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Abandoned, lost or otherwise discarded fishing gear

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Preparation of this document

This document has been prepared by Graeme Macfadyen, Tim Huntington and Rod Cappell of Poseidon Aquatic Resource Management Ltd as part of the 2007 Memorandum of Understanding between the Food and Agriculture Organization of the United Nations (FAO) and the Regional Seas Programme of the United Nations Environment Programme. The document draws on a wide range of data and information sources. It covers the issue of abandoned, lost or otherwise discarded fishing gear (ALDFG) in coastal and marine areas, but has not investigated ALDFG in riverine and lacustrine environments.

A review of available background material has been complemented by e-mail and telephone communication with various industry and government sources, and through the use of a semi-structured online questionnaire which was completed by a number of fisheries experts with an interest in, or previous experience of, issues related to ALDFG.

Abstract

Abandoned, lost or otherwise discarded fishing gear (ALDFG) is a problem that is increasingly of concern. Various United Nations General Assembly resolutions now provide a mandate for, and indeed require, action to reduce ALDFG and marine debris in general. Consequently, the United Nations Environment Programme (UNEP) and the Food and Agriculture Organization of the United Nations (FAO) entered into an agreement to carry out a study in relation to ALDFG in order to raise awareness of the extent of the problem and to recommend action to mitigate the problem of ALDFG by flag states, regional fisheries management bodies and organizations, and international organizations, such as UNEP, the International Maritime Organization (IMO) and FAO.

This report reviews the magnitude and composition of ALDFG, and while noting that information is not comprehensive and does not allow for any global estimates, suggests that gillnets and fishing traps/pots may be the most common type of ALDFG, although netting fragments may also be common in some locations.

The impacts of ALDFG are also considered and include: continued catching of target and non-target species (such as turtles, seabirds and marine mammals); alterations to the benthic environment; navigational hazards; beach debris/litter; introduction of synthetic material into the marine food web; introduction of alien species transported by ALDFG; and a variety of costs related to clean-up operations and impacts on business activities. In general, gillnets and pots/traps are most likely to “ghost fish” while other gear, such as trawls and longlines, are more likely to cause entanglement of marine organisms, including protected species, and habitat damage.

The factors which cause fishing gear to be abandoned, lost or otherwise discarded are numerous and include: adverse weather; operational fishing factors including the cost of gear retrieval; gear conflicts; illegal, unregulated and unreported (IUU) fishing; vandalism/theft; and access to and cost and availability of shoreside collection facilities. Weather, operational fishing factors and gear conflicts are probably the most significant factors, but the causes of ALDFG accumulation are poorly documented and not well understood. A detailed understanding of why gear is abandoned, lost or discarded is needed when designing and tailoring effective measures to reduce ALDFG in particular locations.

A variety of measures are currently in place to reduce ALDFG, and these are profiled in this report. They include those which are preventative or *ex-ante*, and those which are curative or *ex-post.* Evidence suggests that while both are important, much of the emphasis to date has been placed on curative measures such as gear retrieval programmes and clean-up of beach litter, while preventative measures may generally be more cost-effective in reducing ALDFG debris and its impacts.

This report concludes with a number of recommendations for future action to reduce ALDFG debris, be it on a mandatory or voluntary basis. It also considers at what scale and which stakeholders (e.g. international organizations, national government, the private sector, research institutions) might be best placed to address the wide range of possible measures to reduce the amount of ALDFG debris.

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Foreword

Fishing gear has been lost, abandoned or otherwise discarded in all seas and oceans ever since fishing began. The extent and impacts of the problem have increased significantly over the last 50 years with the increasing levels of fishing effort and capacity in the world's oceans and the increasing durability of fishing gear. Fishing activity has now extended to previously untouched offshore and deep-sea environments, which are often very sensitive to the impacts of abandoned, lost or otherwise discarded fishing gear (ALDFG).

ALDFG is of increasing concern due to its numerous negative environmental and economic impacts, including navigational hazards and associated safety issues. The ability of ALDFG to continue to fish (often referred to as "ghost fishing") has detrimental impacts on fish stocks and potential impacts on endangered species and benthic environments. ALDFG also results in both economic and social costs that can be significant.

The transboundary nature of the problem means that regional and international cooperation to deter ALDFG is vital. International recognition of the ALDFG problem as one aspect of the larger global challenge of marine litter is demonstrated through the large number of international organizations, activities and agreements that now focus on marine debris, as well as the numerous national and local level initiatives that are being implemented around the world.

The issue of ALDFG has been raised at the level of the United Nations General Assembly (UNGA) on several occasions:

- Resolution A/RES/60/30 of 2005 notes the lack of information and data on marine debris and encourages relevant national and international organizations to undertake further studies on the extent and nature of the problem;
- Resolution A/RES/60/31 of 2005 calls upon States, the Food and Agriculture Organization (FAO), the International Maritime Organization (IMO), the United Nations Environment Programme (UNEP), and in particular its Regional Seas Programme (RSP), regional and subregional fisheries management organizations and arrangements and other appropriate intergovernmental organizations to take action to address the issue of lost or abandoned fishing gear and related marine debris through the collection of data on gear loss, economic costs to fisheries and other sectors, and the impact on marine ecosystems;
- Resolution A/RES/61/222 of 2006 welcomes the activities of the UNEP relating to marine debris carried out in cooperation with relevant United Nations bodies and organizations; and
- Resolution A/RES/61/105 of 2006 reaffirms the importance it attaches to the issue of lost, abandoned, or discarded fishing gear and related marine debris expressed in its resolution 60/31.

As early as the 1980s, FAO recognized this issue as a major global problem and serious threat to the marine and coastal ecosystems. FAO is currently working to address the ALDFG problem through its Impact of Fishing on the Environment Programme. FAO has also considered the problem in the FAO Committee on Fisheries (COFI) and considers marine debris and ALDFG as an important issue in the Ecosystem Approach to Fisheries. The FAO Code of Conduct for Responsible Fisheries (CCRF) was adopted (1995) to promote responsible fishing practices, and it encourages states to tackle issues associated with the impacts of fishing on the marine environment. Implementation of the CCRF has high priority for FAO both globally and regionally. In this process, the requirements to minimize ALDFG, and the responsibility to recover such gear and to deliver it to port for destruction/recycling should be continuously highlighted.

In response to the UNGA calls, the UNEP (Global Plan of Action (GPA) and the RSP), through its Global Initiative on Marine Litter, which includes the issue of ALDFG, took an active lead in addressing the challenge by assisting 12 Regional Seas around the world in organizing and implementing regional activities and strategies on marine litter. The 12 Regional Seas include the Baltic Sea, the Black Sea, the Caspian, the East Asian Seas, the Mediterranean Sea, the Commission for the Protection of the Marine Environment of the North-East Atlantic (OSPAR), the Red Sea and the Gulf of Aden, the South Asian Seas, the Northwest Pacific, the Southeast Pacific, Eastern Africa and the Wider Caribbean.

While there remains a lack of comprehensive data on ALDFG, the growing recognition of problems caused by ALDFG suggests a need to develop a coordinated and effective response by a wide range of ALDFG stakeholders. These stakeholders include the UNGA, IMO, FAO, UNEP, the Intergovernmental Oceanographic Commission (IOC), Regional Fishery Bodies (RFB), Regional Seas conventions and action plans, the Global Environment Facility – Large Marine Ecosystem (GEF-LME) projects, regional economic groupings, governments, non-governmental organizations and the fishing industry itself.

To establish an appropriate response to the problem of ALDFG and the request of the UNGA, FAO and UNEP joined forces for the preparation of this report on *Abandoned, lost or otherwise discarded fishing gear.* This report gathers available information and examples from around the world on several aspects of ALDFG and marine litter in general including: (a) the magnitude and composition of ALDFG; (b) the impacts of ALDFG and associated financial costs; (c) reasons why fishing gear is abandoned, lost or otherwise discarded; and (d) measures being taken to combat ALDFG and the success of current efforts. It concludes with a series of recommendations to address the problem.

It is the sincere hope of UNEP and FAO that this report will provide the basis for a coordinated and cooperative approach of international, regional and national efforts to seriously address the issue. This, in turn, should contribute to a significant decrease in quantities of ALDFG across our seas and oceans every year, and consequently will contribute to the protection and conservation of our marine and coastal ecosystems and resources.

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Acronyms and abbreviations

ALDFG	abandoned, lost or otherwise discarded fishing gear
ANZECC	Australian and New Zealand Environment Conservation Council
APEC	Asia-Pacific Economic Cooperation
APFIC	Asia-Pacific Fisheries Commission
ASV	autonomous survey vessel
BIM	Bord Iascaigh Mhara (Irish Fisheries Board)
BOBP	Bay of Bengal Programme
CCAMLR	Commission for the Conservation of Antarctic Marine Living Resources
CCRF	Code of Conduct for Responsible Fisheries
COFI	Committee on Fisheries
CPR	continuous plankton recorder
CRFM	Caribbean Regional Fisheries Mechanism
DFO	Department of Fisheries and Oceans (Canada)
EAF	Ecosystem Approach to Fisheries
EC	European Commission
ETESP	Earthquake and Tsunami Emergency Support Project
EU	European Union
FAD	fish aggregating device
FANTARED	ghost net (in Spanish)
FAO	Food and Agriculture Organization of the United Nations
FAOSLAC	FAO Subregional Office for Latin America and the Caribbean
FIIT	Fishing Technology Service (FAO)
FRS	Fisheries Research Services (Scotland)
GFCM	General Fisheries Commission for the Mediterranean
GPA	Global Plan of Action
GPS	global positioning system
GSMFC	Gulf States Marine Fisheries Commission
GT	gross tonnage
HERZ	high entanglement risk zones
IATTC	Inter-American Tropical Tuna Commission
ICCAT	International Commission for the Conservation of Atlantic Tuna
ICES	International Council for the Exploration of the Sea
IEEP	Institute for European Environmental Policy
IMO	International Maritime Organization
IOC	Intergovernmental Oceanographic Commission (UNESCO)
IPHC	International Pacific Halibut Commission
IPOA	International Plan of Action
IUU	illegal, unreported and unregulated (fishing)
MARPOL	International Convention for the Prevention of Pollution from Ships
MCS	monitoring, control and surveillance
MEPC	Marine Environment Protection Committee (of the IMO)
NAFO	Northwest Atlantic Fisheries Organization
NOAA	National Oceanic and Atmospheric Administration
NOWPAP	Northwest Pacific Action Plan
NPOA	National Plan of Action

NRC	National Research Council (United States of America)
OSPAR	Oslo-Paris Commission for the Protection of the Marine Environment of the North-East Atlantic
RFB	Regional Fishery Body
RFMO	Regional Fisheries Management Organization
ROPME	Regional Organization for the Protection of the Marine Environment
ROV	remotely operated vehicle
RSP	Regional Seas Programme (of the UNEP)
SCUBA	self-contained underwater breathing apparatus
SPC	South Pacific Commission
SPREP	South Pacific Regional Environment Programme
SSS	side scan sonar
TED	turtle exclusion device
UNEP	United Nations Environment Programme
UNGA	United Nations General Assembly
UNICPOLOS	UN Open-ended Informal Consultative Process on Oceans and the Law of the Sea
USGS	United States Geological Survey
VMS	vessel monitoring system
WCPFC	Western and Central Pacific Fisheries Commission
WECAFC	Western Central Atlantic Fishery Commission
WWF	World Wide Fund for Nature

Executive summary

INTRODUCTION

Abandoned, lost or otherwise discarded fishing gear (ALDFG) is of increasing concern due to its numerous negative impacts. The ability of ALDFG to continue to fish (often referred to as "ghost fishing") has detrimental impacts on fish stocks and potential impacts on endangered species and benthic environments. Fishing gear has been abandoned, lost or otherwise discarded since fishing began, but increases in the scale of fishing operations and technologies used in recent decades mean that the extent and impact of ALDFG debris have increased significantly with the use of synthetic materials, the overall increase in fishing capacity and the targeting of more distant and deepwater grounds. ALDFG is also a concern because of its potential to become a navigational hazard (with associated safety issues) in coastal and offshore areas.

The issue of ALDFG has been raised at the United Nations General Assembly (UNGA) on several occasions and as ALDFG is part of a wider problem of marine pollution, it comes under the remit of the International Maritime Organization (IMO). The IMO's mandate includes the International Convention for the Prevention of Pollution from Ships (MARPOL), and the IMO's Marine Environmental Protection Committee in 2006 established a correspondence group, which includes the Food and Agriculture Organization (FAO), to review MARPOL's Annex V. The United Nations Environment Programme (UNEP) is dealing with the issue of ALDFG as part of a broader Global Initiative on Marine Litter that is being implemented through the UNEP Regional Seas Programme.

FAO has also considered the problem in the FAO Committee of Fisheries (COFI) and considers marine debris and abandoned, lost or otherwise discarded fishing gear an area of major concern. The FAO Code of Conduct for Responsible Fisheries (CCRF) was introduced to promote responsible fishing practices and encourages states to tackle issues associated with fishing impact on the marine environment. Article 8.7 of the CCRF specifically addresses the requirements of MARPOL.

At a regional level, the Asia-Pacific Economic Cooperation (APEC) has recognized the problem of ALDFG and is seeking solutions to the problem and agreed the Bali Plan of Action (September, 2005) to support efforts "to address derelict fishing gear and derelict vessels, including the implementation of recommendations from research already undertaken in the APEC context". The European Commission (EC) Communication on Promoting more Environmentally-friendly Fishing Methods (EC, 2004) identifies the need to address ghost fishing as part of the broader drive to tackle unwanted catches. EC Regulation 356/2005 (EC, 2005) also lays down rules for the marking of passive gear and beam trawls in EC waters.

At a national level, some countries have taken unilateral action against ALDFG components of marine litter. For instance the Marine Debris Research, Prevention, and Reduction Act came into law in late 2006 in the United States of America, which establishes programmes to identify, assess, reduce and prevent marine debris and its effects on the marine environment and navigation safety. Some states in the United States of America also have their own laws addressing the problem of marine debris, while other states have made substantial progress through voluntary programmes.

To establish an appropriate response to the problem of ALDFG, this report gathers available information and examples from around the world on several aspects of ALDFG.

Report objectives and structure. While there remains a lack of comprehensive data on ALDFG, the growing recognition of problems caused by ALDFG suggests a need to develop a coordinated and effective response by a wide range of ALDFG stakeholders. These stakeholders include UNGA, IMO, FAO, UNEP, the Intergovernmental Oceanographic Commission (IOC), Regional Fishery Bodies (RFB), Regional Seas organizations, regional economic groupings, governments, non-governmental organizations and the fishing industry itself.

To establish an appropriate response to the problem of ALDFG, the report gathers available information and examples from around the world on the following aspects of ALDFG in particular and marine litter in general:

- The magnitude and composition of ALDFG (Chapter 2);
- The impacts of ALDFG and the associated financial costs (Chapter 3);
- The reasons why fishing gear is abandoned, lost or otherwise discarded (Chapter 4); and
- The measures being taken to combat ALDFG and the degree of success achieved to mitigate ALDFG impacts (Chapter 5).

The report concludes with a series of recommendations to address the problem (Chapter 6).

MAGNITUDE OF MARINE LITTER AND ALDFG

Marine litter is either sea-based or land-based, with fishing activity just one of many different potential sources. The report concludes that there is no overall figure for the contribution of ALDFG to marine litter. A number of estimates suggest very different contributions of fishing activity to total marine litter based on locality. Close to or on the shore, the majority of litter originates from land-based sources.

When considered on a global basis, and including litter that does not get washed up on beaches, it appears likely that merchant shipping contributes far more to marine litter than ALDFG from fishing vessels. There are significant differences in terms of the weight and the type of impacts on the environment of marine litter from merchant shipping and synthetic forms of ALDFG. Attempts at broad-scale quantification of marine litter enable only a crude approximation of ALDFG comprising less than 10 percent of global marine litter by volume,[1] with land-based sources being the predominate cause of marine debris in coastal areas and merchant shipping the key sea-based source of litter.

Table 6 (page 27) summarizes ALDFG indicators from a number of fisheries around the world. It should be noted that information on fisheries in which ALDFG has been reported is drawn from sources published over an extended period. It is possible that some of these fisheries have changed in nature and thus the information presented may not reflect the current ALDFG situation.

The table demonstrates the wide variability of loss rates from different fisheries and also highlights the patchiness of data on ALDFG. It should be noted that reports of gear loss do not necessarily equal the same volume of ALDFG remaining in the environment indefinitely, as some may subsequently be retrieved by other operators in the fishery. Furthermore it should be noted that the activity of many of the inshore fisheries in North America and Europe has contracted, while fishing effort elsewhere may have expanded.

ALDFG tends to accumulate and often reside for extended time periods in ocean convergence zones. Mass concentrations of marine debris in areas such as the equatorial convergence zone are of particular concern, creating "rafts" of assorted debris, including various plastics, ropes, fishing nets, and cargo-associated wastes that

[1] It should be noted that literature on marine litter in general and ALDFG in particular uses a mixture of volume, abundance and weight, complicating global estimates and comprising their robustness.

often extend for many kilometres. The ocean convergence zones have been modeled and mapped by various researchers (e.g. Figure 5, page 26).

IMPACTS OF ALDFG

The ability of ALDFG to "ghost fish" is one of the most significant impacts of ALDFG and is highly specific to a number of factors. These include the gear type (whether it has been abandoned as a set gear maximized for fishing or discarded/lost where it is less likely to fish) and the nature of the local environment (especially in terms of currents, depth and location). ALDFG has a number of environmental impacts, which can be grouped as follows:

- **Continued catch of target and non-target species**. The state of the gear at the point of loss is important. For example, lost nets may operate at maximum fishing efficiency and will thus have high ghost fishing catches and, if well anchored, be slow to collapse. Some abandoned or lost gears may collapse immediately and have lower initial fishing efficiencies, unless they become snagged on rock, coral or wrecks where they are held in a fixed fishing position. Discarded gear or parts thereof would also have a low fishing efficiency. Fish dying in nets may also attract scavengers that are then caught in the nets, resulting in cyclical catching by the fishing gear.
- **Interactions with threatened/endangered species**. ALDFG, especially when made of persistent synthetic material, can impact marine fauna such as sea birds, turtles, seals or cetaceans through entanglement or ingestion. Entanglement is generally considered far more likely a cause of mortality than ingestion
- **Physical impacts on the benthos**. *Gillnets* may have little impact on the benthic fauna and the bottom substrate. However, they may be dragged along the bottom by strong currents and wind during retrieval, potentially harming fragile organisms like sponges and corals. In deep water areas where the current is strong and heavy weights (>100 kg) are required to anchor nets, there may be localized impacts. The potential physical impacts of ALD *traps* depend upon the type of habitat and the occurrence of these habitats relative to the distribution of traps. In general, sand and mud-bottom habitats are less affected by crab and lobster traps than sensitive bottom habitats such as sea grass beds or areas where emergent fauna such as corals and sponges occur. ADL *hook and line*, an important commercial and recreational gear, has a low capture efficiency but may entangle both marine animals and habitats, especially in complex inshore habitats such as reef structures.
- **Distribution of marine and terrestrial litter**. At a general level, the UNEP Global Programme of Action (UNEP, 2003) states that as much as 70 percent of the entire input of marine litter to the world's oceans sinks to the bottom and is found on the sea bed, both in shallow coastal areas and in much deeper parts of the oceans. Accumulation of litter in offshore sinks may lead to the smothering of benthic communities on soft and hard seabed substrates.
- **Introduction of synthetic material into the marine food web**. Modern plastics can last up to 600 years in the marine environment, depending upon water conditions, ultraviolet light penetration and the level of physical abrasion. Furthermore, the impact of microscopic plastic fragments and fibers, which result from the degradation of larger items, is not known. Thompson *et al.* (2004) examined the abundance of microplastics in beaches, estuarine and subtidal sediments and found them to be particularly abundant in subtidal sediments. The high accumulation potential suggests that microplastics could be a potential source of toxic chemicals in the marine environment.

ALDFG also results in both **economic and social costs** that can be significant. A key socio-economic impact is the navigational threat of ALDFG to marine users. It is very difficult to rate or compare the magnitude of the wide range of socio-economic costs, as literature is very scarce and there are particular problems in quantifying and comparing social costs. Estimating the costs associated with compliance, rescue, and/ or research costs associated with ALDFG is complex, and does not seem to have been attempted to date.

The lack of accurate data on the costs of measures to reduce ALDFG, plus a failure to quantify the benefits that would result from reduced ALDFG, mean that there are few attempts to balance the respective costs and benefits of different measures designed to reduce ALDFG.

CAUSES OF ALDFG

It is important to recognize that due to the environment in which fishing takes place, and the technology used, some degree of ALDFG is inevitable and unavoidable. As with the magnitude of ALDFG, the causes of ALDFG vary between and within fisheries. When one considers that gear may be a) abandoned, b) lost, or c) discarded, it is clear that some ALDFG may be intentional and some unintentional. Correspondingly, the methods used for reducing abandoned, lost and discarded fishing gear may therefore need to be diverse (Smith, 2001).

Direct causes of ALDFG result from a variety of pressures on fishers, namely *enforcement pressure* causing those operating illegally to abandon gear; *operational pressure* and weather making it more likely that gear will be left or discarded; *economic pressure* leading to dumping of unwanted fishing gear at sea rather than disposal onshore; and *spatial pressures* resulting in the loss or damage of gear through gear conflicts. Indirect causes include the unavailability of onshore waste disposal facilities, as well as their accessibility and cost of use.

MEASURES TO ADDRESS ALDFG

Measures to specifically address ALDFG can broadly be divided between measures that ***prevent*** (avoid the occurrence of ALDFG in the environment); ***mitigate*** (reduce the impact of ALDFG in the environment) and ***cure*** (remove ALDFG from the environment). Experience to date illustrates that many of these measures can be applied at a variety of levels (internationally, nationally, regionally, locally) and through a variety of mechanisms. To successfully reduce the problem of ALDFG, and more generally to reduce its contribution to marine debris, it is likely that actions and solutions will need to address all three types of measures, i.e. preventative, mitigating and curative.

Also of considerable importance is that some measures may need to be supported by a legal requirement, while others may be just as effective if introduced on a voluntary basis and when incentives are provided. The likely success of introduced measures therefore may depend strongly on whether the correct approach is taken with regards to a mandatory or voluntary/incentivized approach.

Preventative measures are identified as the most effective way to tackle ALDFG, as they avoid the occurrence of ALDFG and its associated impacts. Measures include gear marking; the use of onboard technology to avoid loss or improve the location of gear; and the provision of adequate, affordable, accessible onshore port reception/collection facilities. It is also acknowledged that effort reduction measures such as limits to the amount of gear that can be used (e.g. pot/trap limits) or the soak-time (the amount of time gear can remain in the water) could reduce operational losses. Spatial management (e.g. zoning schemes) is also a useful tool in addressing gear conflict, which can be a significant cause of ALDFG. Measures to increase the effectiveness of port State measures in tackling illegal, unreported and unregulated (IUU) fishing would also reduce the abandonment of gear, which contributes to ALDFG.

