values and their lessons are not easily learned.

7. RECOMMENDATIONS

1. Recovery of fisheries resources should focus on management and addressing the key issues that were present before the tsunami. These include long-term problems of resource depletion and ecosystem degradation.
2. Attempts to restore resources and ecosystems should go a step further and ensure that building resilience against future disasters is included in all strategies.
3. In their present condition, fisheries in Aceh and Sri Lanka are not generally in a condition to promote economic recovery. Governments should consider alternative and adjunct activities to fisheries for rebuilding livelihoods and their economies (post-harvest processing, facilities and transport to markets, other sea- or land-based activities).
4. Recovery of fisheries will also need to address the new "human factors" that have arisen since the tsunami. These include problems of increased capacity, increasing fuel prices, declining fish prices, problems with transportation, changes in fishing grounds, financing, illegal fishing and conflicts with other rehabilitation programmes.
5. There is an urgent need to address pre-existing problems of weak institutions and enforcement in fisheries that have been exacerbated by the new problems now arising after the tsunami. This will require increasing capacity for effective research and management of fisheries, including training, facilities, funding and better data collection and utilization mechanisms. It will also require new skills in dealing with conflicts among fisherfolk and industry, equitable and effective assistance to communities and innovative diversification of livelihoods.

6. Replacement of boats and gear in affected communities needs better scrutiny and management. Problems of oversupply, inappropriate beneficiaries, replacing traditional boats with larger, motorized vessels and poor vessel quality urgently need addressing.
7. The relationship between decreased or increased fishing effort after the tsunami and resulting changes in catch and catch/boat present an opportunity for further investigations on the number of vessels for optimal yields.
8. The direct impacts on fisheries resources reported by fisherfolk (for example anchovies/lobster in Sri Lanka) merit further study.
9. Mechanisms for rebuilding fisheries livelihoods should remain flexible and able to adapt to lessons learned through regular monitoring of outcomes. This should include improved data management mechanisms and improved capacity in analysis.

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