Mitigation measures to reduce the impact of ALDFG are limited in their extent and application as many may increase costs through reduced effectiveness of gear or higher gear prices. Consequently, the development of innovative materials has been slow and the return to biodegradable netting by the industry has been very limited. Trials are continuing on net materials that increase sound reflectivity and hence could reduce the by-catch of non-target species such as cetaceans. These and other innovative solutions are being encouraged through initiatives such as the International Smart Gear Competition (www.smartgear.org) of the World Wide Fund for Nature (WWF).

Curative measures are inevitably reactive to the presence of ALDFG in the environment and will therefore always be less effective than avoiding ALDFG in the first instance. However curative measures have still been shown to be cost-effective when considering the costs of leaving the ALDFG *in situ*. Measures can be seen to be broadly sequential in the identification, removal from the environment and appropriate disposal of ALDFG. They include efforts to locate lost gear using various technologies such as the side scan sonar for sea-bed surveys; the introduction of systems to report lost gear; gear recovery programmes; and the disposal/recycling of ALDFG material.

Raising awareness of the ALDFG problem is a cross-cutting measure that can aid the development and implementation of any of the measures previously described. It can target fishers themselves, port operators, marine users or the general public through local, national regional or international campaigns. Education can, if effective, facilitate a change in behaviour and result in self-policing by stakeholders, and it has the potential to extend beyond those directly targeted, to change behaviour in society. To raise awareness effectively, the specific problem being encountered needs to be understood so that actions can be appropriately targeted.

The review concludes the following:

- ALDFG is a serious global marine environmental problem, causing ecological, biodiversity, economic and shoreside impacts.
- There is a paucity of quantitative data on ALDFG for many regions of the world. Relatively good data is available from a few concentrated geographical areas where intensive studies have been conducted, such as near the Hawaiian Islands, the Seas of Northeast Asia and the North Pacific. However in many other regions there is very little or absolutely no data.
- Sound international policy, legislative and regulatory regimes have been developed and are in place (e.g. MARPOL Annex V). However, there are significant deficiencies in the implementation and enforcement of these regimes.
- Addressing the problem is challenging, as it depends to a significant degree on changing human behaviour in addition to providing the relatively straightforward technological fixes.
- A concerted global effort is needed to begin to address the problem, involving continued close cooperation between the main relevant UN agencies (FAO, IMO and UNEP), Regional Fishery Bodies (RFB), Regional Seas organizations, governments, the fishing industry, ports and environmental non-governmental organizations (NGOs).

The report recommends[2] that:

- UN agencies work collaboratively in addressing the revision of MARPOL Annex V and its guidelines with respect to ALDFG, with a particular focus on the marking of fishing gear to identify ownership, defining what constitutes reasonable losses of gear, providing port reception facilities, and lowering the limit of gross tonnage (GT) that requires fishing vessels to carry garbage record books;
- best practice technical guidelines be developed for policy-makers, Regional Fisheries Management Organizations (RFMOs) and resource managers to assist them with formulation of ALDFG abatement plans;

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2 The full set of recommendations can be found in Chapter 6.

- a determined and sustained global awareness and outreach programme be designed and implemented to effect a cultural shift and behavioural change by adopting innovative communication approaches. The primary audience should be the fishing industry and port users/operators. The programme should be implemented regionally and be regionally relevant and culturally appropriate;
- a programme of innovative economic incentives/measures be developed to prevent/reduce abandonment, loss and the discarding of fishing gear at sea; and
- programmes of monitoring and, where necessary, implementation of measures be developed to reduce ALDFG in regions of the world where little or no data is available (e.g. seas around Africa, South Asia and South America).

1. Introduction and context

Abandoned, lost or otherwise discarded fishing gear (ALDFG) is a problem that is increasingly of concern. There is no overall figure for the proportion of ALDFG in marine litter. A number of estimates suggest that fishing activity makes very different contributions to total marine litter based on locality. Close to or on the shore, the majority of litter originates from land-based sources. The few attempts at broad-scale quantification of the source of marine litter to date enable a crude approximation that indicates ALDFG contributes less than 10 percent of global marine litter by volume, with land-based sources being the predominate cause of marine debris in coastal areas. Merchant shipping is the key sea-based source of litter.

ALDFG has numerous negative impacts as discussed in detail later in this document. These impacts include navigational hazards and associated safety issues, the ability of ALDFG to continue to fish (often referred to as ghost fishing), with detrimental impacts on fish stocks, with no generation of economic benefits and with potential impacts on vulnerable or threatened species and on benthic and inter-tidal environments.

Information on ALDFG in river and lake environments is extremely sparse. While it is clear that the majority of fishing (and thus the potential for ALDFG to occur) takes place in marine environments, freshwater environments host major capture fisheries in some countries. Many of these, such as lake and dam fisheries, may be particularly prone to the impacts of ALDFG, as many are low-energy environments in which the impacts of ALDFG persist over long periods. The current lack of information and data has inevitably led to this report, which focuses on ALDFG in the marine environment. But many of the measures and recommendations would be applicable to freshwater fisheries.

Fishing gear has been abandoned, lost or otherwise discarded ever since fishing began. The extent and impacts of the problem are thought to have increased significantly over the last 50 years with increasing levels of fishing capacity and activity in the world's oceans. This increased activity has extended to previously untouched offshore and deep-sea environments, which can be more sensitive to the impacts of fishing gear.

The impact of fishing gear in the environment has been exacerbated by the introduction of non-biodegradable fishing gear, primarily plastics, which are generally more persistent in the environment than natural materials. Therefore, without measures to address ALDFG the amount of fishing gear remaining in the marine environment will continue to accumulate, especially in gyre areas, as will their associated impacts.

INTERNATIONAL RECOGNITION OF THE ALDFG PROBLEM

The transboundary nature of the problem means that regional and international cooperation to prevent ALDFG is vital. International recognition of this is demonstrated through the large number of international organizations and agreements that now focus specifically on ALDFG[1], in addition to numerous national and local-level initiatives that are being implemented around the world.

A number of United Nations General Assembly (UNGA) Resolutions[2] pertain to ALDFG (see Appendix A for details):

- Resolution A/RES/59/25 (United Nations General Assembly, 2004) calls upon States, the Food and Agriculture Organization of the United Nations (FAO), the International Maritime Organization (IMO), the United Nations Environment

[1] Note also that provisions of the United Nations Convention on the Law of the Sea require nations to combat marine debris more generally, e.g. Articles 1, 192, 194, 197, 207, 211 and 216–218.

[2] See www.un.org/Depts/los/general_assembly/general_assembly_resolutions.htm.

Programme (UNEP), in particular its Regional Seas Programme (RSP), regional and subregional fisheries management organizations and arrangements and other appropriate intergovernmental organizations that have not yet done so to take action to address the issue of lost or abandoned fishing gear and related marine debris through the collection of data on gear loss, economic costs to fisheries and other sectors, and the impact on marine ecosystems.

- Resolution A/RES/60/30 – Oceans and the Law of the Sea (United Nations General Assembly, 2006a) notes the lack of information on marine debris and encourages further studies, urges States to integrate the issue of marine debris into national strategies dealing with waste management, and invites the IMO in consultation with relevant organizations and bodies, to review Annex V to the International Convention for the Prevention of Pollution from Ships (MARPOL).
- Resolution A/RES/60/31 (United Nations General Assembly, 2006b) focuses strongly on the need for better information and collaboration, and calls upon States and international organizations such as FAO to address the issue of lost or otherwise abandoned fishing gear and related marine debris through the collection of data on gear loss, economic costs to fisheries and other sectors, and the impact on marine ecosystems, and through both preventative and curative measures.
- Resolution A/RES/61/222 (United Nations General Assembly, 2007a) again urges States to integrate the issue of marine debris into national strategies dealing with waste management and welcomes the review of Annex V of MARPOL by IMO.
- Resolution A/RES/61/105 (United Nations General Assembly, 2007b) reaffirms the importance of ALDFG and encourages COFI to consider the issue at its 2007 meeting.

The UNGA Resolutions are now being acted upon in a wide range of ways, as outlined below.

The 6th **United Nations Open-ended Informal Consultative Process on Oceans and the Law of the Sea (UNICPOLOS)** was held in New York in June 2005 to discuss, upon the request of the UNGA, and among other issues, marine litter and abandoned fishing gear.

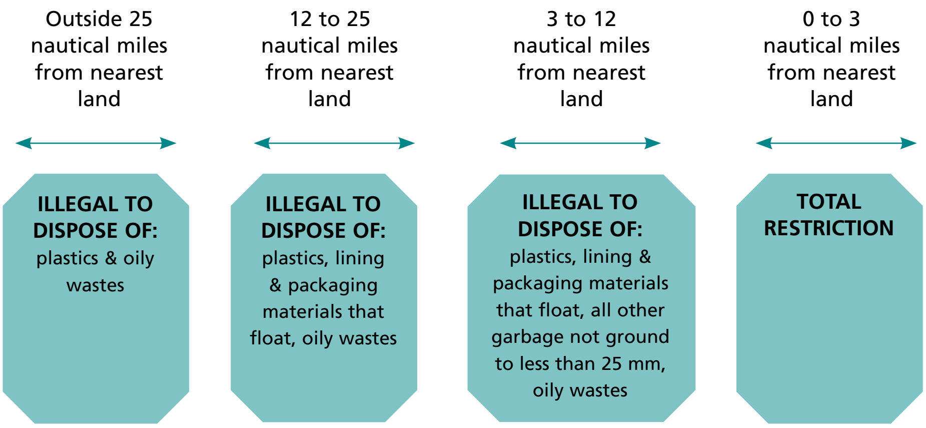
The IMO, a specialized agency of the United Nations that addresses issues pertaining to international shipping, has adopted a wide variety of legally binding and non-legally binding instruments. The objectives of the organization are promotion of maritime safety, protection of the marine environment and enhancement of maritime security.

Annex V of the **International Convention for the Prevention of Pollution from Ships (MARPOL)** (IMO, 1973) deals with the prevention of pollution by garbage from ships and entered into force on 31 December 1988. It has been amended twice since its entry into force.

Annex V completely prohibits certain discharges of ship-generated garbage (e.g. plastics), and for other discharges it specifies the distances from land and the manner in which different types of garbage may be disposed of (see Figure 1). Within certain designated areas, if the general Annex V requirements can be shown to be ineffective, then stricter requirements apply, provided that there are adequate reception facilities available in the area. The prohibition of the discharge of plastics specifically prohibits the discharge of synthetic fishing nets; however, the Annex does not apply to the accidental loss of such nets, provided that all reasonable precautions have been taken to prevent such loss.

Annex V is applicable to all vessel types including fishing vessels of all sizes. Furthermore, Regulation 9 of the Annex requires ships of 400 GT and over to keep records that include reporting the discharge, escape or accidental loss (of garbage that includes synthetic fishing material) referred to in Regulation 6, and to record the circumstances of and reasons for the loss.

FIGURE 1
MARPOL Annex V regulations regarding disposal of garbage from ships



Source: Based on IMO documentation.

The MARPOL Annex V Guidelines call for fisheries managers to utilize fishing gear identification systems that provide information such as vessel name, registration number and nationality, and they encourage governments to consider the development of technology for more effective fishing gear identification.

IMO's Marine Environment Protection Committee (MEPC) at its 56th Session established an intersessional correspondence group to develop the framework, method of work and timetable for a comprehensive review of MARPOL Annex V *Regulations for the prevention of pollution by garbage from ships* and the associated *Revised Guidelines for the implementation of MARPOL Annex V*. The review is to take into account resolution 60/30 of the UNGA, which invited IMO to review MARPOL Annex V in consultation with relevant organizations and bodies, and to assess its effectiveness in addressing sea-based sources of marine debris.

In its report to the 57th Session of MEPC, 31 March to 4 April 2008, the correspondence group offered the following options with regard to managing loss of fishing gear:

- define "reasonable precautions" to exception in Regulation 9(2);
- amend Annex V to apply record-keeping requirements in Regulation 9(2) and 9(3) to smaller fishing vessels;
- amend Annex V to include gear marking requirements;
- amend the guidelines to emphasize the application of Annex V to commercial fishing vessels;
- amend the guidelines to encourage states to apply the provisions of Annex V voluntarily to smaller fishing vessels; or
- make no change to current provisions, as fisheries rules are administered by Regional Fisheries Management Organizations (RFMOs).

Following the review of the report of the correspondence group, MEPC agreed to extend the target completion date of the work to July 2009.

At the same session, MEPC debated the inadequacy of shoreside reception facilities. It approved an Action Plan to tackle the alleged inadequacy of port reception facilities, seen as a major hurdle to overcome in order to achieve full compliance with MARPOL. The Plan was developed by the IMO Sub-Committee on Flag State Implementation (FSI) and it is hoped that its outcome will contribute to the effective implementation of the MARPOL Convention and promote quality and environmental consciousness among administrations and shipping.

The IMO Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter was agreed to in 1972 and entered into force in 1975, with a related protocol entering into force in 2006. The convention and its protocol focus on preventing the dumping of wastes and other materials into the sea, including dumping from vessels. Discharging items from vessels at sea is not considered as dumping if the items concerned are wastes generated during "normal operations"; however, it is considered dumping if the discharged materials were transported for the express purpose of disposal at sea. The protocol prohibits at-sea dumping unless the items have been specifically included on an approved list issued by parties to the protocol. The protocol also requires preventative action to be "taken when there is reason to believe that wastes or other matter introduced into the marine environment are likely to cause harm even when there is no conclusive evidence to prove a causal relation between inputs and their effects" (1996 Protocol to the Convention, Article 3).

The FAO Code of Conduct for Responsible Fisheries (CCRF) (FAO, 1995) was introduced to promote, *inter alia,* responsible fishing practices and encourage states to tackle issues associated with fishing's impact on the marine environment. Article 8 of the CCRF specifically addresses the requirements of MARPOL, while paragraph 7.2.2 (g) considers ALDFG in stating that fisheries management measures should provide *inter alia* that:

> *"pollution, waste, discards, catch by lost or abandoned fishing gear, catch of non-target species, both fish and non-fish species and impacts on associated or dependent species be minimized, through measures including, to the extent practicable the development and use of selective, environmentally safe and cost-effective fishing gear and techniques."*

Paragraph 7.6.9 also states that:

> *"States should take appropriate measures to minimize waste, discards, catch by lost or abandoned gear, catch of non-target species, both fish and non-fish species, and negative impacts on associated or dependent species, in particular endangered species..."*

Paragraph 8.2.4 indirectly relates to the issue when it states that:

> *"Fishing gear should be marked in accordance with national legislation in order that the owner of the gear can be identified. Gear marking requirements should take into account uniform and internationally recognizable gear marking systems."*[3]

Paragraph 8.9.1 (c) directly addresses waste reception facilities where it states that:

> *"waste disposal systems should be introduced, including for oil, oily water and fishing gear;"*

Furthermore, the first in the series of Technical Guidelines for Responsible Fishing contains guidance on Procedures for the Development and Management of Harbours and Landing Places for Fishing Vessels (1996), covering management, environmental auditing procedures and environmental assessments.

The FAO Committee on Fisheries (COFI) in its 27th Session (FAO, 2007) considered marine debris and lost or abandoned fishing gear an important issue in the Ecosystem Approach to Fisheries (EAF), in particular noting that:

> *"The issue of marking fishing gear was first raised at FAO in 1987 during the 17th Session of COFI. In reviewing the report of the Expert Consultation on the Marking of Fishing Gear, Victoria, British Columbia, 14–19 July 1991, the 20th Session of COFI in 1993 recommended that the draft Standard Specification on the Marking of Fishing Gear be reviewed before being incorporated in the CCRF. The matter was further addressed during the Expert Consultation on the Code of Conduct and Fishing Operations, Sidney, 6–11 June 1994, which in relation to Article 8 of the Code identified as possible solutions: the reporting of all lost gear in terms of numbers and location to national management entities, and that industry and governments should consider efforts and means to recover extant ghost fishing gear. The Consultation proposed a regulatory framework to deal with violators, recommending that all fishing gear should be marked, as appropriate, in such a way so as to uniquely identify the ownership of the gear."*

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[3] The first in the series of Technical Guidelines (Fishing Operations) for the application of the Code of Conduct for Responsible Fisheries provides additional information.

A requirement for the marking of fishing vessels and fishing gear is also included in Article 18, Duties of the Flag State of the Agreement for the Implementation of the **Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982,** relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks (Fish Stocks Agreement).

Another FAO initiative concerns the development of port state measures to counter illegal, unreported and unregulated (IUU) fishing. An Expert Consultation on this matter was held in the United States of America, on 4–8 September 2007 to draft a binding agreement, and a Technical Consultation was held 23–27 June 2008 to finalize the instrument's text before it was presented at the COFI 28th Session in 2009[4]. The draft includes inspection of the fishing gear by a port state. Furthermore, in general, FAO Regional Fisheries Management Bodies require fishing gear to be marked in order to identify the vessel to which it belongs. Also, while details differ, the International Radio Call Sign is a common requirement.

FAO has also recently concluded a study into the feasibility of developing a comprehensive record of fishing vessels, refrigerated cargo ships and support vessels and their beneficial ownership. Such a record would be a more accurate record of the numbers and types of decked seagoing fishing vessels of 10 GT and over. This, together with other information, would provide a much better indication of geographic distribution of fishing vessels and a unique way to identify an individual vessel throughout its life, even if it changed name, flag or ownership. It would also benefit port state control/measures initiatives and tie in with the marking of fishing gear to enhance traceability.

As long ago as 1987, FAO and IMO agreed to cooperate through the FAO Bay of Bengal Programme (BOBP) to address marine pollution in the Bay of Bengal region. It was further agreed that BOBP would implement pilot projects to reduce pollution in fishery harbours, including reception facilities for the disposal of oil waste and redundant fishing gear. The current FAO Cleaner Fishery Harbours Programme continues in the same vein.

The RSP of the UNEP, initiated in 1974, aims to address the increasing degradation of the world's oceans, coastal and marine areas through sustainable management and use of these environments, by engaging member countries to cooperate in comprehensive and specific actions for the protection of their shared marine environment. Activities of UNEP on marine litter were initiated in 2003 through the work of the RSP and the Global Programme of Action (GPA) for the Protection of the Marine Environment from Land-Based Activities, and since then numerous activities on the regional and global level have been carried out.

In response to the UNGA call, UNEP (GPA and RSP), through its Global Marine Litter Initiative, took an active lead in addressing the challenge of marine litter by assisting 12 Regional Seas around the world in organizing and implementing regional activities on marine litter. Currently each of the 12 participating Regional Seas is publishing regional documents on the State of the Marine Litter and Regional Action Plans on Management of Marine Litter. In addition, UNEP (GPA and RSP) have been developing and implementing a number of activities on the management of marine litter, including:

- publication in 2005 of the document Marine Litter: An Analytical Overview (available at www.unep.org/regionalseas/marinelitter/);
- publication in 2005 of a leaflet on marine litter entitled Tightening the noose (available at www.unep.org/regionalseas/marinelitter/);
- expansion of the UNEP/RSP website to include a chapter devoted to information on marine litter (www.unep.org/regionalseas/marinelitter/). This chapter serves

[4] FAO, 2007a.

as an information portal on marine litter, providing information and news on the Global Marine Litter Initiative, activities in the regions, links to partners and additional resources;

- publishing a document entitled An Overview of the Status of Marine Litter in UNEP-Assisted Regional Seas, covering the work in the 12 Regional Seas;
- reporting by the UNEP on the problem of the management of marine litter as a part of its contribution to the UN Secretary General's Report on Oceans and Law of the Sea to various sessions of the General Assembly (2005, 2006, and 2007);
- presentations on the problem of the management of marine litter at various international meetings, including UNICPOLOS (June 2005);
- publishing a Practical and operational UNEP/Intergovernmental Oceanographic Commission (IOC) Guidelines on Survey and Monitoring of Marine Litter, including litter that is floating or onshore or on the sea floor (in preparation); and
- preparation of Guidelines on the Use of Market Based Instruments to Address the Problem of Marine Litter, a joint effort by UNEP, the Institute for European Environmental Policy (IEEP) and Sheavly Consultants, Inc.

Most of these activities have been developed by UNEP/RSP in consultation with and, when appropriate, in cooperation with UN Agencies, including IMO, IOC of UNESCO, FAO and the Basel Convention.

REGIONAL RECOGNITION OF THE PROBLEM

UNEP is dealing with the issue of ALDFG as part of a broader Global Initiative on Marine Litter, which is being implemented through the UNEP Regional Seas Programme (RSP). The RSP took an active lead on the marine litter issue and in 2005 began organizing and implementing regional activities on marine litter in 12 Regional Seas (the Baltic Sea, the Black Sea, the Caspian, the East Asian Seas, Eastern Africa, the Mediterranean Sea, the Northwest Pacific, OSPAR, the Red Sea and the Gulf of Aden, the South Asian Seas, the Southeast Pacific and the Wider Caribbean). The regional activities were arranged through an agreement concluded between each of 12 Regional Organizations/Regional Coordinating Units and UNEP/RSP on the management of marine litter in the region. Each of the regions has a customized programme and a work plan based on the same concept. The main activities detailed in the agreement were: (a) preparation of the Review of the Status of Marine Litter in the Region; (b) preparation of the Regional Action Plan on the Sustainable Management of Marine Litter in the Region; (c) organization of a regional meeting of national authorities and experts on marine litter; and (d) participation in a Regional Cleanup Day, within the framework of the International Coastal Cleanup campaign.

The Asia-Pacific Economic Cooperation (APEC) Fisheries Working Group held a Seminar on Derelict Fishing Gear and Related Matters in Honolulu, Hawaii, 13–16 January 2004. The seminar requested FAO to reprint and disseminate the 1991 FAO Fisheries Report No. 485 on the *Marking of Fishing Gear* and to consider whether the report and its supplement should be revised based on recent knowledge and technological developments.

It also stated in its report (APEC, 2004) that:

> *"Derelict fishing gear and related marine debris is recognized as a critical problem in the marine environment and for living marine resources because it causes economic loss in terms of the long-term sustainability of fish stocks due to ghost fishing and habitat loss, safety of navigation, and a further decline in endangered and other marine species that are killed or maimed from entanglement or ingestion. As such, and taking into account the precautionary approach, the Seminar recognized the need and calls on the APEC Economies to take action at the national, regional, and global levels, and to secure adequate funding to do so. Additionally, the Seminar recognized the need for a standing*

body of people from concerned APEC Economies to dedicate time to addressing this issue."

The more recent **Bali Plan of Action** (The 2nd APEC Ocean-Related Ministerial Meeting, Bali, 16–17 September 2005) also supports efforts "to address derelict fishing gear and derelict vessels, including the implementation of recommendations from research already undertaken in the APEC context".

Within the **European Community (EC)**, integration of environmental protection requirements into Community policies is an obligation under Article 6 of the Community Treaty. Under the "basic" Common Fisheries Policy Regulation (2371/2002), measures should be taken for resource conservation and management purposes, and the limitation of the environmental impact of fishing (Article 1). As ALDFG contributes to fishing mortality and has impacts on the wider marine environment, there is a clear legal basis for measures to address ALDFG.

The European Commission Communication on Promoting more Environmentally-friendly Fishing Methods (EC, 2004), tabled in June 2004, identifies the need to address ghost fishing as part of the drive to tackle unwanted catches more broadly. It noted that there is a need to take measures to identify ghost fishing gear, to encourage the reporting of lost gear and to recover it from the sea bed. EC Commission Regulation 356/2005 (EC, 2005) also lays down rules for the marking of passive gear and beam trawls in Community waters.

IDENTIFICATION OF STAKEHOLDERS

There are a wide range of groups that may be considered stakeholders in the issue of ALDFG. The stakeholder may be any person, group or organization that causes, is affected by, or is concerned with ALDFG. Identification of specific groups of people who are stakeholders in the issue of ALDFG is important when considering how to target solutions.

Stakeholder groups may be classified by:

- their relationship to the issue of ALDFG;
- the potential impact of the group on the issue (either positive (+) or negative (–) or both); and
- their influence in affecting and supporting change/action that addresses the issue of ALDFG.

A stakeholder analysis is provided in Table 1.

STRUCTURE OF THE REPORT

The report is primarily based on a literature review. However, to collect additional information, a small survey was conducted with experts known to be interested in and involved with the issue of ALDFG (see Appendix B). Interviews and communication with a select group of vessel owners/skippers and experts were also undertaken. The results of this survey are embedded in the text of the report and summarized in Appendix C.

The purpose of this document is therefore to address the following questions (each of which is addressed in the specified chapters):

- What is the magnitude and composition of ALDFG? (Chapter 2)
- What are the impacts and costs of ALDFG? (Chapter 3)
- Why is fishing gear abandoned, lost or otherwise discarded? (Chapter 4)
- What is being done to address ALDFG and how successful are these initiatives? (Chapter 5).

The report concludes with recommendations covering a range of possible measures for addressing ALDFG (Chapter 6).

TABLE 1
Stakeholder analysis

Stakeholder	Relationship to the issue of ALDFG	Potential impact	Potential influence in addressing ALDFG
United Nations General Assembly	Provides a mandate through its Resolutions for the issue to be addressed globally, and for specific international organizations to address the issue	+	High, if Resolutions are acted upon, due to global influence
FAO	Mandated by member countries and the UNGA as the leading international fisheries organization to conduct research, make technical recommendations, support RFBs, and provide an advocacy role	+	High, due to extent to which people look to FAO for leadership on fisheries issues, and due to ability to feed solutions back to member countries through COFI and other structures/activities
IMO	Adopts legally binding and non-legally binding instruments pertinent to international shipping. Oversees MARPOL Annex V, which addresses ship-generated garbage and prohibits the disposal of plastics, including synthetic fishing nets	+	High, especially due to ongoing MARPOL Annex V review
UNEP	Advocate, educator, catalyst and facilitator for sustainable development. Sees ALDFG importance in the context of widespread marine litter and its Regional Seas Programme	+	High, due to extent to which people look to UNEP for leadership on environmental issues, and due to ability to feed solutions back to member countries and to regional programmes
Regional Fishery Bodies (RFBs)	May have a management, scientific or advisory role	+	High, as can either legislate for, or encourage preventative/curative measures. Also because RFBs provide for government to act in a coherent manner
Regional Fisheries Management Organizations (RFMOs)	Have the potential to pass resolutions that are binding on signatory parties	+	High, as can directly influence cooperating member fleet activities and practices
Regional Seas Conventions and Action Plans (UNEP and non-UNEP)	Facilitate, assist and provide financial support for activities on marine litter in 12 Regional Seas, as well as several activities at the global level. ALDFG is considered one of the major issues in such work.	+	High, the work of RSP in Regional Seas and at the global level is considered the only systematic work on the marine litter problem at the regional and supra-regional level
Regional Economic Groupings (e.g. APEC)	May choose to pick up the issue of ALDFG as important within working groups established to address the issue	+	Medium, due to potential ability to make recommendations to governments on a regional level, but many such groups will not view ALDFG as a priority issue
National governments	Often bear the costs of clean-up. Important role in legislating for, and supporting voluntary measures to reduce ALDFG. May also support/fund research	+	High
Commercial and recreational fishing sectors	Cause of ALDFG, and those vessels not causing ALDFG are often directly affected by it	+ (in making change) / – (in causing problem)	High, because it is this sector that must be encouraged (voluntarily or through legislation) to adopt change to reduce ALDFG. Given enforcement problems with any legislation, it is therefore very important for the catching sector to "buy in" to proposed solutions.
Processing sector	Ghost catches by ALDFG may reduce available catch being sold to processors, thereby impacting on value-added and socio-economic benefits	+	Low, because of little ability to influence behaviour of catching sector, unless some sort of certification scheme were introduced and processors refused to buy product from vessels not complying with standards designed to reduce ALDFG
Gear manufacturers	May be involved in solutions related to marking of gear or technical solutions to reduce ALDFG. May have an interest in continued ALDFG as a means of increasing sales of new gear	+ (in identifying solutions / – (if not interested in change)	Medium – high, depending on the extent to which marking of gear or technical solutions are deemed to be important in reducing ALDFG

TABLE 1
Stakeholder analysis

Stakeholder	Relationship to the issue of ALDFG	Potential impact	Potential influence in addressing ALDFG
Other commercial marine users	May be impacted by the presence of ALDFG with associated costs from entanglement, safety issues due to hazards	+	Low, because of little ability to impact on ensuring that solutions are effective, except in so far as advocacy activities may be supported through forums in which both fishing and other commercial marine users are jointly engaged
Researchers	May be able to assist with the provision of better information on the extent, impact and costs of ALDFG, as well as with the provision of appropriate solutions	+	Medium
Public and civil society	May be impacted by ALDFG in terms of beach litter and other forms of environmental impacts. Note there may be positive uses of ALDFG washed ashore (see Box 3) as well as the negative aspects of visual pollution. Civil society organizations may be involved in advocacy activities to reduce ALDFG	+	Low – medium
Non-governmental organizations (NGOs)	Can be powerful public advocates at both global, regional and national levels. Tend to focus upon the impact on iconic species, e.g. seals, turtles	+	Medium – high. Can leverage public opinion, especially at the national level, which can accelerate legislative action

Source: Poseidon, 2008.

2. Magnitude and composition of ALDFG

First, this chapter considers what proportion of marine litter generally is comprised of ALDFG. It then identifies available information on the magnitude of abandoned, lost or otherwise discarded fishing gear and highlights information gaps. It also examines the characteristics of abandoned, lost and discarded gear as described by UNEP Regional Seas Programme and attempts to provide an indication of the magnitude of the issue in different parts of the world.

The main sources of marine litter are either sea-based or land-based, and fishing activity is just one of many different potential sources.

In 1997, the United States Academy of Sciences estimated the total input of marine litter into the oceans at approximately 6.4 million tonnes per year, of which nearly 5.6 million tonnes (88 percent) was estimated to come from merchant shipping (UNEP, 2005a). The Academy also noted that some 8 million items of marine litter are estimated to enter oceans and seas every day, about 5 million (63 percent) of which are solid waste thrown overboard or lost from ships (UNEP, 2005a). Furthermore, it has been estimated that currently over 13 000 pieces of plastic litter are floating on every square kilometre of ocean. In 2002, 6 kg of plastic was found for every kilogram of plankton near the surface of the central Pacific gyre[5] (Moore, 2002).

There is no information available on the overall proportion of marine litter that is made up of ALDFG. A number of studies suggest that there are large differences in the proportion of ALDFG found among all marine litter in various regions. For example:

- "In urban areas or beaches close to major urban centers between 75% and 80% of all debris originates from terrestrial sources. In areas remote from urban development it is typically the fishing and shipping industry that is responsible for the majority of marine debris, contributing between 50% and 90% (Faris and Hart, 1994)".
- In Brazil, fishery-related debris represented 46 percent of total marine litter most commonly found in the subtidal benthic environment (Oigman-Pszczol and Creed, 2007).
- In a 1988 survey in Japan, of over 35 000 objects recovered from a beach litter survey, 1 percent and 11 percent were comprised of fishing nets and fishing

TABLE 2
Sources of marine litter

Sea-based sources	Land-based sources
• Merchant shipping, ferries and cruise ships	• Waste from municipal landfills located on the coast
• Fishing vessels and fish farming	• A wider context of waste management
• Naval vessels, research ships and pleasure craft	• Discharge of untreated municipal sewerage and storm water
• Offshore oil and gas platforms	• Industrial facilities
	• Deforestation
	• River transport
	• Tourism and beach users' debris

Source: UNEP, 2005a.

[5] An ocean circulation system that tends to concentrate ALDFG and other flotsam.

gear, respectively – the rest was styrofoam (27 percent), petrochemical products (22 percent), wood (15 percent) and seaweed (17 percent) (Watanabe *et al.*, 2002).
- Evidence from a five-country UNEP survey suggested that fishing gear generally was relatively rarely found along the beaches of the Mediterranean (UNEP/IOC/FAO, 1991; Golik, 1997).
- In nationwide beach clean-ups in the United States of America, fishing or boating gear comprised 6.1 percent of the total litter items collected by number in 1988 (O'Hara, 1990).
- In the most recent United States National Marine Debris Monitoring Program results (Sheavly, 2007), 17.7 percent of beach litter originated from the ocean. Fishing nets, fishing line, rope, fish baskets, floats and buoys and traps and pots represented 1.4 percent, 3.4 percent, 5.5 percent, 1.5 percent and 0.9 percent, respectively.
- In the United Kingdom, fishing debris such as line, nets, buoys and floats is the second biggest source of marine debris after visitor's litter (Marine Conservation Society (MCS), 2007), representing about 11.2 percent (MCS Beachwatch, 2006 survey).

OVERVIEW OF EFFORTS TO ASSESS THE MAGNITUDE OF ALDFG

A number of countries and regions, such as the National Oceanic and Atmospheric Administration (NOAA) Marine Debris Program in the United States of America, the Carpentaria Ghost Nets Programme in Australia, and the Marine Debris Collection Program in the Republic of Korea (including ALDFG, see Donohue *et al.*, 2001; Boland and Donohue, 2003; Dameron *et al.*, 2007), have developed initiatives to assess the quantities and nature of marine debris in the water column, on the sea bed and washed up on the shore. There are also a number of cases where initiatives have focused specifically on determining the rates attributable to gear abandonment/loss/discarding from certain fisheries with the aim of developing regulatory measures, management approaches and awareness programmes to reduce input of ALDFG into the marine system.

Much of the earliest work in assessing the magnitude of ALDFG was conducted in North America, and it was focused particularly upon lost traps and gillnets. The first documented work on lost gillnets appears to be that of Way (1977) in Atlantic Canada. A number of other studies followed (such as High, 1985, and Carr *et al.*, 1985) but most tended to be in response to specific incidences of loss or following some opportunistic identification of an accessible lost net. The exception to this general observation concerns the high value trap fisheries in North America, which were investigated systematically for many years (see Blott, 1978; Stevens *et al.*, 2000; High and Worlund, 1979). However, most of these studies focused on the general impact of ALDFG in terms of ghost fishing and habitat destruction rather than on the causes and rates of gear loss.

More recent efforts to assess the magnitude of fishing gear being abandoned, lost or otherwise discarded have included:
- the FANTARED 1 project (EC Project no. 94/095, 1995 to 1996) focusing on gillnets in the United Kingdom, Spain and Portugal;
- the FANTARED 2 project (FAIR-PL98-4338, 1998 to 2005), focusing on Norway, Sweden, United Kingdom, Spain, Portugal, France (on gillnets in all counties and on traps in Portugal);
- the DeepNet project (Hareide *et al.*, 2005), focusing on deepwater fixed net fisheries on the Shelf Edge to the west and north of Great Britain, Ireland, around Rockall and Hatton Bank;

- The South Pacific Commission (SPC) Fisheries Observer Program in the South Pacific, where observer data is collected on the extent and causes of ALDFG from pelagic longline fisheries but has not been collated or published to date; and
- International Pacific Halibut Commission Logbooks, which uses logbook data to estimate adult halibut mortality due to lost/abandoned longline gear in the halibut fishery and has produced reasonable estimates of ALDFG.

Unlike many fisheries indicators, there are few sector-wide processes (i.e. institutional or vessel-based monitoring systems) to quantify gear loss at a national or regional level. Most existing information is from small-scale surveys and underwater censuses, and is thus indicative and case-specific rather than systematic. The following analysis is therefore based on information on the quantities and distribution of ALDFG globally.

REVIEW OF ALDFG FROM GILLNET AND TRAP FISHERIES BY REGIONAL SEA

The Baltic, the Northeast Atlantic and the Mediterranean Regional Seas

Gillnets

Baltic. In 1998, under FANTARED 2, the gear loss from active Swedish gill-netters operating in the Baltic Sea in 1998 was examined, especially the loss from those vessels operating in open sea conditions, either in coastal waters or in distant grounds. It was found that regular gear loss only occurred among fishers targeting demersal species (turbot and cod) with bottom-set gillnets, and particularly those operating in the open sea away from the coast. The total estimated loss per year was about 1 500 nets, equal to 155–165 km in length, and equal to 3.6–3.8 nets per active vessel, although this was less than 0.1 percent of nets lost per year (FANTARED 2).

The recovery rate of nets by the fishers themselves was estimated to be close to 10 percent. Because fishing gear conflicts were reported as the main reason for gear loss, the areas with higher gear loss rates could be identified. Eventual "ghost nets"[6] were identified (usually in trawl hauls) in two forms: (a) longer nets found apparently in the vicinity of the conflict area; and (b) small remnants found randomly over a larger, less defined area.

Northeast Atlantic (shelf fisheries). The majority of nets lost in Norwegian fisheries tend to be those used in offshore operations, especially those targeting spawning saithe, although this represented less than 0.1 percent of the nets used in the whole capture fisheries sector. In general most of the Norwegian fisheries had a high rate of net recovery of around 80–100 percent. Despite these reportedly low loss rates, between 1983 and 1997 the Norwegian net retrieval programmes recovered 6 759 gillnets targeting Greenland halibut (Humborstad *et al.*, 2003). This survey represents the longest time period available and the situation in a highly regulated fishery, so despite the mandatory requirement to report lost nets and controls on net length and soak time, there is clearly still a need to conduct retrieval surveys (Dr Norman Graham, Marine Institute (Ireland), personal communication, 2008).

Studies around the United Kingdom examined a combination of the hake (western approaches and the Channel), tangle netting and wreck netting. The tangle net losses were the greatest, consisting of 263 nets per year from 18 vessels. On average, a third of the lost nets were recovered. The hake métier of 12 vessels lost 62 nets per year, of which half were recovered. Within the wreck métier[7], whole gear was seldom lost, although there was a high incidence of reported snagging and resultant losses of portions of net sheets and segments (884 incidences from a fleet of 26 vessels). In France, most gillnet

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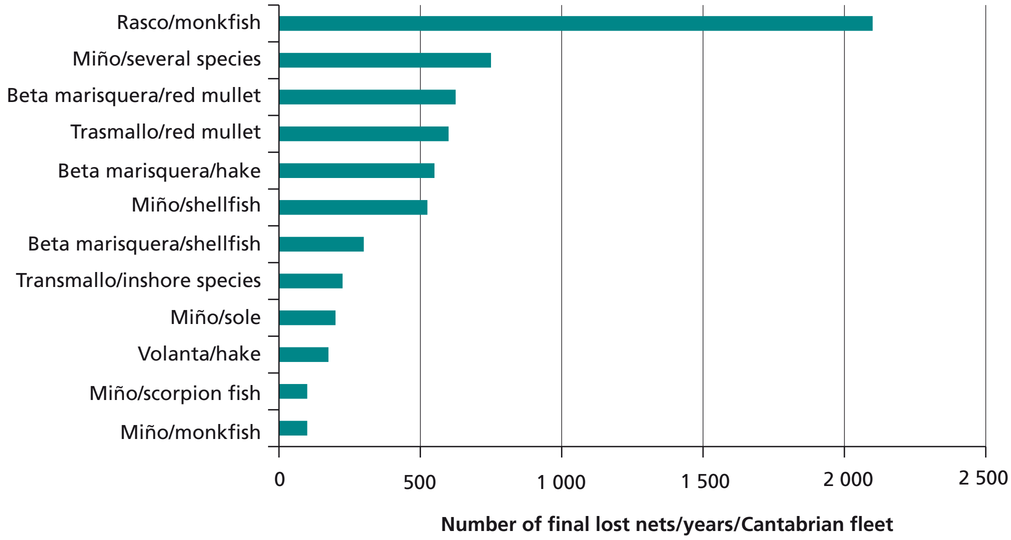
[6] A net that continues fishing after all control of the fishing gear is lost by a fisher.

[7] Métier: A group of vessel voyages targeting the same (assemblage of) species and/or stocks, using similar gear, during the same period of the year within the same area.

FIGURE 2
Net loss in the Spanish Cantabrian fleet by fishing métier



Source: Reproduced from FANTARED 2 (2003).

fisheries lost less than 0.5 percent of their nets annually, although loss at the seabass fishery was significantly higher, at 2.11 percent (FANTARED 2).

A detailed study under FANTARED 2 looked at net loss from the gillnet fishing fleet in the Cantabrian region of northern Spain (around 645 vessels, 79 percent of which have a tonnage of under 10 GT). An average annual loss of 13.3 nets per vessel was recorded, where the fishing métiers with the greatest losses per vessel (27.9 nets per vessel) are those practiced in waters on the outer part of the continental shelf or platform, between 70 and 600 fathoms (for rasco/monkfish), mainly due to the interaction of trawling gear (see Figure 2). Generally, larger vessels have greater net losses than those under 10 m (16.2 nets per larger vessel, against 10.4). Other fishing métiers with high losses are bottom-set net fisheries close to the coast (beta marisquera/shellfish, trasmallo/red mullet, trasmallo/coastal species) with losses ranging between 7 and 15 nets/vessel/year. The rest of the fishing métiers have losses of less than 4 nets/vessel/year.

The FANTARED 2 study conducted a rare extrapolation of these loss rates to the entire Cantabrian fleet. The biggest losses occur in the rasco/monkfish métier, with 2 065 nets lost. Another fishing métier with important losses (774 nets/year) is that fishing for miño/different species. It is worth highlighting that the fishing métier of red mullet with betas lose between 550 and 650 nets per year. The rest of the fishing métiers, mainly in shallow waters (except for the volanta/hake métier), have annual losses of between 100 and 500 nets per year.

In Brittany in France, an examination of the three key fishing métiers showed that wreck gillnetting results in the largest proportional loss – just under 3 percent of nets – although the largest net length loss is by the flatfish and monkfish métier (just under 5 km of net per vessel per year). On the Algarve coast of Portugal, under the FANTARED 2 project, net fishers in the local, coastal and hake fisheries were interviewed about the extent and causes of gear loss and retrieval rates. This FANTARED work is also reported in Santos *et al.* (2003a). The number of nets lost in these fisheries was considered to be very low because of fishers' success in retrieving their nets. It was estimated that the mean number of sheets effectively lost by boat per year was 3.2, 6.0 and 7.4 for the local, coastal categories and hake métier, respectively. The rate of net loss is slightly higher in the hake category due to the greater distance from shore and water depths of the fishing operations.

Northeast Atlantic (deepwater fisheries). Building on the findings and concerns from the FANTARED work, the DeepNet project (Hareide *et al.*, 2005) examined the deepwater and upper-slope net fisheries of the northeast Atlantic in more detail, including an estimate of gear loss. It was considered highly likely that large quantities of nets would be lost, and there is also evidence of illegal dumping of sheet netting in the northeast Atlantic deepwater net fisheries (largely north and northwest of the United Kingdom and Ireland). The vessels involved in the deepwater net fisheries are often not capable of carrying their nets back to port (the net stores are used to hold fish) and only the headline and footropes are brought ashore while the net sheets are discarded, being either bagged on board, burnt or dumped at sea (Hareide *et al.*, 2005).

The amount of lost and discarded nets is poorly estimated. Hareide *et al.* (2005) note that anecdotal evidence from one shark vessel suggests that on a typical 45-day trip approximately 600 x 50 m sheets of net (30 km) are routinely discarded after having been damaged. Taking the level of effort to be in the region of 1 881 days (based on the German and United Kingdom effort data in Hareide *et al.*, 2005), a crude estimate of gear loss by these vessels in the region is 1 254 km of sheet netting per year. Based on the relationship between water depth and net loss rate and estimates of net loss in the Greenland halibut net fishery, it was estimated that in the deep-slope fisheries these vessels lose approximately 15 nets (750 m) per day.

Mediterranean. The extensive use of gillnets, trammel nets and traps in many small-scale Mediterranean fisheries, plus the very large number of small-scale vessels involved in fishing in Greece and Italy in particular, makes ALDFG a potentially important problem in Mediterranean waters, but to date it has attracted limited attention. The level of gear loss in the Mediterranean has only been studied in the western European countries, particularly in France. Only in the French hake gillnet fishery has an estimate been made of total net loss, as data from other fisheries is considered insufficiently reliable (FANTARED 2, 2002). However, a number of studies into gillnet and coastal fisheries indicate that gears are lost (Baino *et al.*, 2001; Sacchi *et al.*, 1995). The French gillnet fishery mentioned above consists of two components, the coastal fleet and the offshore fleet. The 65 vessel-strong offshore fleet loses around 0.2 percent of its nets annually (between 36 and 73 nets). The 32-strong coastal fleet has a similar rate of loss, but with a lower set rate, of about 9 to 17 nets per year. Other French fisheries that have been examined include other gillnet fisheries, where the quantity lost per year and per boat is between 0.7 km for red mullet métier and 1.2 km for hake and crawfish, and the percentage of lost nets represents 0.2 to 3.2 per boat and per year, respectively, for hake métier and sea bream métier. For the crawfish métier, it is 1.2 km/boat per year or 1.6 percent of all gear deployed.

Bingel (1989, in Golik, 1997) also attempted to estimate the quantity of all types of fishing gear lost in the Mediterranean Sea, based on an extrapolation of data from the Turkish industry's losses, vessel numbers, coastline length and shelf area. The estimate varies between 2 637 and 3 342 tonnes of fishing gear lost per year.

Table 3 provides a preliminary estimated summary of the extent of gillnet loss from those fisheries selected for study under FANTARED 2. These figures should be used with some caution as they represent estimates made in the period from 1998 to 2005 and the scale, nature and therefore extent of ALDFG may have changed since then. Furthermore, these fisheries represent only a small fraction of gillnet fisheries in the whole northeast Atlantic region.

TABLE 3
Estimates of gillnet loss in selected Northeast Atlantic fisheries

Region **Northeast Atlantic**	Fishery	No. of vessels in fishery	Km of net lost (boat / yr)	% loss (nets/boat/yr)	No. of nets lost (per year)
Continental shelf fisheries					
Baltic (Sweden)	Mixed (mainly cod)	...	156	0.10	1 448
North Sea & NE Atlantic (Norway)	Spawning saithe	...	...	0.09	431
	Cod	...	...	0.02	187
	Monkfish	...	...	–	–
	Greenland halibut	...	...	0.04	5
	Blue ling and ling	...	...	0.04	62
UK (all coastal fisheries)	Tangle	18	24	...	263
	Hake	12	12	...	62
	Wreck	26	n.a.	...	...
English Channel and North Sea (France)	Flatfishes & monkfish	...	1.5	0.42	...
	Cod	...	1.2	0.24	...
	Wreck	...	0.4	0.33	...
	Seabass	...	0.8	2.11	...
	Sole & plaice	...	2.8	0.20	...
	Plaice	...	1.1	0.37	...
	Cuttlefish	...	n/a	n.a	...
Brittany (France)	Flatfishes & monkfish	...	5.0	0.50	...
	Spider crab	...	0.3	0.04	...
	Wreck	...	0.2	2.81	...
Cantabria (North Spain)	Red mullet (bottom gillnet)	413	...	...	661
	Hake (bottom gillnet)	309	...	...	556
	Sole (trammel)	217	...	...	195
	Several species (trammel)	215	...	...	774
	Shellfish (trammel)	158	...	...	521
	Scorpion fish (trammel)	111	...	...	100
	Red mullet (bottom gillnet)	79	...	...	600
	Monkfish (bottom gillnet)	74	...	...	2 065
	Hake (gillnet)	59	...	...	159
	Monkfish (trammel)	53	...	...	101
	Inshore species (bottom gillnet)	34	...	...	228
	Shellfish (bottom gillnet)	22	...	...	332
Algarve (Portugal)	Inshore species (gill/trammel)	439	...	...	3
	Coastal (gill/trammel)	64	...	...	6
	Hake (gill/trammel)	22	...	...	7
Mediterranean (France)	Crawfish	...	1.2	1.60	...
	Hake	...	1.2	0.20	...
	Sea bream	...	1.2	3.20	...
	Scorpion fish	...	1.1	1.00	...
	Red mullet	...	0.7	0.50	...
	Sole	...	0.9	0.25	...
	Hake (inshore)	32	...	0.15	13
	Hake (offshore)	65	...	0.20	55
Deepwater fisheries	**N & NW of UK & Ireland**		**1 254**		**25 080**

Source: Brown *et al.* (2005), derived from EC contract FAIR-PL98-4338 (2003).
Note: ... = not available.

Traps and pots

Northeast Atlantic. There are few quantitative studies into the rate of pot losses in the northeastern Atlantic, mainly because of the lack of a perceived problem with this gear type, which is largely regarded as environmentally benign due to its small footprint and static nature. In the United Kingdom, Swarbrick and Arkley of the Seafish Industry Authority examined the reasons behind the loss of traps around the country and the effectiveness of "ghost fishing preventers" (Swarbrick and Arkley, 2002), but

TABLE 4
Pot losses in Portuguese octopus fishing fleets

Fleet	Zone	Trap type	
		Octopus	Cuttlefish
Local	Barlavento	30.9 ± 55.4	78.8 ± 147.5
	Sotavento	145.6 ± 102.2	13.5 ± 11.1
Coastal	Barlavento	213.0 ± 213.8	113.3 ± 19.3
	Sotavento	318.5 ± 507.8	10.0

Source: EC contract FAIR-PL98-4338 (2003).

no attempt was made to quantify trap losses, as their contribution to overall shellfish mortality was considered to be low.

Surveys were conducted in ten ports of the Algarve coast in southern Portugal in 2003 as part of the FANTARED 2 project. They examined the rate of pot losses by both the local and coastal fleet components of boats licensed to fish with small octopus traps and large cuttlefish traps. The average number of octopus traps lost at sea per vessel and per year for each port and fleet type is presented in Table 4. On average, the number of small octopus traps lost at sea is higher for the coastal fleet than for the local fleet.

For the larger cuttlefish traps, the results are the opposite, in that the local fleet loses more traps than the coastal fleet. Although the study produced relative loss rates, absolute figures for permanently lost pots were not determined, even though the recovery rates were estimated. It should be noted that loss of these octopus traps does not necessarily lead to ghost fishing (Andrew Smith, FAO, personal communication, 2008).

In summary, while the effects of lost pots in European waters have been studied in greater depth than in net fisheries, studies have been far from systematic, with small-scale surveys of certain pot types in a few locations. Therefore estimates of overall pot loss rates are lacking. While the FANTARED work looked at this in Portuguese trap fisheries, and reported that loss rates are low because of successful retrieval, the results are not presented in a manner that permits deduction of total gear loss. The same is true for the studies undertaken in the United Kingdom pot fisheries. In both cases loss rates were not considered to be high enough to warrant concern because of high retrieval rates, and pots lost generally being subject to damage because of gear conflicts.

Trawl nets and other mobile gear

Apart from the Norwegian, FANTARED and some Irish and United Kingdom surveys, there is little other reference in European literature to the levels of loss of trawl nets and other mobile gear. Anecdotal information suggests that considerable effort is put into the immediate recovery of lost gears due to their high value, combined with improvements in navigation and gear marking technologies. However, it is apparent that some trawl nets are lost, possibly even in considerable volume (John Willy Valdemarsen, personal communication, 2007), and it is likely that trawl warps are sometimes discarded at sea.

The South Asian Seas, the Red Sea and the Gulf of Aden, and the ROPME Sea Area (Arabian/Persian Gulf)

Gillnets

Bottom-set gillnets are extensively used for inshore coastal fishing and larger-mesh gillnets are used in open water for large pelagic species such as kingfish (*Scomberomorus commersoni*) and the smaller tunas. However very little information appears to be available on either the rates or magnitude of gillnet loss in these three regional seas.

Pots and traps

Red Sea and Gulf of Aden. Al-Masroori (2002), in a study to estimate ghost fishing rates of lost traps off Muscat and Mutrah in the Sultanate of Oman, estimated that trap loss rates might be as high as 20 percent per year in this fishery. Huntington and Wilson (1997) also reported that trap loss in the Hadramout lobster fishery in the Yemen is likely to be high, although again difficult to quantify.

ROPME Sea Area[8]. Lost traps and resultant ghost fishing have been considered a major issue in the Arabian Gulf. A quantitative estimate of the number of abandoned traps was conducted in the waters of the United Arab Emirates in 2002 that showed approximately 260 000 traps being lost per year (Gary Morgan, personal communication, 2007). The United Arab Emirates authorities have since made degradable panels in traps mandatory.

The East Asian, the Pacific and the Northwest Pacific Regional Seas

Gillnets

Brainard *et al.* (2000) summarizes ALDFG data for the Pacific as follows:

- Dedicated vessels combined with vessels of opportunity have been used in Pacific-wide surveys conducted by the Fisheries Agency of Japan from 1986 to 1991 (Matsumura and Nasu, 1997). They reported fishing net density to be higher in parts of the eastern Pacific Ocean. They also noted a high density of fishing nets on the Pacific Ocean side of Japan.
- Mio *et al.* (1990) and Mio and Takehama (1988) previously reported a high-density area of ALDFG nets northeast of Hawaii during sighting surveys conducted in 1986. . Other baseline studies on ALDFG numbers have been conducted in the North Pacific (Dahlberg and Day, 1985; Ignell, 1985; Ignell and Dahlberg, 1986; Day *et al.*, 1990).
- Altamirano *et al.* (2004) reported that data from the Inter-American Tropical Tuna Commission's (IATTC) On-Board Observer Program, which includes records of sightings of discarded fishing gear (DFG), indicates that ALDFG appears to have increased in the eastern Pacific from 1992 to 2002.

There are few studies attempting to quantify the abandonment, loss or discard of fishing gear in southeast Asia or the western central Pacific. Only the Republic of Korea, Japan and Australia have actively identified ALDFG as a significant issue and responded with attempts to examine the problem (Raaymakers, 2007). Most studies have examined the extent of fisheries debris being recorded from coastal areas, and some attempt to identify the likely origin of these items.

Various studies in Australia (Alderman, *et al.*, 1999; Kiessling and Hamilton, 2001) have indicated that over three-quarters of fishing debris in Cape Arnhem, Northern Territory in Australia, consists of trawl nets, and that the majority of fishing debris is of southeast Asian manufacture (around 79 percent)(see Table 5).

Limpus (personal communication, cited in Kiessling, 2003) estimated on the basis of aerial surveys of the eastern Gulf of Carpentaria (between Torres Strait and the Northern Territory border), that a total of around 10 000 nets (or around 250 kg of fishing net per km) litter the Queensland coastline. The ongoing Carpentaria Ghost Net Programme (see www.ghostnets.com.au) indicated that in 29 months of collection to November 2007, 73 444 m of net had been collected from the Gulf of Carpentaria (see Figure 3). Although 41 percent is of unknown origin, 17 percent is of Taiwanese origin, 7 percent of Indonesian and Taiwanese/Indonesian origin, 6 percent of Korean

[8] Regional Organization for the Protection of the Marine Environment (ROPME) Sea Area includes Bahrain, Iran, Iraq, Kuwait, Sultanate of Oman, Qatar, Saudi Arabia and the United Arab Emirates.

TABLE 5
Origin of fishing debris recorded at Cape Arnhem, Northern Territory, in Australia

Country of manufacture	Net type	Number of nets	Proportion of total nets *(percentage)*
Taiwan	Trawl	108	26
	Gill (drift net)	94	
	Subtotal	**202**	
Indonesia	Trawl	131	17
	Gill	6	
	Subtotal	**137**	
Taiwan/Korea	Trawl	99	13
Japan	Trawl	63	8
Philippines	Trawl	52	7
Japan/Korea	Trawl	25	3
Thailand	Trawl	23	3
Republic of Korea	Trawl	19	3
	Gill	1	
	Subtotal	**20**	
Australia	Trawl	68	12
	Gill	26	
	Subtotal	**94**	
Unknown	Trawl	7	9
	Gill	3	
	Unknown	59	
	Subtotal	**69**	
TOTAL		784	100
Trawl	76%	SE Asia	79
Gill (drift net)	12%	Australia	12
Gill (other)	5%	Unknown	9
Unknown	8%		
Total	**100%**	**Total**	**100**

Source: Derived from Kiessling, 2003.

origin and 5 percent of Australian origin. No details are provided on the type of nets, but it is understood they mainly consist of gillnets and trawl net fragments.

The Gulf of Carpentaria is a typical example of a circulating gyre system, where ALDFG is stuck in a repetitive cycle of fishing, being washed ashore and being washed back into the water during a storm or spring-tide event. On the eastern side of the Gulf (western Cape York) the nets arrive during the monsoonal season from November to March, while on the western shores the nets are swept in during the southeast trade winds, mainly between May–September (see Figure 3).

Northwest Pacific. A detailed survey in the Republic of Korea (Chang-Gu Kang, 2003) located an estimated 18.9 kg/ha of marine litter in fishing grounds, 83 percent of which was composed of fishing nets and related materials (e.g. ropes). A six month survey of the Incheon coastal area located 194 000 m^3 of marine debris weighing 97 000 tonnes, mainly originating from fisheries (Cho, 2004). A subsequent follow-up programme has resulted in recovery of 91 tonnes of marine-related debris per km^2 on an annual basis, of which 24 percent was of marine (as opposed to coastal) origin. Over the six-year period 2000 to 2006, 10 285 tonnes of fishing-related debris was recovered from coastal areas through a nationally coordinated coastal clean-up campaign (Hwang and Ko, 2007) (see Figure 4).

Up to 1 000 tonnes of ALDFG are recovered from the Sea of Japan annually, mostly bottom gillnets and pots, which are apparently mainly of non-Japanese origin (Inoue and Yoshioka, 2002).

The United States National Marine Fisheries Service estimated that 0.06 percent of driftnets deployed are lost each time they are set, resulting in 12 miles of net lost each

FIGURE 3
Examples of ALDFG in northern Australia

A 6 tonne Taiwanese gillnet with large entangled shark washed ashore in Arnhem Land.

Aboriginal rangers loading an ALDFG fishing net collected from the shore onto a truck for recycling/disposal, Arnhem Land, Australia.

Source: www.ghostnets.com.au

FIGURE 4
Recovery of ALDFG in the Republic of Korea

Source: Hwang and Ko, 2007.

night of the season and 639 miles of net lost in the North Pacific Ocean alone each year (Paul, 1994[9]). In Hawaii, fisheries-related marine debris surveys over 1998–2002 (Northwestern Hawaiian Islands Multi-Agency Marine Debris Cleanup) showed that debris consists mainly of trawl/seine nets (83.6 percent) with the balance being mono- and multifilament gillnets (5.2 percent and 3.2 percent, respectively) (Donohue and Schorr, 2004; Dameron *et al.*, 2007; Pichel *et al.*, 2007; Donohue and Foley, 2007). To date, over 600 metric tonnes of ALDFG have been removed from the Hawaiian

[9] www.earthtrust.org/dnpaper/waste.html

archipelago by NOAA and its partners (Elizabeth McLanahan, NOAA, personal communication, 2008).

Pots and traps

A survey of commercial crabbers in the blue swimmer crab fishery in Queensland, Australia, conducted in early 2001 showed that significant pot loss occurred during a fishing season (McKauge, undated). The vast majority of respondents stated that they had lost pots during the previous 12 months, with an average loss of about 35 pots per annum (range 0 to 400). Given these figures, it was estimated that over 6 000 pots are lost each year in the fishery. The actual proportion of the pots that remain in the environment is difficult to estimate as some are trawled up and others disappear through theft and cannot be regarded as ALDFG. It was estimated by the researchers that less than 50 percent of lost pots remain in the environment.

The Southeast Pacific and the Northeast Pacific Regional Seas

Gillnets

There appears to be little published information on gillnet losses in either the Southeast or Northeast Pacific. Given the intensity of both Pacific salmon and halibut netting in the Northeast Pacific, ALDFG might be considered an issue that deserves more attention.

Pots and traps

Considerable numbers of pots are also lost each year from some fisheries in the Northeast Pacific, although estimates vary greatly between different studies. For example, Kruse and Kimker (1993) estimated that in 1990 and 1991, 31 600 pots per year were lost in the North American Bristol Bay king crab (*Paralithodes camtschaticus*) fishery, whereas Paul *et al.* (1994) and Stevens (1996) estimated that losses from the same fishery were, respectively, 20 000 and 7 000 pots per year. In a one-year study of Dungeness crab pots of British Columbia, Canada, the estimated annual trap loss rate was 11 percent (Breen, 1987).

The Wider Caribbean Regional Sea and the Northwest Atlantic

Gillnets

The Wider Caribbean. A recent NOAA and United States Department of State co-hosted Caribbean-wide Derelict Fishing Gear Workshop in Key West, Florida, 17–19 July 2007 brought representatives from many Caribbean nations together to discuss topics related to ALDFG, but no proceedings are available as yet (Leigh Espy, NOAA, personal communication, 2007).

It is understood that the workshop concluded that in discussing ALDFG in the Wider Caribbean, there appears to be little information or agreement on whether it is viewed as a significant issue (Bisessar Chakalall, FAOSLAC, personal communication, 2007). The meeting was not sure how big a problem ALDFG was in the region, or whether the primary causes were storm events or the lack of disposal facilities onshore or if the primary cause of ALDFG in the region was in outside sources. The general view was that fish traps and gillnets have the greatest potential of contributing to ghost fishing. One participant claimed that on the basis of empirical evidence, most ALDFG was from outside the region.

Northwest Atlantic. The first documented work on lost gillnets appears to be that of Way (1977) in Atlantic Canada. Over two years, Way retrieved 148 and 167 net fragments in 48.3 and 53.5 hours of trawling with a grappling device. A number of other studies followed (e.g. High, 1985; Carr *et al.*, 1985) but most tended to be in response to specific incidents of loss or following some opportunistic identification of an accessible lost net.

Studies that have attempted to estimate the amount of lost nets in a given area by using remotely operated vehicles (ROVs) or by net retrieval include Barney (1984), Carr and Cooper (1987), Cooper *et al.* (1987) and Carr *at al.* (1985). Fosnaes (in Breen, 1990) estimated an annual loss rate of Newfoundland cod gillnets of 5 000. Carr and Cooper (1987) estimated that in an area of 64 km^2 traditionally fished by gillnets, there were 2 240 lost nets. Canadian Atlantic gillnet fisheries were estimated to suffer a 2 percent loss rate (8 000 nets per year) up to 1992 (Chopin *et al.*, 1995). More recently, Anon. (2001) (in EC contract FAIR-PL98-4338, 2003) reported losses of 80 000 nets or net sheets between 1982 and 1992 throughout Canadian Atlantic waters.

Pots and traps

The Wider Caribbean. In Puerto Rico, 24 percent of fishers are unable to locate and retrieve traps if lost (Schärer *et al.*, 2004). Of the 40 000 Caribbean traps around Guadeloupe, about 20 000 are lost each year during hurricane season, but continue to catch fish for many months (Burke and Maidens, 2004). Otherwise there is little specific information available on the level of gear losses in this shallow sea.

Northwest Atlantic. In the snow crab (*Chionoecetes opilio*) trap fishery in the Gulf of St. Lawrence, it was estimated that over 19 000 traps were lost at sea between 1966 and 1989 (Chiasson *et al.,* 1992). This is equal to an average of around 792 traps per year. Anecdotal reports of lobster pot loss rates off New England, in the United States of America, run as high as 20–30 percent per year (Smolowitz, 1978a). Along the Maine coast the pot loss rate reported in 1992 was 5–10 percent (ICES, 2000).

Conservative estimates suggest that more than 500 000 commercial crab traps are deployed in the Chesapeake Bay on a typical day during the summer months. It is suggested that each commercial fisher may lose as many as 30 percent of his traps for a variety of reasons over the course of one year (NOAA Chesapeake Bay Office, 2007). This would equate to losses of around 150 000 traps annually in this one large bay. Estimates of ALDFG trap densities for the surveyed portions of the Lower York River and the Chesapeake main stem adjacent to the South River range from 20 to 690 traps per km^2. Cost-effective methods for retrieval of these traps are currently being considered (NOAA Chesapeake Bay Office, 2007).

Estimates derived from trap loss calculations suggest an ALDFG trap number of 605 000 in 1993 in Florida, Alabama, Mississippi and Louisiana, though Guillory and Perret (1998) state that this number is probably an underestimate. Guillory *et al.* (2001), using an annual total number of one million traps fished commercially and a 25 percent loss/abandonment rate, suggests that 250 000 derelict traps are added to the Gulf of Mexico annually, with ghost fishing leading to a loss of four million to ten million blue crabs each year in Louisiana (GSMFC, 2003). This figure underestimates the actual number of derelict traps because of the cumulative addition of derelict traps over time and exclusion of traps used by recreational fishers (Brown *et al.*, 2005).

GLOBAL REVIEW OF ALDFG ORIGINATING FROM OTHER FISHERIES AND AQUACULTURE

Other fisheries

Longlines and jigs

The extensive use of longlines, their often extremely long-set configuration and low cost, means that the overall quantity of longlines lost is likely to be high. But figures to substantiate this are few and far between. The SPC fisheries observer schemes have been collecting data on lost/discarded gear since about 2003 but this has never been compiled into an electronic format or summarized/reported. However, anecdotal information suggests that data are likely to show a high rate of gear discarding when tangled or damaged (Brett Moloney, personal communication, 2007).

Logbook data are used by the International Pacific Halibut Commission (IPHC) to estimate adult halibut mortality due to lost/abandoned gear in the halibut fishery. The IPHC reported that in the Alaskan halibut (Hippoglossus stenolepis) fishery, 1 860 "skates"[10] were lost in 1990 alone, with an estimated gear replacement cost per fisher of US$200 per skate. Overall gear losses have decreased markedly since the introduction of individual transferable quotas – when excessive amounts of gear are no longer necessary, less gear is lost and there is more time for its retrieval because of the longer season (Barlow and Baake, undated).

In the Maldives, it was found that a number of hooks were lost from longlines after most fishing nights (Anderson and Waheed, 1988). It is assumed that most of this damage was done by sharks, although large billfish may also have been responsible. The rate of hook loss on fish aggregating devices (FADs) is estimated at about 3 percent per set.

Fish aggregating devices (FADs)

The use of FADs is now widespread in the world's tuna fisheries, and indeed the use of FADs has increased significantly over recent years, making this type of fishing gear a potentially important component of ALDFG.

FADs essentially consist of an anchored or free-drifting, floating object that might be constructed of anything from netting or palm fronds, to tires or high tech rafts with locator beacons. They are used to aggregate fish before setting purse seines or handlining around them. FADs can be highly concentrated – for instance there are over 900 FADs in the Papua New Guinea waters of the Bismarck Sea alone (Kumoro, 2003). However, due to their vulnerability to storm damage or to having their anchor ropes accidentally severed during adjacent fishing operations, FADs are frequently lost to a fishery. They may also be deliberately abandoned in the oceans, in contravention of MARPOL Annex V (if made of synthetic materials).

Box 1, which charts the history of FAD deployment in Samoa, demonstrates the vulnerability of these devices to loss.

Data on global FAD loss are very poor. The contribution of lost FADs to marine litter has not received much attention, although studies by Donohue (2005) and SPC (unpublished) are notable, and the recent draft United States National Research Council report (2008) places considerable emphasis on the FAD issue but notes that "the ability to infer the extent to which derelict FADs are contributing to the marine debris problem is hampered by a lack of information on FAD use and their contribution as components of the DFG stream" (NRC, 2008).

The NRC study, however, reports some interesting data. The IATTC fleet deployed 8 188 FADs in 2006 and 8 721 FADs in 2007, while the number of FADs retrieved during these years was 6 163 in 2006 and 7 769 in 2007. But the difference between deployment and retrieval numbers does not permit an estimate of abandoned FADs, as some may still be actively "fishing" or may have been appropriated by other vessels. The NRC study also notes with respect to the central and western Pacific that "information on how many FADs are deployed and the rate of FAD loss, appropriation, and recovery is unknown for the WCPFC fleet", and that "Skipper surveys from French and Spanish purse-seine vessels operating in the western Indian Ocean estimated the total number of actively monitored FADs at approximately 2 100 at any given time." (NRC, 2008).

Aquaculture

While aquaculture lies outside the main scope of this report, it is worth commenting briefly on the potential contribution of coastal mariculture to the marine litter problem.

[10] Longline gear uses "skates" (leaded ground line 300 fathoms long) with approximately 140 hooks attached to them by "gangion" lines. Skates are tied together in "sets". Each set lies on the ocean bottom with anchors and buoys attached at each end.

BOX 1

Fish aggregating device (FAD) losses in Samoa between 1979 and 1999

Five FADs were deployed in 1979 off Samoa by NOAA staff from Hawaii. All five FADs were lost in less than one year. The Samoa Fisheries Division then deployed seven FADs in late 1980, all around ten miles off the coast and in depths over 1 000 fathoms. In 1981, six of the FADs deployed in 1980 were lost. They were replaced and another four deployed. In 1982, 8 FADs were lost and another 11 deployments were made. During 1983 and 1984 another 17 FADs were deployed, but at the end of 1984, only 1 FAD remained. The losses were attributed to purse-seine vessels setting their nets and cutting the mooring lines. Limited FAD were deployed from 1989 to 1993, and a cyclone in 1990 caused the loss of all FADs. In 1993 and 1994, eight FADs were deployed – four of them were lost in 1994. In August 1999, four FADs were deployed, and one was lost in the first six months.

Source: SPC, unpublished report.

It is accepted that greater control can be exerted on these mainly static facilities. The main sources of ALDFG in aquaculture would be associated with sea-based farms, such as cages, longlines, poles and other floating and fixed structures used for culture of marine animals and plants. There are no global estimates of the levels of ALDFG from aquaculture to date. The types of material lost would depend on the type of culture systems, construction quality, vulnerability to damage, and management practices.

- For marine fish cages, the major losses would be nets and cage structures (wood, metal).
- For seaweed systems, the major losses would be lines or floating raft structures.
- For mollusc farming, the debris could include poles, bags, lines, concrete, and other structures. Some mollusc farming areas contain large amounts of debris from damaged or discarded poles, some of which are discarded after removal of mussels or oysters.

Because many of these items are expensive, one might expect farmers to take considerable care to avoid losses. The most significant losses are likely in events such as ship collisions, storms and other extreme events. One such extreme event was the Indian Ocean tsunami in December 2004. This led to the partial or total loss of much of the rapidly expanding marine cage farming infrastructure in Aceh and Nias in Indonesia. The losses are briefly summarized in Box 2 below to illustrate the magnitude of the event.

OCEAN CIRCULATION, MOVEMENT AND ACCUMULATION OF ALDFG

ALDFG found accumulating on many coastlines of the world often originates from sources far afield, sometimes even from the other side of a vast ocean. In developing actions and measures to address ALDFG, it is therefore important for scientists, regulators and industry to have an understanding of ocean circulation patterns.

Over the long term, the mean of these generic patterns are probably indicative of ocean circulation. However, over shorter time periods and at larger scales, which are of more relevance to the assessment and management of ALDFG, the real situation is far more complex, highly variable and seasonally dynamic. In reality, ALDFG will not follow generic, mean ocean circulation patterns, but will be driven by rather more complex patterns resulting from a combination of wind-driven currents, wave-driven currents and thermohaline, or density-driven, currents (Brainard *et al.*, 2000).

BOX 2
Infrastructure loss of marine cage farming in Indonesia as a result of the 2004 tsunami

The main losses in marine cage culture were in Aceh province and in Nias island in North Sumatra. Losses included nets and floating and fixed cage structures. It is estimated that all 80 cages were lost on Kota Subang (100 percent loss), and 57 out of 65 units on Simeuleu island (88 percent loss). In Simeulue, all the floating and fixed marine fish cages on the island, a total of 65 units (each with approximately eight to ten cages) located in Sinabang Bay and Teluk Dalam Bay, lost crops. Cages were culturing tiger grouper (E. fuscoguttus) and greasy grouper (E. tauvina) and lobsters, which were also lost during the tsunami. Of the floating nets used for grouper culture on the island, two were lost, two were seriously damaged, and two suffered light damage, for a loss of Rp50 million (US$5 500). Fixed pen nets suffered severe damage. Twenty-six units were lost, 27 units were seriously damaged and six units were lightly damaged, for total damages estimated at Rp305 million (US$33 000). On Kota Sabang, some cage cultures (two units, each unit with 40 cages (for a total of 80 cages) were lost. These cage cultures were used for grouper and previously kept milkfish for tuna longline near Pulau Klah in Sukakarya subdistrict.

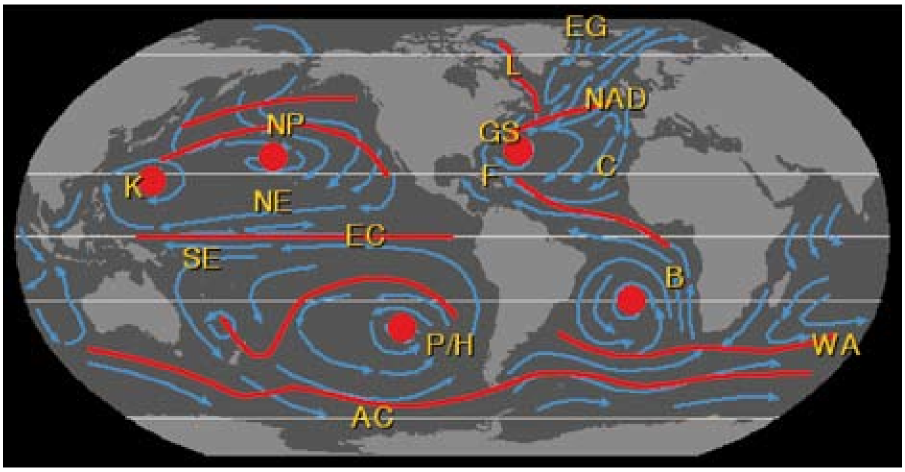
Source: Phillips and Budhiman, 2005.

In recent years significant advances have been made in the mapping and modeling of complex ocean circulation patterns, at various scales, and incorporating the different elements that drive these patterns. The outputs of such models, based on satellite imagery and remote sensing, can greatly assist scientists and managers in interpreting the results. Today an array of satellite sensors can be used by oceanographers to measure various aspects of the world's oceans, including parameters such as surface winds (e.g. QuickSCAT), sea surface height and computed geostrophic currents (TOPEX/Poseidon), sea surface temperature (e.g. GOES) and chlorophyll as indicated by ocean color (e.g. SeaWiFS). When combined with numerical modeling, and supported by in-field oceanographic data collection and physical tracking to ground-truth/verify the models, these systems provide powerful tools to assist in the assessment and management of ALDFG.

There are many examples of the use of oceanographic tracking and modeling in the assessment and management of ALDFG. For example, Kubota (1994) tracked virtual marine debris in the North Pacific using a simple numerical model over five years, which indicated the accumulation of debris from the whole North Pacific in the northern Hawaiian Islands. The results of this predictive modeling have been verified by real-life sightings in this area, including the current NOAA Marine Debris Program – which is undertaking significant work in collaboration with many others to address ALDFG in the northern Hawaiian Islands, as outlined above – and including further use of ocean circulation models (Donohue, 2004). More recent work has been conducted by Kubota *et al.* (2005), Morishige *et al.* (2007), Pichel *et al.* (2007) and Donohue and Foley (2007).

Work by various parties has shown that ALDFG tends to accumulate (and often reside for extended time periods) in ocean convergence zones and move away from ocean divergence zones. Mass concentrations of marine debris in high seas accumulation areas, such as the equatorial convergence zone, are of particular concern. In some such areas, rafts of assorted debris, including various plastics; ropes; fishing nets; and

FIGURE 5
Examples of ocean convergence zones



The red dots indicate where marine litter may accumulate

Source: Penn State School of Earth and Mineral Sciences.

cargo-associated wastes such as dunnage, pallets, wires and plastic covers, drums and shipping containers, along with accumulated slicks of various oils, often extend for many kilometres (Steve Raaymakers, pers. obs. 1989, 1998 and 2000). Such zones have been modeled and mapped by various researchers (Figure 5), and this information is vital to improving the monitoring and management of ALDFG.

In order to be effective in addressing ALDFG, oceanographic models need to be developed and applied at much finer scales than that shown in Figure 5, and also regional, national and local scales.

SUMMARY OF MAGNITUDE AND COMPOSITION OF ALDFG

In a summary of net loss across all European Union (EU) fisheries, Brown et al, (2005) concluded that "In relation to the total number of nets being used in EU waters, the rates of permanent net loss appear to be rather low – well below one percent of nets deployed[11]. This is largely because most nets are deployed in shallow waters, and after they are first lost a significant proportion of nets are then recovered through the use of global position systems (GPS); fishers typically go to considerable lengths to recover nets given their cost. However, because the total length of nets being set is high, the total length of netting permanently lost may be significant, although exact figures are not available. An exception to the low loss rates seen in most European fisheries is in the deep water net fishery targeting deep water shark and monkfish in the north east Atlantic[12]."

In North America, studies that have attempted to estimate the amount of lost nets in a given area by using remotely operated vehicles (ROVs) or by net retrieval include Barney (1984), Carr and Cooper (1987), Cooper *at al.* (1987) and Carr *et al.* (1985). Fosnaes (in Breen, 1990) estimated an annual loss rate of Newfoundland cod gillnets of 5 000. Over two years, Way (1977) retrieved 148 and 167 nets in 48.3 and 53.5 hours of trawling with a grappling device. Carr and Cooper (1987) estimated that in an area of 64 km^2 traditionally fished by gillnets, there were 2 240 lost nets. Canadian Atlantic

[11] It is not possible or wise to estimate any total figure of net loss in EU fisheries from this estimate because the fisheries studied to date by projects such as FANTARED represent only a tiny proportion of total fisheries in the EU, so any estimates would be highly unreliable.

[12] Conducted on the continental slopes between 150 and 1 200 m from south of Porcupine Bank (49° N) to Tampen (61° N) and the Rockall and Hatton Banks.

TABLE 6
Summary of gear loss/abandonment/discard indicators from around the world

Region	Fishery/gear type	Indicator of gear loss (data source)
North Sea & NE Atlantic	Bottom-set gillnets	0.02–0.09% nets lost per boat per year (EC contract FAIR-PL98-4338 (2003))
English Channel & North Sea (France)	Gillnets	0.2% (sole & plaice) to 2.11% (sea bass) nets lost per boat per year (EC contract FAIR-PL98-4338 (2003))
Mediterranean	Gillnets	0.05% (inshore hake) to 3.2% (sea bream) nets lost per boat per year (EC contract FAIR-PL98-4338 (2003)
Gulf of Aden	Traps	c. 20% lost per boat per year (Al-Masroori, 2002)
ROPME Sea Area (UAE)	Traps	260 000 lost per year in 2002 (Gary Morgan, personal communication, 2007)
Indian Ocean	Maldives tuna longline	3% loss of hooks/set (Anderson & Waheed, 1998)
Australia (Queensland)	Blue swimmer crab trap fishery	35 traps lost per boat per year (McKauge, undated)
NE Pacific	Bristol Bay king crab trap fishery	7 000 to 31 000 traps lost in the fishery per year (Stevens, 1996; Paul *et al.*; 1994; Kruse and Kimker, 1993)
NW Atlantic	Newfoundland cod gillnet fishery	5 000 nets per year (Breen, 1990)
	Canadian Atlantic gillnet fisheries	2% nets lost per boat per year (Chopin *et al.*, 1995)
	Gulf of St Lawrence snow crab	792 traps per year
	New England lobster fishery	20–30% traps lost per boat per year (Smolowitz, 1978)
	Chesapeake Bay	Up to 30% traps lost per boat per year (NOAA Chesapeake Bay Office, 2007)
Caribbean	Guadeloupe trap fishery	20 000 traps lost per year, mainly in the hurricane season (Burke and Maidens, 2004)

gillnet fisheries were estimated to have a 2 percent loss rate (8 000 nets per year) up to 1992 (*in* Chopin *et al.*, 1995).

The United States National Marine Fisheries Service estimated that 0.06 percent of driftnets[13] were lost each time they were set, resulting in 12 miles of net lost each night of the season and 639 miles of net lost in the North Pacific Ocean alone each year (Davis, 1991, in Paul, 1994[14]). More recently, Anon. (2001, in FANTARED 2, 2003) reported losses of 80 000 nets between 1982 and 1992 throughout Atlantic Canadian waters.

Outside of Europe and Northern America, the picture provided of the extent and nature of ALDFG is much more patchy, in terms of rates for different gears and thus the ability to estimate the overall magnitude of ALDFG. The rate and magnitude of ALDFG from the South and Central Pacific, southeast Atlantic, the Caribbean and much of the Indian Ocean is still largely unknown.

Table 6 summarizes ALDFG indicators from a number of fisheries around the world. It should be noted that information on fisheries in which ALDFG has been reported is drawn from sources published over an extended period. It is possible that some of these fisheries have changed in nature and that the information presented may not reflect the current ALDFG situation.

[13] A UN General Assembly adopted a resolution that bans driftnet fishing in international waters effective December 1992. The United States of America still permits drift gillnet fisheries within United States waters, and as of March 2007, there were over 1 300 vessels fishing with driftnets in European waters (www.ec.europa.eu/fisheries/fleet/index.cfm?method=Search.menu). The use of driftnets in EU waters is carefully regulated, and driftnets exceeding 2.5 km in length have been banned since the early 1990s. The use of driftnets of any length in fisheries targeting specific species, including tuna and swordfish, was banned in 1998. The prohibition on the use of driftnets was extended to EU waters of the Baltic Sea from 1 January 2008.

[14] www.earthtrust.org/dnpaper/waste.html

Table 6 demonstrates the wide variability of loss rates from different fisheries and also highlights the lack of recent data on ALDFG. It should be emphasized that these figures simply attempt to bring a sense of scale to the issue, but given the current reliance on patchy and largely survey-based information (as opposed to first-hand observation), it is difficult to provide any robust quantification of the level of gear lost in the world's oceans on an annual basis, or of its overall contribution to marine debris as a whole.

The main difficulties in estimating the level of ALDFG from the world's fisheries are as follows.

- Most gear is not deliberately discarded – the predominant source of ALDFG is through loss resulting from gear conflicts, loss in storms or strong currents (see Chapter 4) – but this may not be immediately apparent, thus compromising reporting.
- Some of the gear lost is from IUU fishing, especially in artisanal fisheries where the use of light monofilament nets is common.
- The abandonment, loss or discard of gear has not been considered a major issue in fisheries management. As a result it is rarely required to be quantified in mandatory or voluntary reporting requirements.
- The best way to quantify gear loss is through independent observations, yet the level of observer coverage is low and is usually instigated for some other reason, such as bycatch monitoring, and thus may not capture high risk fisheries.
- There is no accepted standard for recording gear loss. There needs to be a standard that reflects the difference in gear designs and vulnerable components, such as dhans and headropes, and standardizes terms such as "nets" (is this a single sheet or a whole fleet of sheets?).
- Many of the experimental studies on gear loss (and particularly on its subsequent impact) are compromised by poor experimental design, which often does not reflect either the commercial or environmental conditions in which they are most likely to be used.
- Many studies of gear loss indicate relative rates of gear loss, yet rarely indicate the total level of usage of that gear by the studied fishery and thus the absolute levels of gear lost.

This chapter also emphasizes the importance of global oceanic currents in concentrating marine litter in oceanic gyres or convergence zones. These areas are well known and relatively easily monitored, thus allowing the targeted recovery of floating marine debris, including ALDFG, that might have accumulated.

3. Impacts of ALDFG

This chapter considers the impacts of ALDFG. ALDFG has a number of environmental impacts, including:

- continued catch of target and non-target species;
- interactions with threatened/endangered species;
- physical impacts on the benthos;
- a role as a vector for invasive species; and
- introduction of synthetic material into the marine food web.

ALDFG also impacts upon marine users with marine litter causing, among other things:

- navigational hazards;
- loss of amenity and disruption to enjoyment of beaches and coastal areas
- safety concerns; and
- additional costs resulting from fouling vessels and other gear.

CONTINUED CATCHING OF TARGET AND NON-TARGET SPECIES

The way in which a gear changes during its progression from initial loss of control to its eventual demise is a key variable in determining its catching efficiency. Furthermore, the state and position of a net or pot at the start of this process is also important. Abandoned nets or pots may be set for maximum fishing efficiency and will thus have higher ghost fishing catches and in the case of nets, if well anchored, be slow to collapse. Or discarded nets may collapse immediately and will thus have lower initial fishing efficiencies. Nets and pots may also be discarded in areas where they have less potential to ghost fish. Once ALDFG has lost its burden of captured fish and marine growth, it has the potential to regain its shape and start fishing again.

As control over fishing gear is lost, the selectivity and efficiency of the gear for the original target species may be altered. This change in specificity may result from:

- alteration in the mesh characteristics if a net becomes distorted;
- changes in gear transparency and "detectability" due to marine growth (itself a function of depth, water transparency and productivity);
- translocation of the gear to different environs; and
- accumulated catches that may act as bait for other species that get entangled or entrapped in the gear. As a result, ALDFG typically increasingly catches other fish and shellfish species that may or may not have a commercial value.

Overall ghost fishing catches are probably very low compared to controlled fishing (Brown *et al.*, 2005). However, this varies according to gear type and operating conditions.

Gillnets

Vertical profile, mesh size, mesh stiffness and transparency are the primary characteristics that make gillnet gear effective. Mesh size is important for species and size selectivity but is less important in terms of effectiveness than the other characteristics (ICES, 2000). Other factors relating to the overall catch from gillnets are depth and sea bottom type. Together with the availability of vulnerable species, the gear's exposure to environmental incidents such as storms, wave surge, currents and fouling are thus key determinants of the effective mortality rate/catching efficiency of ghost gillnets.

The work under the European Commission's FANTARED project and other international studies show that while nets may be set in a wide range of environmental conditions, their change over time and the resulting catches show some similar patterns and tendencies. The catching efficiency of nets generally shows the same pattern of changing species composition over time, typically from fish to crustaceans, and initial rapid declines in catching efficiency towards lower levels.

Static nets on open ground experience an initial sharp decrease in net height followed by a prolonged period of slow decrease in net height and increased degradation and tangling due to catches and biofouling. Fishing may nonetheless continue at significant rates (Carr and Cooper, 1987; Brothers, 1992).

On rocky ground, gillnets may maintain a nearly horizontal configuration with some vertical profile as they are caught around rocks (Carr, 1988). Depending on the level of exposure to the elements, however, catch rates can near zero over an 8 to 11 month period as the nets become destroyed and fouled (Erzini *et al.*, 1997). Nets deployed on wrecks and rocky bottoms tend to degrade rapidly and/or are tangled in the structure of the wreck, resulting in reduced catch rates within months of being set. While studies in Canada showed that nets set in very deep water continued to fish for many years, the effective fishing lifetime of the nets in the FANTARED study was from 6 to 12 months in the majority of cases.

Various studies have been conducted that monitor the ability of different types of ALD gillnets to continue fishing and how this changes over time as the net collapses and degrades.

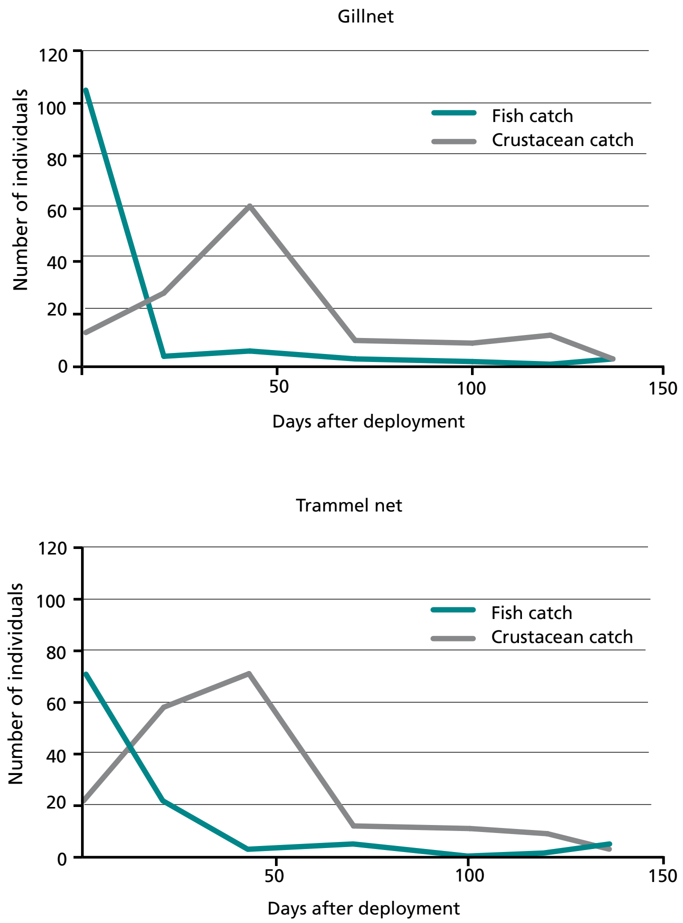
Results of net loss simulations and wreck surveys around the United Kindgom were reported in the FANTARED 2 study, and by Revill and Dunlin (2003). One of the gillnet fleets lost on open ground was virtually intact and appeared to be operating at around 90 percent efficiency after four weeks but contained no gadoid species or hake in the net. A second gillnet fleet was at 50 percent efficiency while the third was lost. In both nets, the bulk of species captured were crustacea predating upon decomposing fish. This suggests that for much of the time the net was not standing vertically and that it contained decomposing fish for some of the time. Very few skeletal remains were seen and both replicates were clear of marine growth and colonization. These observations were similar to those made by Pilgrim *et al.* (1985).

Tschernij and Larsson (2003) reported on the "catchability" of 24 experimentally set cod gillnets in the Baltic Sea that were shown to continue to catch cod after their "loss", with catch rates dropping off to around 20 percent of initial catch after three months, due to net degradation from storms and currents and capture of fish. From this point, catches continued even though the nets were biofouled and hence visible. Catches appeared to stabilize at about 5 percent to 6 percent after 27 months. This catching efficiency was expected to continue over several years.

Nakashima and Matsuoka (2004) investigated the catching efficiency of lost bottom-set gillnets by setting nets in three experiments for up to 1 689 days. The nets were monitored through underwater observation. Catching efficiency declined to 5 percent by day 142, during which period the total number of ghost-fishing mortalities was 455 fish. Ghost fishing for red sea bream (Pagrus major) and jack (Decapterus sp.) occurred in a short initial period and for filefish, (Stephanolepis cirrhifer) over a longer period.

Gillnets studied in inshore waters of North America also demonstrated a collapse in net and subsequent decline in catch rates over time. Carr *et al.* (1992) deployed two 100 m sections of 130 mm stretched gillnets at 20 m depth in Buzzards Bay, Massachusetts, United States of America. Over a two-year period, skates, dogfish and a number of finfish were caught initially while lobster and other crustacea continued to be caught throughout the study. A two-year fishing life was also observed in Canadian nets by Way (1977). Carr and Cooper (1987) estimated that in protected, near-shore locations where depths are less than 30 m, gillnets may continue to catch fish at a reduced, yet substantial, rate of 15 percent of normal the gillnet rate if roundfish and flatfish are present.

FIGURE 6
Change in catch composition of a "lost" gillnet and a trammel net



Source: Kaiser *et al.*, 1996.

Kaiser *et al.* (1996) observed two types of fixed gear, a gillnet and a trammel net, set 1 km offshore from a rocky coastal area in southwest Wales, United Kingdom (see Figure 6). The nets were allowed to fish continually for nine months, during which time they were surveyed by divers. Several hours after both nets had been set, a large number of dogfish were caught, causing the nets to collapse. Catch rates began to decline within a few days of the initial deployment, probably related to a decline in the effective fishing area of the net resulting from entanglement of target and non-target fish species and crustaceans. Initially, more fish than crustaceans were caught, although this reversed after 43 days. The catch of fish approached zero, 70 and 22 days after deployment for the gillnet and trammel net, respectively. It was estimated that the gillnet caught 226 fish after 70 days and 839 crustaceans after 136 days, while the trammel net caught 78 fish after 22 days and 754 crustaceans after 136 days. Even though the nets were damaged by storm action, the work demonstrated that lost nets could continue to catch commercial crustacean species for at least nine months after initial loss. The gradual reduction of fishing was attributed to a reduction in net size and degree of entanglement as the net rolled up. It should be noted that that these nets were deliberately deployed in shallow water to aid diving observations. The conditions were therefore not necessarily typical of commercial operations.

In an earlier study, Carr *et al.* (1992) also noted that the species makeup of the catch changes with a reduction in net height, resulting in increased capture of crustaceans.

Under the FANTARED 1 project, four 100 m lengths of monofilament gill and trammel nets were set in 15 m to 18 m of water and cut loose to simulate lost gear. Similar patterns were observed in all the nets, with a sharp decrease in net height and effective fishing area, and an increase in visibility within the first few weeks. Net movement was negligible except in the case of interference from other fishing gears. Catch rates were initially comparable to normally fished gillnets and trammel nets in the area, but decreased steadily over time. No seabirds, reptiles or mammals were caught in any of the eight nets. Catches were dominated by fish (89 percent by number, with at least 27 species), in particular by sea breams (Sparidae) and wrasses (Labridae). The fishing lifetime of an ALDFG net was found to be between 15 and 20 weeks under the study conditions. When the nets were surveyed in the following spring, between 8 and 11 months after being deployed, they were found to be completely destroyed or heavily colonized by algae and had become incorporated into the reef.

Baino *et al.* (2001) examined a 1 200 m trammel net lost in 20 m to 35 m water after four months of ghost fishing. By this stage one-third of the net was still fishing, with a catch of around 20 percent of normal "controlled fishing". When hauled in, it was seen that 80 percent of the biomass consisted of various seaweeds and corals, while 6 percent comprised live fish and 1 percent dead fish. The authors concluded that "during the four-month period the trammel net must have fished some hundreds of kilograms of commercial species".

Tangle nets

Twenty-seven tangle nets used for targeting monkfish were deployed in the Cantabrian region, with the results reported in Sancho *et al.* (2003) and FANTARED 2. Catch rates were equivalent to those of commercial gears after 135 days but no monkfish were caught after 224 days. The cumulative monkfish catches in 50 m length nets were estimated to be 2.37 fish. This was a total of 18.1 tonnes for the entire ghost catch, which constituted 1.46 percent of the total commercial landings in the area. This was considered an overestimate given that the studied nets were not trawled away. A very worst case estimate of ghost catch was put at 4.46 percent of total commercial landings, or 55.3 tonnes.

Deepwater gillnets

Humborstad *et al.* (2003) monitored deepwater gillnets set at over 500 m in the Greenland halibut fishery off the Norwegian coast. They found that the catching efficiency of gillnets decreased with soak time, presumed to be due to the weight of the catch causing the headline height to decrease. After 45 days, efficiency was from 20 percent to 30 percent of equivalent nets in the commercial fishery. These rates corresponded to 28 kg to 100 kg per day per gillnet. Catch rates stabilized at this level and the nets continued to fish for "long periods of time". Way (1977) reported ghost catch by nets in the deeper waters of Newfoundland and found that the nets continue catching over several years, although at much reduced levels. High (1985) also observed continued catching after three years of fish and seabirds in pieces of lost salmon gillnet, despite biofouling. Ten gillnets caught about 9 090 kg of cod in Placenta Bay, Newfoundland (ICES 2000).

Pelagic or drift gillnets

Gerrodette *et al.* (1987) monitored 113 mm mesh, 9 m deep monofilament nets (50 m, 100 m, 350 m and 1 000 m in length). They found that the nets collapsed soon after deployment and that relatively few fish or other organisms were caught in the bundle of netting. Mio *et al.* (1990) deployed five pelagic gillnets of 2 000 m length and similarly concluded that they formed a large mass of netting within four months.

Pots and traps

Pots[15] and traps also tend to pass through a progressive process of ghost fishing. As they are usually baited when they are set, if the pot is lost, over time the bait or lost catch attracts scavengers, some of which are commercially important species. These scavengers may become entrapped and subsequently die, forming new bait for other scavengers. Entrapped animals may escape over time. Animals captured in ALDFG traps die from starvation, cannibalism, infection, disease, or prolonged exposure to poor water quality (i.e. low dissolved oxygen) (Van Engel, 1982; Guillory, 1993). The effect of ALDFG blue crab traps on other species such as terrapins and commercially important finfish has been documented (Smolowitz, 1978; Guillory, 1993; Guillory and Prejean, 1998).

A key point that can be inferred from the FANTARED project and other studies is that catching efficiency is as variable as pot loss rates, and is dependent upon gear design, species behaviour and seasonality. Entry, escapement and mortality rates are the result of dynamic processes, as demonstrated by the following examples.

As with bottom-set nets, the effective catching efficiency of potting gear is dependent primarily on the availability of susceptible species and the lost gear's exposure to environmental incidents such as storms, currents, wave surge and fouling. With the exception of wire fish traps, the other two types of traps (crab traps in Norway and octopus traps in Portugal) studied in the 2003 EC FANTARED project did not show significant degradation over the course of the project. However, unlike nets, the catch rates of pots depend to a large extent on the bait; once this has been eaten or has degraded, catch rates decline sharply. In work conducted on blue crab traps in the Chesapeake Bay, United States of America (Havens *et al.*, 2006), there was a significant difference between baited and unbaited traps; the traps simulating "self-baiting" captured slightly more than double the unbaited traps (mean catch rate 0.785 and 0.385 crabs/trap/day, respectively).

In the case of the octopus and the fish traps in Portugal, there were almost no catches three months after deployment. While fish were found to be less able to escape from traps, escape rates for octopus and the king crab were high. Post-escape mortality following retention in pots for prolonged periods (days or weeks) is a possibility in the case of the crabs. There is little information concerning such unaccounted mortality and this is an area that was considered to warrant further study.

The continued fishing by ALDFG pots was evaluated experimentally by Bullimore *et al.* (2001). A fleet of 12 pots were set in a manner to simulate ghost fishing, off the coast of Wales, United Kingdom. The original bait was consumed within 28 days of deployment yet the pots continued to fish, mainly for spider crab (*M. squinado*) and brown crab (*Cancer pagurus*). The catch declined over time, reaching a minimum between nine and ten months after the experiment began, although it rose again later, possibly linked to rising water temperatures. The actual mortality of crustaceans was difficult to estimate, as some were able to escape and the pots were not under continual observation (dive surveys were conducted at 1, 4, 12, 27, 40, 69, 88, 101, 125, 270, 333, 369 and 398 days after initial immersion), although it was possible to calculate a catch rate per day and estimated total catch for a fixed period of time (Michel Kaiser, personal communication, 2008). Non-target species such as the Ballan wrasse (*Labrus bergylta*) were also observed in the trap, especially towards the end of the experiment, when crustacean levels were lower.

As reported in Godøy *et al.* (2003), an experiment was conducted whereby pots were deliberately "lost" for periods of between five days and one year. A newly designed

[15] There does not seem to be any definitive difference between "pots" and "traps" and the two terms are used interchangeably in most literature.

rectangular, collapsible pot was the main gear used, while in a single five-day trial the traditional conical pot was used. In a string of four pots, all 92 tagged individuals left the pots after four months, while 61 new crabs entered them. Very few dead crabs were found in the pots. While there were limitations to the experiment design, it was concluded that lost pots do not substantially contribute to crab mortality in these fisheries. The size of the crabs increased with soak time in the rectangular pots, while it decreased with soak time in the conical pots.

In a study of catch rates of lost wire fish traps in fishing grounds nears Muscat and Mutrah, Sultanate of Oman (Al-Masroori *et al.*, 2004), ghost fishing mortality was estimated at 1.34 kg/trap per day, decreasing over time. A model was used to estimate a trap ghost fishing mortality rate of 67.27 and 78.36 kg/trap during three and six months, respectively.

The reported catch of lobster in pots lost off the New England coast was 5 percent of the total lobster landings in 1976 (Smolowitz, 1978). Sheldon and Dow (1975) observed American lobsters (*Homarus americanus*) entering pots over two years and confirmed the ghost fishing of crabs and lobsters by pots, although the rates were not quantified. Pecci *et al.* (1978) studied the ratio of mortality to entrapment in a pot and it was the first quantitative research that reported ghost fishing efficiency and the mortality rate per gear. Breen (1987) conducted a sector-wide research on ghost fishing in a pot fishery, where the ghost fishing mortality for Dungeness crab was estimated to be equivalent to 7 percent of the landed quantities in the studied sector. Conversely, another study reported numerous exits of the entered spiny lobster and slipper lobster and little direct mortality in pots in comparison to the total mortality in their population, and concluded that ghost fishing by those pots was inconsequential (Parrish and Kazama, 1992).

Hébert *et al.* (2001) demonstrated a ghost fishing mortality rate of 94.6 percent in the snow crab (*Chionoecetes opilio*) trap fishery in the Gulf of St Lawrence. Based on a mean catch rate of 51 kg per haul, 1 000 gears were calculated as resulting in killing 84 194 snow crabs, or 48.2 tonnes per year. It was also demonstrated that catches increase in the new season again to their saturation level, due to the self-baiting effect, which re-initiated a ghost fishing cycle. Guillory *et al.* (2001) suggested that ghost fishing leads to a loss of 4 to 10 million blue crabs each year in Louisiana (GSMFC, 2001).

In the Caribbean, Munro (1974) examined the mode of operation of Antillean fish traps and the relationships between ingress, escapement, catch and soak. Dive surveys showed that the daily ingress of reef fishes into traps set on the south coast of Jamaica tended towards a constant value, but that with increased duration of immersion (soak), an increasing proportion of the cumulative ingress escapes from the traps and the cumulative catch tends towards an asymptote. It was shown that a nearly constant fraction of the number of fishes contained in a trap escape each day, and that the catch stabilizes when mean daily escapement equals mean daily ingress. The rate of escapement from Antillean fish traps varied within narrow limits and averaged 11.6 percent per day. Baiting a trap temporarily increases the rate of ingress, but when the bait is exhausted the rate of ingress decreases and the catch declines and stabilizes at a point where daily escapement equals the daily ingress. Steel-framed stackable traps captured 22 percent less (by weight) than wooden-framed traps of almost identical dimensions. It is believed that the more complex visual outline of the wooden-framed traps may attract fishes in some manner and thus enhance rates of ingress into such traps.

Matsuoka *et al.* (1995) carried out underwater observations of lost pots and their ghost fishing in a coastal fishing ground in Japan. Many commercially important finfish and cephalopod species were observed in the intact pots. Fewer organisms were observed in pots deformed by frame damage, buried in sediment or covered by accumulated fouling organisms. The decline in ghost fishing over time was proven to be very slow, with 43 percent of ALDFG pots continuing to ghost fish. This value was dependent on the water depth in which pots are lost, the current conditions, water temperature, fouling rates and adjacent ground conditions. Deepwater pots which are less damaged by waves and storms and less fouled by organisms, may continue to ghost fish for longer time periods than those in shallow waters.

Bottom trawl gear

The larger diameter synthetic multifilament twine common to trawl nets is the key factor that reduces ghost fishing mortality in lost trawl gear. The material has a larger diameter than gillnet monofilament and is visible or of such a size that it can be sensed by the fish. Although lost trawl gear will often be suspended by floats and form a curtain that rises well above the bottom, many of the losses form additional habitat for such organisms as ocean pout, wolfish and cod, and substrate for attaching benthic invertebrates such as hydroids and sea anemone, again reducing their capacity to continue fishing (Carr and Harris, 1994).

Diving observations using SCUBA, submersibles and ROVs have shown that on deep substrate and bottom locations where currents are at a minimum, trawl gear usually has an overburden of silt. The webbing is thus quite visible or detectable. Trawl netting, though, is often also found floating or just subsurface. Many of the synthetic twines are buoyant, and sometimes the twine buoyancy is augmented by floats attached to major pieces of trawl webbing. This attracts pelagic marine species, invertebrates such as the attached tunicates and barnacles, and pelagic invertebrates. This webbing may also attract other marine species that can become entangled (Laist, 1994, in ICES 2000). Page *et al.* (2003) states that New Zealand fur seals were commonly entangled in loops of packing tape and trawl net fragments suspected to be from rock lobster and trawl fisheries.

In dynamic areas such as tidal streams or even oceanic current gyres, ALD trawl nets may not accrete to the sea bed and may cause more damage as they move around. In this case they may represent a potential navigation hazard or cause physical abrasion to the benthic substrate.

Nets used by Asian fisheries found on northern Australian coastlines tend to be of larger mesh size and of much greater area and weight than Australian prawn trawl nets (Sloan *et al.*, 1998; Kiessling and Hamilton, 2001). Nets from foreign vessels are also causing great harm to marine animals, especially turtles (Kiessling, 2005; Roeger, 2004).

Longlines

The mortality rate from lost demersal longlines is usually low (ICES, 2000; Huse *et al.*, 2002). Such lost gear may persist in the environment, however, when it is constructed of monofilament. Ghost mortality is a function of the gear type, the operation and the location in regard to active ocean features and elements. Lost longline gear may continue to catch fish as long as bait exists on the hooks. Fish caught on the hooks may themselves become a form of bait for subsequent fish, both target and non-target. ALDFG in the form of longlines will not stop fishing until all of the hooks are bare. The extent to which this occurs and its effects on community structure have not been analysed (NOAA, 2004).

INTERACTIONS WITH THREATENED/ENDANGERED SPECIES

Many of the species that are impacted by ALDFG are listed as endangered or threatened under national and international conservation conventions (Laist, 1997; Laist and Liffman, 2000). ALDFG, especially when made of persistent synthetic material, can impact marine fauna in two main ways (Shomura and Yoshida, 1985; Laist, 1997):

- entanglement, whereby ALDFG entangles or entraps animals and their habitats; and
- ingestion, whereby ALDFG is intentionally or accidentally ingested.

The most comprehensive review of the impacts of marine debris globally, including lost gear, is perhaps that undertaken by Laist (1997). Entanglement was considered far more likely as cause of mortality than ingestion. Fishing gear (monofilament line, nets and ropes) was found to be the most significant source of entanglements in all documented records regarding sea turtles, coastal and marine birds, marine mammals and fish and crabs. The greatest source of this material was considered to be commercial fishing operations, although recreational fishing and cargo ships were also considered potential sources.

Some years ago it was estimated that some 100 000 marine mammals die every year from entanglement or ingestion of fishing gear and related marine debris (Laist, 1997). According to the United States Marine Mammal Commission, 136 marine species have been reported in entanglement incidents in the wider United States area, including 6 species of sea turtles, 51 species of seabirds and 32 species of marine mammals (Marine Mammal Commission, 1996). However, most information is provided through casual observations and little is known about how the capture of threatened and endangered species changes during the evolution of fishing gear.

Turtles. In northern Australia, 29 dead turtles were found in ALD fishing nets over a four-month period at Cape Arnhem (over an area covering about 10 percent of the mainland perimeter of the Gove fisheries statistical area), of which 50 percent were already dead when found (Roeger, 2002). While it is not possible to accurately compare the impact of active fishing activity and that of ALD fishing gear on marine turtles on the basis of these figures alone, Roeger suggests that the threat to marine turtles posed by fishing debris is comparable to the threat posed by active fishing efforts prior to the introduction of turtle exclusion devices (TED) (Kiessling, 2003).

Seals. Entanglement in static fishing gear and abandoned nets is thought to have a serious impact on monk seals (*Monachus monachus*) in the Mediterranean, as discussed by Johnson and Karamanlidis (2000). This is a population suffering rapid decline despite being listed as a critically endangered species[16]. Prior to the establishment of a protected area, the extensive use of gillnets constituted a major threat to the survival of the small surviving monk seal colony in the Desertas Islands of Madeira. It was reported in 1998 that animals had been dying frequently as a result of entanglement in lost nets (Anselin and van der Elst (1988) in Johnson and Karamanlidis (2000)). The latter authors also reported that a major clean-up operation, coupled with an initiative to have fishers convert from net gear to longlines, effectively solved the problem.

The incidence of entanglement of marine mammals in floating synthetic debris in the Bering Sea has been related to the growth in fishing effort and the use of plastic materials for trawl netting and packing bands. In the northeast Pacific, it was estimated that 15 percent of the mortality of young fur seals (*Callorhinus ursinus*) could be attributed to net debris, with the average seal expecting to encounter 3 to 25 pieces of net debris annually (Fowler, 1987 in Goñi, 1998).

In Australia, estimates suggest that 1 478 seals die from entanglement each year (Page *et al.*, 2003). Australian sea lions are most frequently entangled in monofilament gillnet that probably originates from the shark fishery that operates in the region where sea lions forage. In New Zealand, fur seals are most commonly entangled in loops of

[16] Monk seal is listed as Critically Endangered on the IUCN Red List and as an Appendix I species under CITES. It is also listed as an Appendix II species under the Bern Convention, as an Appendix I and Appendix II species under the Bonn Convention, and as an Annex II and Annex IV species under the EU Habitats Directive.

packing tape and trawl net fragments suspected to be from regional rock lobster and trawl fisheries (Page, 2004).

In Hawaii, ALD fishing gear entanglement is a known cause of mortality to critically endangered Hawaiian monk seals (*Monachus shauinslandi*). All the main Hawaiian monk seal breeding subpopulations are within the northwestern Hawaiian Islands and suffer one of the highest entanglement rates of any seal or sea lion reported to date (Donohue *et al.*, 2001). Donohue *et al.* reported that from 1982 to 1998 annual Hawaiian monk seal population entanglement rates were from 0.18 percent to 0.85 percent (Henderson, 1990 and 2001), as compared to rates of 0.15 percent to 0.71 percent during the period 1967 to 1992 for juvenile male, northern fur seals, a species for which entanglement has been proposed as one among other reasons to explain decreasing population trends (Fowler *et al.*, 1993).

In the Antarctic, the rate of entanglement of Antarctic fur seals (*Arctocephalus gazella*) halved over a five-year period (1990–1994) after the introduction of MARPOL Annex V, although there was also a doubling of the population. Polypropylene packing straps, fishing net fragments and, to a lesser extent, synthetic string were the most common debris items to entangle seals in all years (Arnould and Croxall, 1995).

Seabirds. It has been estimated that over one million birds die each year from entanglement in, or ingestion of, plastics (Laist, 1997). Furthermore, at least 135 species of marine vertebrates and eight species of marine invertebrate have been reported entangled in marine litter (Laist, 1997). However, the species-level impacts of entanglement in marine debris are unclear.

For most seabirds (particularly procellariiform seabirds, penguins, grebes and loon), evidence is lacking or is based only on isolated or infrequent reports. Species such as northern gannets, herring gulls, fulmar petrels and shags have large or increasing populations in which entanglement may be a chronic low-level source of mortality but has little effect on population numbers.

Offal itself is usually discarded from longliners and poses a serious threat to seabirds since such offal will often contain hooks – fish heads with hooks in them are often discarded. Large seabirds such as albatross are regularly found with hooks embedded in their mouthparts or ingested, and although they may be digested, there is a serious risk of esophageal damage or heavy metal poisoning (David Agnew, Imperial College, London, personal communication, 2007). Although lost lines create litter and may sometimes catch diving mammals such as seals, the hooks probably do not contribute to large amounts of ghost fishing. This is because the bait, or any fish caught on them, is usually stripped off the hooks by benthic organisms.

Whales. Entanglement of marine mammals in fishing gear has been documented widely and may affect a significant proportion of some populations of baleen whales (Kraus 1990; Lien 1994; Volgenau *et al.*, 1995; Knowlton and Kraus, 2001; Robbins and Mattila, 2001, 2004; Knowlton *et al.*, 2005). In a recent study, the prevalence of non-lethal entanglements of humpback whales (*Megaptera novaeangliae*) in fishing gear in the northern part of southeastern Alaska was quantified using a method based on scars identified on the whales (Nielson, 2006). The percentage of whales assessed to have been entangled ranged from 52 percent (minimal estimate) to 71 percent (conditional estimate) to 78 percent (maximal estimate). Eight percent of the whales in Glacier Bay/ Icy Strait acquired new entanglement scars between years, although the sample size was small. Calves were less likely to have entanglement scars than older whales, and males may be at higher risk than females. The percentage of whales with entanglement scarring was comparable to that in the Gulf of Maine where entanglement is a substantial management concern (Nielson, 2006). However, it remains unclear as to what percentage of entrapment arises from ALDFG as opposed to entrapment from fishing gears in commercial use.

Other animals. In Australia, anecdotal reports suggest that many other protected species such as dugong and sawfish are being entangled in ALDFG and other debris (Kiessling, 2003). For example, in addition to several turtles, Sloan, *et al.* (1998) also found fish, sharks and seabirds (including a pelican) entangled in ALD fishing nets at Groote Eylandt in the Gulf of Carpentaria. At the very least, more than 794 marine turtles, many sharks, sea-snakes and birds, and several whales, dolphins and dugong have been entangled in ALD commercial and recreational fishing gear and plastic bags in northern Australian waters since 1994. Of those net types that have been identified, trawl and drift nets of Taiwanese, Indonesian and Japanese manufacture appear to be causing some of the greatest harm to marine wildlife, including turtles, sea-snakes, sharks, fish and birds. There are no known records of wildlife entanglements in Australian trawl netting.

On the Pacific coast of the United States of America, lost, abandoned and otherwise discarded gillnets from commercial and subsistence fisheries can kill substantial numbers of juvenile and adult white sturgeon in impounded areas (M. Parsley, USGS Cook, Washington, Blaine Parker, Columbia River Inter-Tribal Fish Commission, personal communication, from Lower Colombia Fishery Recovery Board, 2004).

PHYSICAL IMPACTS OF ALDFG ON THE BENTHIC ENVIRONMENT

Gillnets

As a consequence of the loss of control once a gillnet becomes ALD, its form and impact on the surrounding environment becomes the function of the gear characteristics and the nature of the local ground, currents and tidal exchange, as well as water depth and clarity. In sensitive or more dynamic environments, e.g. those in shallow water with tidal bidirectional flows, ALD fishing nets can impact benthic environments through smothering, abrasion, "plucking" of organisms, meshes closing around them, and the translocation of sea-bed features.

Some authorities state that gillnets have little impact on the benthic fauna and the bottom substrate (Huse *et al.*, 2002) as the bottom line of gillnets are relatively light and the pressure on the bottom sediments is therefore very low. However, gillnets may be dragged along the bottom by strong currents and wind during retrieval, potentially harming fragile organisms like sponges and corals. In many areas where gillnets are used, the water is deep or the current is periodically strong, necessitating the use of heavy anchors (>100 kg) which may also cause localized impact.

Fishers who lost nets in Algarve claim that the nets interfere with normal fishing practices, possibly leading to further gear loss, and that reefs are smothered to the extent that reef fish may have reduced access (Erzini *et al.,* 1997). However, Erzini's studies also suggest that nets may eventually become incorporated into the reefs and provide a complex habitat for colonizing animals and plants. This was also supported by anecdotal information from gillnet fishers in southwest England (Brown *et al.*, 2005). Carr and Milliken (1998) noted that in the Gulf of Maine cod reacted to lost gillnets as if they were part of the seafloor. Thus, other than damage to coral reefs, effects on habitat by gillnets are thought to be minimal (ICES, 1991, 1995; Stephan *et al.*, 2000). The impact of lost gillnets on coral reefs can be more severe. Al-Jufaili *et al.* (1999) found that ALD nets affected coral reefs at 49 percent of sites surveyed throughout the Sultanate of Oman and accounted for 70 percent of all severe human impacts. Donohue *et al.* (2001) have confirmed the threat of ALDFG to the coral reefs of the northwestern Hawaiian Islands, where derelict fishing gear is threatening coral reef ecosystems by abrading and scouring living coral polyps and altering reef structure through large-scale destruction of the reefs' coral skeleton foundation (Donohue and Schorr, 2004).

Traps

In general, traps are often advocated on an environmental basis for having a lesser impact on habitat than mobile fishing gear such as trawls and dredges (Rogers *et al.*, 1998; Hamilton, 2000; Barnette, 2001) as well as being a less energy intensive fishing method (Brown and Tyedmers, 2005). The potential physical impacts of ALD traps depend upon the type of habitat and the occurrence of these habitats relative to the distribution of traps (Guillory, 2001). In general, sand- and mud-bottom habitats are less affected by crab and lobster traps than sensitive bottom habitats such as submergent aquatic vegetation beds or non-vegetated live bottom (stony corals, gorgonians, sponges) (Barnette, 2001).

The impact of ALD traps on sensitive habitats differs from that of actively fished traps. The effects of frequent trap deployment and recovery would be less in ALD traps than in actively fished traps, while the opposite would be true for the effects of smothering. Jennings and Kaiser (1998) suggested that the frequency and intensity of physical contact are important variables when evaluating the effects of fishing gear on the biota. ALD traps, while individually occupying a small area, may impact benthic flora because of their large number and potential smothering effect (Guillory, 2001).

A study of the impact of ALD traps and other fishing gear on the Florida Keys showed that they tend to accumulate on aggregate offshore patch reefs compared to near shore hard-bottom and deeper fore-reef strata (Chiappone *et al.*, 2002). While hook-and-line gear accounted for the majority of damage to reef communities (see below), remnant lobster traps were also important, accounting for 64 percent of the stony corals impacted, 22 percent of the gorgonians impacted and 29 percent of the sponges impacted.

Hook and line

While it is an important commercial gear, hook and line is also used by a large number of recreational and subsistence fishers, and therefore losses, especially within shallow inshore waters, may be very high. In the Florida Keys, Chiappone *et al.* (2002) reported that the debris type causing the greatest degree of damage was hook and line gear (68 percent), especially monofilament line (58 percent), and that it accounted for the majority of damage to branching gorgonians (69 percent of damage), fire coral (83 percent), sponges (64 percent), and colonial zoanthids (77 percent). This indicated that a gorgonian sponge-dominated reef would be more susceptible to damage from lost hook and line gear than coral-dominated reefs.

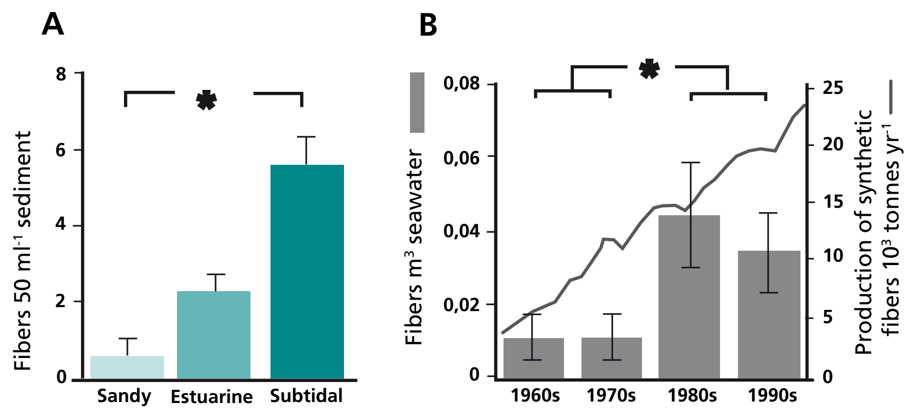
While examining the impact of fishing on the coldwater corals of the northeast Atlantic, although lost longlines were observed on video surveys of coral areas, no evidence of actual damage to reefs was found, although it was supposed that coral branches might be broken off during the retrieval of longlines (ICES, 2002).

FATE OF ALDFG IN THE MARINE ENVIRONMENT

The components of ALDFG litter many areas of the sea floor. At a general level, UNEP GPA (2003) states that as much as 70 percent of the entire input of marine litter to the world's oceans sinks to the bottom and is found on the sea bed, both in shallow coastal areas and in much deeper parts of the oceans.

Accumulation of litter in offshore sinks may lead to the smothering of benthic communities on soft and hard sea-bed substrates (Parker, 1990). Once on the sea bed, accumulations may smother sea life, or inhibit water movement to the extent that they contribute to the creation of anoxic mud (Rundgren, 1992). When in general

FIGURE 7
Presence of plastic microfibers in sediments (A) and CPR (B) samples



Source: Thompson *et al.*, 2004.

circulation in the sea, or resident in temporary sinks, litter items may also smother plants and animals on the seashore, and provide solid attachment for species that would not usually occur there, in addition to providing nuclei for sand dune formation.

The longer-term fate of lost fishing gear is unclear. Modern plastics can last up to 600 years in the marine environment, depending upon water conditions, ultraviolet light penetration and the level of physical abrasion. Furthermore, the impact of microscopic plastic fragments and fibers, the result of the degradation of larger items, is not known. Thompson *et al.* (2004) examined the abundance of microplastics in beaches, estuarine and subtidal sediments and found them to be particularly abundant in subtidal sediments (see Figure 7A). In a related experiment, the same authors examined the levels of plastic archived in plankton collected regularly though a continuous plankton recorder (CPR) since the 1960s and found a significant increase in abundance over time (see Figure 7B). Small quantities of microscopic plastics were also added to aquaria containing amphipods (detritivores), lugworms (deposit feeders) and barnacles (filter feeders). This indicates the possibility of plastics being incorporated into the food chain. Recent studies have provided further information on the likely impacts, such as the ability of these plastics to adsorb, release or transport chemicals and their toxic effects (Teuten *et al.*, 2007; Rios *et al.*, 2007).

A study in the Northeast Atlantic gyre system showed that a total of 27 698 small pieces of plastic weighing 424 g were collected from the surface water in the gyre, yielding a mean abundance of 334 271 pieces/km² and a mean mass of 5 114 g/km² (Moore *et al.*, 2001). Abundance ranged from 31 982 pieces/km² to 969 777 pieces/km², and mass ranged from 64 to 30 169 g/km². An examination of the sizes of the fragments indicated that pieces of line (polypropylene and monofilament) comprised the greatest proportion of the material collected in the largest size category (> 5 mm mesh size).

Not all ALDFG is necessarily negative. Box 3 gives examples of the usefulness of ALDFG flotsam in the South Pacific.

NAVIGATIONAL HAZARDS

Traditionally, concerns about ALDFG and marine debris in general have been driven by environmental and ecological concerns. However, the impacts of ALDFG on safety of navigation also deserve priority consideration, especially when considering that various cases of injury and loss of human life have been caused.

FIGURE 8
The effects of ALDFG on propellers

Rope and cable found wrapped around the propeller of the Esperanza of the Greenpeace fleet, off the coast of St Helena, South Atlantic, 7 March 2006
© Greenpeace/Dave Walsh

Nylon fishing tackle entangling an outboard motor propeller.

Source: NOAA.

The presence of ALDFG in the world's oceans can interfere with the safety of navigation in a number of ways (Johnson, 2000).

- Fouling or entanglement of a vessel's propeller, propeller shaft, rudder, jet drives or water intakes, can potentially affect the vessel's stability in the water and/or restrict its ability to maneuver. If disabled with reduced visibility, such a vessel may be endangered by a larger vessel or poor weather (see Figure 8).
- Benthic or subsurface debris has the potential for fouling vessel anchors as well as equipment deployed from research vessels and fishing trawlers, putting a vessel and its crew at risk.
- Damage to a vessel's propeller shaft seal can result from collision with ALDFG.
- Incidents may create the need to send divers underwater to attempt to clear the debris. Depending on the state of the sea state, work in close proximity to a vessel's hull can be dangerous.

An extreme example of impacts on navigational safety comes from the Republic of Korea. Cho (2004) reported that in 1993, while underway with 362 passengers and crew off the west coast of Korea, the propellers of the 110 GT passenger ferry Seo-Hae became entangled in a 10 mm nylon rope, which coiled around both propeller shafts and the right propeller, causing the vessel to suddenly turn, capsize and sink. A total

BOX 3
Utilization of ALDFG in the South Pacific

For longline gear, as well as some other gear types (i.e. purse seine), the most visible lost/abandoned pieces of gear are floats, which are highly prized in the outer islands and have all sorts of uses. Purse seine netting normally sinks to very deep ocean floor, but when it does wash ashore for some reason, it is used for hammocks and pigpens, and to cover the thatch on reefs. Another common item that washes ashore are the radio beacons used to mark logs for seining.

Source: Bob Gillett (consultant), personal communication, 2007.

BOX 4

Letter from an albacore tuna fisher to the United States Coast Guard

"Last year was particularly bad for debris for the albacore fleet. I imagine it was exacerbated by the La Niña current conditions that put us in the zone, although some previous years have been quite bad too. Several boats, including my own, encountered fouling en route to Hawaii in April, mainly pieces of light net; 1 to 1.5 mesh, black tarred twine as used in sardine seines or aquaculture. One boat encountered some hefty pieces of trawl web. In the area between 36° to 40° N and 145° to 165° W there were frequent encounters with the same net and also a lot of monofilament gillnet, about 3" mesh. This is particularly hard to cut once it is wound tightly onto a propeller shaft. In one incident, a fishing partner's boat was stopped dead, and after he had almost drowned trying to cut the propeller loose from debris, I swam over to finish removing the debris from the propeller. Among the mixture of net and rope were two banding straps such as one finds around frozen bait boxes, with Korean characters."

Source: Johnson, 2000.

of 292 persons died. The accident enquiry concluded that the accident was caused by overloading and by the effect of the fishing gear. Cho (2004) also reported that over a two-year period (1996–1998), there were a total of 2 273 navigational incidents that involved vessels and marine debris in Korean waters, including 204 involving propeller damage, 111 involving operational delay, 15 involving engine trouble (for example, due to coolant water blockage) and 22 involving "disaster" (loss of vessel and/or people).

Further highlighting the navigational hazards posed by ALDFG, Johnson (2000) reported that in a Pacific-wide survey by the United States Coast Guard in 1992, Japan responded that ALD fishing nets were considered the most dangerous drifting objects for the Japanese fishing fleet. A personal experience with the issue of hazardous debris is summarized from comments made by an albacore tuna fisher about his encounters with ALDFG in the Pacific (Box 4).

COSTS OF ALDFG

Types of costs

ALDFG presents not only a wide range of environmental impacts/costs, but also results in significant social and economic/financial costs. Table 7 attempts to summarize all the environmental, economic and social costs caused by ALDFG. Some important points to note in the table are the following.

- The costs of ALDFG are not distributed evenly between stakeholders.
- It may be in the economic/financial interests of fishers to deliberately discard or abandon fishing gear. This may be the case when doing so avoids greater costs associated with vessel damage and/or loss of other parts of the gear, or when the gear that is temporarily lost or otherwise snagged is not valuable, and retrieving it would result in reduced fishing time and greater fuel costs. For IUU fishing, discarding gear may enable vessels to avoid arrest by inspection authorities and subsequent penalties/fines.
- Some technical gear measures aimed at reducing ALDFG may result in associated costs to fishers, for example, through increased costs of gear, reduced catch rates, and/or reduced handling efficiencies.
- Some scavenger species may use "ghost" nets and pots for foraging, while fouled ghost nets may act as FADs, rather than actively catch fish. By inference, and in relation to environmental benefits of ALDFG, environmental costs may

TABLE 7
Economic and social costs of ALDFG

Economic costs
Direct costs: • cost of time spent disentangling vessels whose gear/engine become entangled in ALDFG, which results in less fishing time; • cost of lost gear/vessels because of entanglement as well as cost of replacement; • cost of emergency rescue operations because of entanglement of gear/vessels; • cost of time and fuel searching for and recovering vessels because of gear loss, which results in less fishing time; and • cost (to fishers or administrations) of retrieval programmes/activities to remove lost/discarded gear, or other management measures, e.g. cost of time required for better communication, cost of better marked gear, cost of monitoring regulations intended to reduce ALDFG. **Indirect costs:** • reduced income/value-added resulting from ghost fishing mortality, which means fish are lost from the fishery; • reduced multiplier effects from reduced fishing income; • cost of research into reducing ALDFG; and • potential impact on buying because of consumer fears/concerns about ghost fishing and ALDFG.
Social costs
• reduced employment in fishing communities resulting from decreased catch levels associated with unintended fish mortality; • reduced recreational, tourism and diving benefits from lost gear on beaches and at sea; and • safety risks for fishers and vessels if vessel maneuverability is compromised by entanglement or navigational hazards.

Source: Poseidon, 2008.

sometimes occur as a result of clean-up programmes to remove ALDFG from the marine environment. Removing fouled nets and other gear may itself cause damage to benthic environments if gear is deeply embedded in the sea floor.

- While the social costs of ALDFG are likely to be considerable, some stakeholders may gain benefits from ALDFG. Examples include the use of ALDFG washed up on beaches, as well as the use of recovered ALDFG in recycling activities by individuals or companies, as discussed under heading "Disposal and recycling" page 71.

Quantification of costs

Quantitative costs of ALDFG are not well documented, however some individual examples are provided below. Perhaps most interesting is the lack of any information on many of the different types of costs presented in Table 7, and the current inability to make any global estimation of the total costs of ALDFG.

Lost gear and fishing time costs

In the Scottish Clyde inshore fishery, gear conflict was identified as resulting in two sources of financial cost: the cost of replacing lost or otherwise damaged gear and the loss in earnings from reduced fishing time. Estimates made by fishers of the financial losses incurred due to such conflicts were found to be considerable. For example, losses of up to US$21 000 in lost fishing gear and an estimated US$38 000 worth of lost fishing time for 2002 was reported by one trap fisher (Watson and Bryson, 2003).

At-sea retrieval programme costs

With the proviso that unit costs differ among countries, it would certainly seem logical that a key determinant of the cost of a retrieval programme is the depth of water from which ALDFG is to be removed. However, gear retrieval programmes are varied in their scope and duration, and comparative costs across different retrieval programmes (for example, based on costs per tonne or length of net retrieved) are often difficult. Wiig (2005) attempted such a comparison and found a range of between US$65/tonne and US$25 000/tonne, but the extent to which such a huge range really demonstrates differing cost effectiveness is far from clear. Moreover, such comparisons are problematic in terms of assessing the benefits of removing gear from the sea, unless they take account of the differing extent to which ALDFG might be impacting on the environment in terms of ghost catches and other impacts. This in turn, as discussed elsewhere in the report, depends on the length of time the gear has been in the water, its particular characteristics and catching efficiency, the extent to which the gear is in a high or low energy environment, the specific ecosystem involved, and so on.

- Information collected over the past four years (2004–2007) during the Northwest Straits Initiative's ALD fishing gear survey and removal programme in Puget Sound, Washington, suggested that the costs of ALD net survey and removal totaled US$4 960 per acre of net removed. Costs of survey and removal of ALD pots/traps totaled US$193 per pot/trap (Natural Resources Consultants, Inc., 2007).
- Annual Swedish costs associated with a retrieval programme in the Baltic Sea are estimated at US$70 000, while Norway's annual costs are thought to be in the order of US$260 000. A pilot retrieval programme for the deepwater fishery in the Northeast Atlantic was estimated at around US$185 000 (Brown *et al.*, 2005). A breakdown of these cost estimates is provided in Appendix D.
- It is reported that in an expedition in 2004 to retrieve lost gear along the south coast of Sweden, it cost a stern trawler made for pelagic trawling US$800 to retrieve each kilometre of lost net (Tschernij and Larsson, 2003).
- A 2003 expedition in north Hawaii retrieved 120 tonnes of net; the major expense was the cost of two chartered boats for US$10 000 per day (Wiig, 2005).
- Woolaway's "Points for Pounds" programme encouraged fishers to bring debris into the Kaneohe Bay pier. The effort yielded 3 tonnes at a cost of US$7 400, for an average of US$2 467 per tonne (Wiig, 2005).
- The Northwest Straits Commission, acting on information provided by fishers, cleared 3 to 4 tonnes of floating net from a 12-acre sanctuary at a cost of US$35 000, for an average of US$10 000 per tonne (Wiig, 2005).
- In the Republic of Korea, (Captain Dong-Oh Cho, APEC, 2004) a subsidy is paid to local government for coastal clean-up, while the Korean central government's programme pays fishers US$3.50 per 40-litre bag of marine debris, and the Inchon Municipal Government pays fishers US$5.23 per bag (Wiig, 2005). The Inchon Municipal Government previously did the marine clean-up itself at a cost of between US$1 685 and US$3 075 per tonne.
- The Sea Fisheries Institute in Poland carried out a net retrieval programme in 2004 (Anon, 2004). The project was conducted for ten days at an estimated cost of US$19 000.
- A report in 1995 (Bech, 1995, as reported in Brown *et al.,* 2005) undertaken by the Fisheries and Marine Institute of Memorial University for the Department estimated the cost of lost gear retrieval as follows: design and testing of practical retrieval equipment US$305 000 (€198 250); ghost gillnet retrieval (Atlantic-wide programme) US$800 000/year (€520 000/year).

Costs related to marine litter

Regular clean-up operations are carried out in many countries throughout the world. In most cases, the work is done by local authorities, volunteers or NGOs. The costs for such clean-up can be significant, but as with retrieval programmes, costs are often difficult to quantify and compare because of the use of volunteer labour and non-standardization of whether costs include landfill charges. Unfortunately there are no figures on the sources of litter by group for any of these studies, i.e. to what extent can the costs involved be attributed to ALDFG from fishing activity.

- In England and Wales, local authorities, industry and coastal communities spend approximately US$30 million a year to clean up coastal marine litter (Environment Agency, 2004). Harbour authorities also have to pay for the costs of keeping navigational channels clear of litter, with United Kingdom harbour authorities spending up to €55 000 per year in some ports, to clear fouled propellers and remove debris from the water (Hall, 2001).
- In Alaska, there are reports of beach-clearance of heavy nets on St Paul Island in the Privilofs, at a cost of about US$1 000 per tonne, held down mainly to the presence of "free" heavy machinery and some volunteer labour (Wiig, 2005)
- In Taiwan Province of China, Dr Don-Chung Liu (APEC, 2004) reported a budget for the Environmental Protection Administration of TW$100 million/ US$2.9 million in 2002 for beach clean-up activities.
- In Japan, Kiyokazu Inoue (APEC, 2004) reported that with respect to the debris other than fishing gear, entangled with fishing nets, there is a problem of cost to dispose of them after bringing them back to land. For this purpose, retention and disposal projects have been established in which a part of the costs for disposal are subsidized by the government.
- Along with six other partners, Kommunenes Internasjonale Miljorganisasjon (KIMO)/Local Authorities International Environmental Organisation have undertaken a project called "Save the North Sea" to reduce marine litter. The total project is worth €5.7 million and KIMO's contribution is €1.2 million.
- In 1988, it was estimated that New Jersey in the United States of America lost between US$379 million and US$3.6 billion in tourism and other revenue as a result of debris washing ashore (NRC, 2008)
- Johnson (2000) reported that in 1992 Japan's maritime safety agency estimated that its fishing industry spent JP¥4.1 billion in vessel repairs following damage caused by marine debris.
- The costs of marine litter to fishers are not at all well reported, but KIMO[17] suggests that marine litter could cost each vessel studied in Shetland up to US$60 000 per year in lost time, damage to nets, fouled propellers and contaminated catches. KIMO suggests a breakdown of costs per year to fishers of marine litter as: time mending nets (US$20 000), cost of net repairers (US$20 000), time clearing nets (US$14 000), time cleaning equipment (US$2 000), fouled propellers (US$1 400) and gearbox inspections (US$100). The issue of fouled propellers has become so acute that some engine installations have the facility to increase the clearance between the seal and the propeller to allow a vessel to limp home.

SUMMARY OF THE IMPACT OF ALDFG

The capacity of ALDFG for ghost fishing is highly specific to gear type and the conditions under which it was abandoned, lost or discarded on whether the gear has been abandoned, lost or discarded and operates at maximum. It also depends on the nature of the local environment, especially in terms of currents, depth and location.

Some gears, such as gillnets and traps/pots have the ability to ghost fish. In the case of both gillnets and traps/pots, there is a common tendency to continue fishing with a declining catch as the gear becomes less effective, although the duration of this cycle can vary widely depending upon the local environmental conditions. Overall catch rates of ALDFG vary so greatly that a global estimate would be meaningless, but Sancho *et al.* (2003) considered lost tangle nets to catch around 5 percent of the total commercial catch.

[17] See www.kimointernational.org/Economic-Impacts.aspx

Other gears, such as lost trawls, rarely ghost fish but have other impacts such as smothering the benthos and damaging delicate habitats such as coral reefs. Lost longlines also rarely ghost fish but may become entangled or the hooks may be embedded in the bodies of seabirds.

Although the level of entanglement and ingestion may not be particularly relevant to commercial fish stocks, entanglement and ingestion become more significant when considering rare or endangered sea mammals, turtles or other animals. There are few comprehensive global studies on the overall significance of this, but specific studies have indicated that ALDFG may be a significant cause for mortality for some species at local level.

In terms of costs, it is very difficult to rate or compare the magnitude of the wide range of costs identified in Table 7, not least because of the difficulty in attributing meaningful figures to environmental and social costs. However, literature even on the economic costs associated with ALDFG is also very scarce, and if at all available, it generally attempts to quantify one type of economic cost at a time, rather than attempting any composite estimates for a particular fishery.

Specifically identifying monitoring, control and surveillance (MCS) costs, and rescue and/or research costs associated with ALDFG is very difficult, and does not seem to have been attempted to date. Nor have economic costs been attributed in any meaningful and comprehensive way to ghost fishing catches or to the value of gear that is lost, abandoned or discarded. This means that those working to reduce ALDFG are left in the rather unsatisfactory position of having to lobby and work for improvements without sufficient information on costs at their disposal. Better information could provide a powerful tool in encouraging policy-makers and the catching sector itself to make necessary changes. This is perhaps a key research area that could be meaningfully pursued in the future.

The lack of good data on the costs of measures to reduce ALDFG, plus a failure to quantify the benefits that would result from reduced ALDFG, mean that there has also been very little, if any, attempt to balance the respective costs and benefits of different measures designed to reduce ALDFG. Natural Resources Consultants, Inc. (2007) and Brown and Macfadyen (2007) raise this issue as being a potentially important one. This lack of information is now being addressed in some regions. Australia, Indonesia and Chile are to target the economic dimensions of marine debris prevention and mitigation through an APEC Marine Resource Conservation Working Group project entitled *Understanding the economic benefits and costs of controlling marine debris in the APEC region.* This type of investigation would be useful in other regions.

4. Reasons why fishing gear is abandoned, lost or otherwise discarded

INTRODUCTION

The causes of ALDFG are important both in terms of affecting lost gear evolution and for developing appropriate prevention and mitigation measures that fit with and address the principal causes. As with the magnitude of ALDFG, the causes of ALDFG vary among and within fisheries. When one considers that gear may be a) abandoned, b) lost or c) discarded, it is clear that some ALDFG may be intentional and some unintentional. Correspondingly, the methods used for reducing abandoned, lost and otherwise discarded fishing gear may therefore need to be different (Smith, 2001).

The impacts of ALDFG vary significantly due to numerous variables, including the vulnerability and sensitivity of the receiving environment, and therefore there is no clear correlation between type of ALDFG and its impact. Figure 9 does, however, show the different types of ALDFG, the reasons and motivations for each type, and the key pressures at play that result in each type. The impacts of ALDFG vary significantly due to numerous variables including the vulnerability and sensitivity of the receiving environment and therefore there is no clear correlation between type of ALDFG and its impact.

Despite the division of causes of ALDFG into discrete subsections, in most fisheries, fishing gear is probably lost, abandoned or discarded for a number of different reasons (Figure 9). Swarbrick and Arkley (2002), for example, found that in shellfish trap fisheries in the United Kingdom (pots and creels), bad weather was the primary cause of loss (43 percent), while the secondary cause of loss was due to other fishing activities (26 percent). Other causes included other marine traffic, their own fault/mistakes and "something else" (usually theft).

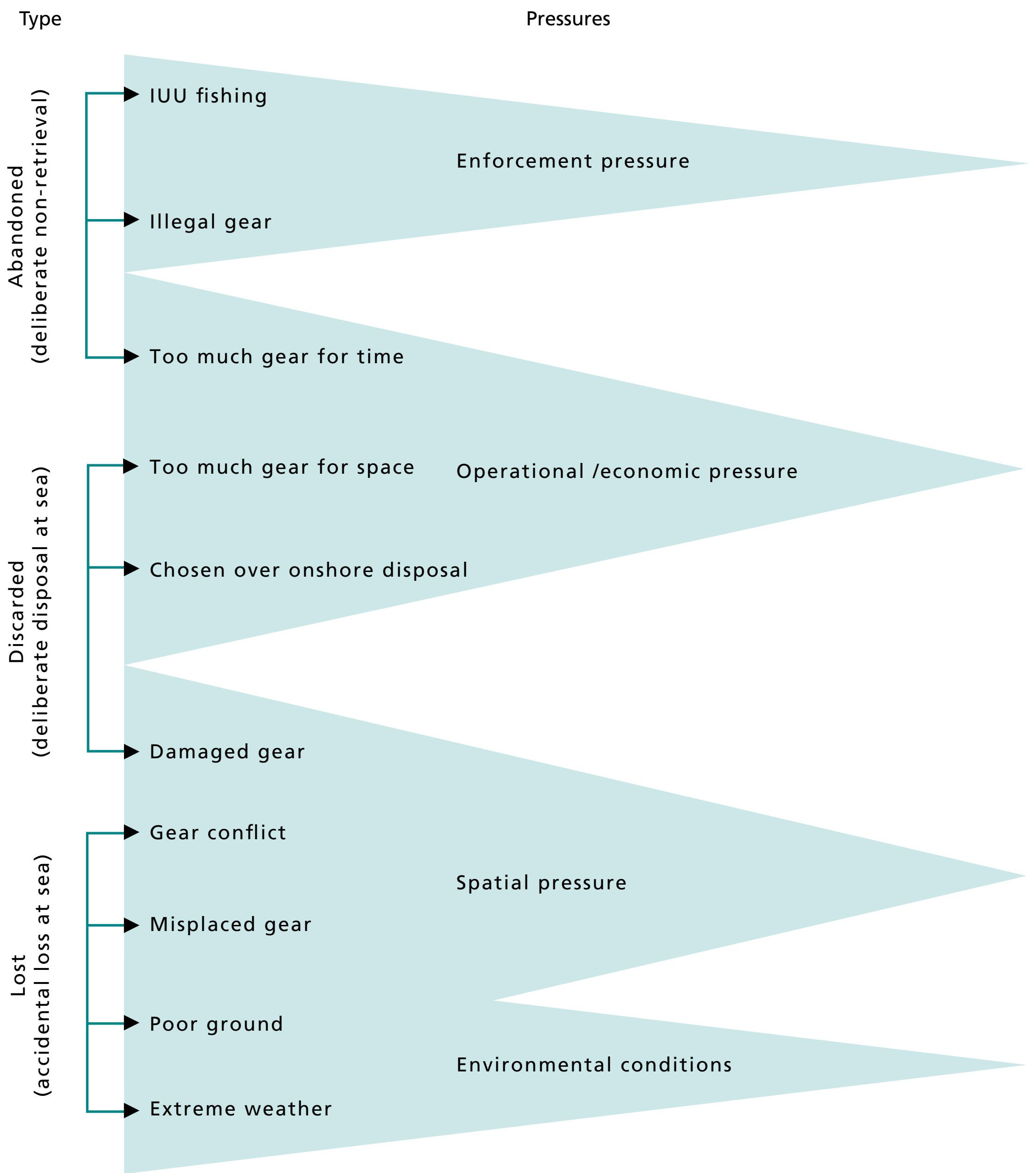
During the EC-funded research project on ghost fishing conducted by IEEP and Poseidon (Brown *et al.,* 2005), a small survey was conducted with vessel owners in three fisheries in the European Union.

Surveys were completed in:

- the Baltic cod net fishery of Sweden and Denmark;
- net fisheries of Greece; and
- the English and French net fishery in the English Western Channel.

While the survey numbers were small and not equally representative, they nevertheless provide some interesting results. In addition, while the deepwater net fisheries of the northeast Atlantic were not surveyed, some information on causes of ALDFG in this fishery is available (e.g. Hareide *at al*., 2005). Information on causes of ALDFG is also available from the FANTARED project reports, also focusing on EU fisheries. Apart from the above-mentioned sources, most of the other literature on ALDFG only deals with causes of ALDFG in a very cursory manner, if at all. The APEC workshop (2004), for example, hardly touched on the issue of the causes of ALDFG, concentrating instead only on the impacts and measures being taken to address the issue. The text below draws on literature that is available, while also providing some anecdotal, but nevertheless interesting, evidence in text boxes from fisheries around the world, based on communication made by the authors with individual contacts known to them.

FIGURE 9
Reasons why fishing gear is abandoned, lost or otherwise discarded



Source: Poseidon, 2008.

GEAR CONFLICTS

ALDFG is often the result of conflict between different types of gear, and is therefore dependent to a certain extent on the range and mix of gears being used in any one area. ALDFG from gear conflict is most commonly reported as being due to trawled/mobile gear passing through an area in which static gear is positioned. Anchored gillnets may also be lost as a result of merchant shipping. In the United Kingdom, FANTARED 2 (2002) reported that the most significant net losses in tangle net fishing are described as being whole fleet or partial fleet losses from gear conflicts. A partial fleet loss varied from one net to several nets and a whole fleet loss would be on average 30 nets. The amount of netting used in this netting operation is very great, with an average of 12 km hauled per day. The vessels involved patrol their nets at night but are not able to do this while hauling operations are ongoing. This leaves the nets vulnerable to fishing vessels engaged in towing operations. The approach of the vessel towing either trawl, scallop dredge or beams usually determines whether a whole or partial net loss will occur. Dahns and end ropes are particularly vulnerable to shipping, especially in areas of intense activity, such as the English Channel, and can on occasion be cut leaving, the entire fleet without any positional indication on the surface. However, where this is likely to happen, the use of intermediate buoy lines can be used to minimize the risk.

The extent of gear conflicts may also vary over time in any one location. In some areas such as the Baltic Sea (Brown *et al.*, 2005), losses of static nets due to trawling have been reduced in recent years due to improved communications between skippers in the two sectors. In other areas, conflicts and resulting ALDFG may have intensified. FANTARED 2 (2002) reported that hake net fishers in the English Channel and Western Approaches reported greater losses than previously because of developments in ground gears for trawls, which have resulted in trawlers being able to tow in many areas previously inaccessible to them. Trawlers, beamers or scallopers using modern technology (particularly sonar, 3-D mapping software and differential GPS) are now able to fish within 25 m of wrecks[18].

Gear conflicts are not restricted to static and towed gears. In some areas netters, liners and potters can all be in competition for fishing grounds. These conflicts, however, are generally considered to be much less serious, and the gears are not usually moved any distance, making it easier for gear that was lost temporarily to be found.

Brown *et al.* (2005) reported that gear conflict was a main cause of ALDFG in both the Baltic cod net fishery and in many Greek fisheries (both between mobile and static gear, and between part-time/recreational and professional fishers). Hareide *et al., (*2005) also suggested that gear conflicts are an important determinant of lost gear in the deepwater net fisheries in the northeast Atlantic. However, conflicts were found to be less frequent in the English/French Western Channel net fisheries due to communication between vessel skippers and producer organizations (see heading "Spatial management (zoning schemes)" page 63 for more on fishers' agreements). There is a formal gentleman's agreement between the French and English associations whereby "blocks" are allocated to either static or mobile gear – these are then swapped periodically (every six weeks). This arrangement functions well and reduces gear loss considerably (Norman Graham, personal communication, 2008). For the most part, ALDFG from gear conflicts can be viewed as being unintentional.

OPERATIONAL FACTORS AND THE NATURAL ENVIRONMENT

Operational factors and the natural environment are a very significant cause of ALDFG. Sometimes gear loss may be unintentional, while at other times intentional but unavoidable. Some operational factors may provide an economic incentive to deliberately discard fishing gear. However, it is important to recognize that due to the environment in which fishing takes place and the technology used, some degree of ALDFG is inevitable and unavoidable.

Poor weather and differing natural environments in which fishers operate (with differing currents, sea-bed conditions, temperatures, strong winds and swell) may have huge impacts on the operational ability of vessels to successfully deploy, work and subsequently retrieve fishing gear.

[18] Nathan de Rozarieux (skipper), personal communication, 2007.

BOX 5
The case of the *Radiant* in Scotland

In the late evening of 10 April 2002, the fishing vessel *Radiant* was fishing about 45 miles northwest of the Isle of Lewis, off Scotland, when she became snagged on an underwater obstruction (fastener). About 1 735 m (950 fathoms) of warp was out and the water depth was about 730 m (400 fathoms). It was apparent that only the port warp was fast, indicating that the port trawl door was snagged. *Radiant* effectively became anchored to the seabed when her port net snagged on a seabed obstruction and power was lost to the winches. There was now a heavy load on the port warp, causing a large list to port. The engine room flooded, and, eventually, the vessel capsized while trying to free the fishing gear. During the abandonment, one of the crew was lost, the other five were successfully rescued.

Source: Report on the investigation of the capsizing and foundering of *Radiant* PD298. Marine Accident Investigation Branch (MAIB). Report No 2/2003. January 2003.

Weather and operational factors combine to cause ALDFG

In some fisheries, a common reason for permanent losses appears to be a combination of rough bottom and strong currents that result in the snagging (or "hooking") of the nets on the bottom. Brown *et al.* (2005), for example, suggested that in the English/French Western Channel net fisheries, causes of gear loss (although not significant) were mainly caused by weather and bottom snagging, and very little was reported as loss due to gear conflicts. Net losses may be in the form of fragments or pieces of netting, or larger quantities when fishing vessels need to cut gear adrift for safety reasons (often in very bad weather conditions) or when they have snagged an underwater obstruction and are unable to free the gear. Lost or otherwise snagged gear may be dangerous or difficult to retrieve, especially in bad weather, and "fishing gear" loss may take the form of losses of complete vessels (see Box 5).

Gear loss may also occur as a result of poor weather combined with the quality and/or age of the gear being used. This may be the case particularly when old gear, which is more likely to break or tear, is not replaced. An interesting example involving a fishery in Sri Lanka is provided in Box 6. In the Gulf of Mexico wire trap blue crab fishery, it is also suggested that old or improper gear use is a cause of pot loss, with deterioration of buoys/lines/knots, negligence in assembling and maintaining gear, and the use of plastic jugs/bottles as floats as important causes (Perry *et al.,* 2003). However, the use of old gear as a cause of ALDFG is also relevant to developed country fisheries; wherever fishing activity is financially marginal there may be a reluctance or inability of fishers to invest in upgrading the fishing gear they use.

In other cases, the retrieval of fishing gear may simply be technically too complicated or time consuming and the results too variable and uncertain to warrant much effort, for instance, when only pieces of netting and/or ropes, or large bundles of badly tangled nets, are likely to be recovered. In such cases, ALDFG may be more intentional and caused in part by an economic incentive, for example, if it is quicker to discard entangled gear to avoid interfering with hauling and to maximize fishing time while at sea, or when the value of temporarily lost gear that might be retrieved has no or little economic significance, or when it costs more than it is worth to retrieve. Likewise, floating FADs may be deliberatively abandoned.

However, the considerable investment that fishers often make in fishing gear means that typically they do not want to permanently lose or abandon it. Fishers may therefore spend significant amounts of time trying to find lost gear. Recent developments in, and

BOX 6

Causes of gear loss in the Sri Lankan spiny lobster fishery

In Sri Lanka, one fishery that has raised some concern regarding ALDFG and ghost fishing is the bottom-set net fishery conducted for spiny lobsters. In the south (mainly in Hambantota district), there is a seasonal fishery conducted by 6–7 m open-decked and outboard-powered fiberglass boats, and targeting spiny lobsters. These boats use bottom-set gillnets, often made up of old and discarded nets (mesh size 4½ to 6") originally used for pelagic drift-gillnet fishing for skipjack and immature yellowfin tuna. The nets are typically set in the evening and collected the next morning. However, when the seas are rough they may remain in the water for a few days, and since the nets used are already old, when laid and retrieved from rocky areas there is increased risk that parts of the gear may be broken/torn and lost.

Source: Dr Leslie Joseph (consultant), personal communication, 2007.

use of, GPS have increased the ability of fishers to find temporarily lost gear, at least in the case of many medium- to large-scale fishing vessels, and especially in the developed world.

There is a clear economic incentive to more readily abandon low-value gear when it is lost, compared to very high-value gear, because of the difference in replacements costs. This also means that fishers may spend more time and effort to recover different parts of gear that have different associated costs/values and life spans. For example, cheap net sheets with a short operational life span may be cut loose, while floats and ropes with higher values and/or longer life spans are retained. It should be noted that items with a short operational life span, nevertheless often have a long residence time in the environment, such as synthetic netting. Data on gear costs indicating the wide range of a) gear costs and b) contribution of gear costs to total investment costs among different vessel types and fishing methods are available in a number of FAO Fisheries Technical Papers (e.g. Lery *et al.,* 1999; Tietze *et al.,* 2001).

ALDFG from operational factors

Some gear may be lost irrespective of the weather, and simply due to the operational characteristics of particular vessels and fishing methods. In the deepwater net fisheries of the northeast Atlantic, which are thought to be a particular problem in terms of ALDFG and ghost fishing, conflict between towed and static gear sectors is important as noted above, but so are many operational factors. These include the depth in which fishing takes place, the hardness of the ground being worked, the quality and appropriateness of the specified gear, and the amount of gear being worked in relation to the time available for hauling (Hareide *et al.,* 2005). Working more gear than can be hauled may result in very long soak times, especially when considering the time period vessels may spend in port between trips, thereby increasingly the likelihood of nets being dislodged by trawlers or lost for other reasons. It also implies that some operational losses, while not necessarily explicitly intentional, may nevertheless be expected.

In United Kingdom wreck net fisheries, some net loss is also generally expected. As reported in the FANTARED 2 project (2002), the main type of net loss in wreck netting is described as being pieces. A piece of net could vary from just a section 0.5 m^2 to a whole sheet of netting. The construction of wreck nets includes drop straps every 30 to 40 yards, which allow the netting to tear off at that point, leaving the rest of the frame intact. Drop straps are ropes that join the headrope to the footrope and enable retrieval of ropes even if the footrope is hitched and then parts. Due to the height of the

BOX 7

Gear loss in Indonesian handline fisheries

"My name is Renaldi Safriansyah. I fish in my 2 GT inboard engine boat operating from Sabang, Pulau Weh. I fish using panjung (hand line). I fish on reefs for grouper, snappers, little tuna, bluefin tuna, Spanish mackerel and jackfish. If I fish close to the reef I usually catch higher-value reef fish such as tiger grouper. When I do this, I snag my lines about two times out of ten, but the rewards are good. Most of the time, I snag my lines and hooks on corals. I know this because I can usually see through the clear water."

Source: Interview by Poseidon/Gomal H. Tambunan (NACA/ETESP), personal communication, 2007

headline above the wreck, snagging (and parting) of the headline is very rare and when this happens, boats generally simply go to pick up the other end of the gear. However, some net loss does occur and is an accepted part of wreck netting. But skippers in this sector try very hard to keep lost netting to a minimum because of both gear costs and their awareness that lost gear can ghost fish for a limited length of time and therefore damage their future fishing. Gear in this fishery is never abandoned or disposed of on a wreck as this may indicate the location of the wreck to competitors (Nathan de Rozarieux (skipper), personal communication, 2007).

Further anecdotal examples of unintentional gear loss are provided in Boxes 7, 8 and 9. In the case of longlining described in Box 8, however, while some aspects of gear loss may be unintentional and to a large extent unavoidable, the discarding of offal is clearly intentional and can have serious impacts.

ALDFG from poor weather

Poor weather can cause ALDFG irrespective of operational factors. Extreme weather events such as tsunami or hurricanes can cause catastrophic losses in coastal areas, and these losses extend to the fisheries sector.

The NOAA Marine Debris Program's Gulf of Mexico Mapping Project was established to address the impacts of hurricane Katrina in 2005, which deposited large

BOX 8

Gear loss in bottom longline fishing

Bottom longlining gear is rigged in two principal ways: a single line set automatically from which snoods and hooks hang; or a double line, with a main line holding the snoods and hooks and a hauling line to which it attaches. Hooks and lines are regularly lost through contact with the sea bed – for instance when they are caught around rocks or other projections. In shallow water the line is usually buoyed at regular intervals so if it breaks it is generally possible to recover it. In deep water, however, it is only buoyed at the ends. A break may be recovered by hauling on the other end, but often sections of lines or even whole lines are lost. A certain amount of gear may be recovered when other longlines get caught on them. Balls of monofilament and hooks may be discarded by vessels with poor environmental records and these can end up either sinking or, if they are mixed with offal, attracting seabirds. Offal itself is usually discarded and, from longliners, poses a serious threat to seabirds since such offal (e.g. heads) will often contain hooks.

Source: David Agnew, MRAG, personal communication, 2007.

BOX 9
Gear loss in pelagic longline fishing

Many tuna longline vessels store their mainline on a line drum that may hold in excess of 80 km of monofilament line. In many cases, the line is pulled off the drum as the vessel proceeds at high speed. Although hydraulic and manual braking can to some extent control overrun of the line, the presence of knots (extremely common) in the line and "burying" of the line (as a result of tension) in the spool often results in the line becoming snagged. Since the drum continues to turn at high speed even though the line is snagged, several hundred metres of line may become entangled around the spool (this is called a bird's nest). Often, the fastest way to remove the bird's nest is to sever the line in multiple places, retie the line and discard the short pieces. Since the vessel is midway through shooting, there is often no time to store the monofilament, which is often thrown overboard. The repaired line will have a greater number of knots than before and thus the problem of snagging tends to increase with the age of the fishing gear.

Source: Frank Chopin, FAO, personal communication, 2007

amounts of debris over large areas of the Gulf Coast, causing myriad new and uncharted navigation and fishing hazards. An extensive survey and debris recovery programme were initiated to support the re-establishment of a viable commercial fishery. Figure 10 shows that lost fishing gear contributes to the recovered debris.

Estimates of trap losses from hurricanes Katrina, Rita and Wilma suggest that well over 50 percent of all traps were lost (National Fish and Wildlife Foundation, 2006). Other chapters of this document (Box 2) also report losses resulting from the Asian tsunami in December 2004, which were enormous in both the capture and aquaculture sectors. Regular hurricanes and cyclones in Asia, the Pacific and the Caribbean (see Box 10) are likely to result in considerable amounts of ALDFG. Gear loss and other debris resulting from extreme weather events further interfere with fishing operations (see Box 11).

FIGURE 10
Marine debris, including fishing gear, collected from the Gulf of Mexico

Source: NOAA.

BOX 10

Gear loss in the Caribbean from weather events

In the Caribbean, a project to consider socio-economic data collection examined vessel profitability across a range of gear types. Costs and earnings models suggested that there were large losses associated with reef nets and lobster pots during hurricanes, with losses typically running to around 50 percent of a string of 20 pots once in every three years. Fishers usually tried to recover the pots, but rather unsuccessfully, and reef nets were often almost all lost.

Source: Scales/Poseidon (2001).

BOX 11

Gear loss in Indonesia, resulting from post-tsunami debris

"My name is Ahmad Saiful. I am a skipper of a 20 GT purse seiner, with 16 crewmen targeting skipjack tuna. I am based in Lampulo, Banda Aceh. In the last two years I have lost two purse seine nets. These were damaged in areas familiar to us but on wreckage from the tsunami. Each net is valued at Rp200 000 (US$ 19 000). I recently participated in an ADB-funded sonar mapping programme. This plots debris identified by myself and my other fishing colleagues (around 30 local vessels). We have also been equipped with GPS under the same programme."

Source: Interview by Poseidon/Gomal H Tambunan (NACA/ETESP), personal communication, 2007

In many capture fisheries, operational losses due to severe storms may to some extent be mitigated if fishers are aware of approaching rough weather, as they understandably seek to minimize their own exposure, and that of their gear, to risk. However, aquaculture equipment and gear may be particularly susceptible to loss in poor weather because of practical difficulties or impossibilities of removing gear and product from the sea (see Box 12).

It is widely predicted that climate change is expected to result in more frequent and more extreme weather events. This may lead to bad weather becoming a more significant cause of gear loss than at present. The ability to predict and adequately forewarn of extreme weather events will therefore be increasingly important in avoiding ALDFG.

BOX 12

Gear loss in Indonesian seaweed farming, resulting from bad weather

"My name is Hasan Hanawi, I am a seaweed farmer in Bira, South Sulawesi, Indonesia. I lay 20 longlines of around 60 m, that are anchored to the sea, and have surface floats. Each year I probably lose around 10 percent of my equipment through storm damage. The equipment is washed up onto the land but is not often salvaged. The seaweed attached to these lines, around 30 to 40 kg, is usually lost. My normal gear would usually last around three years."

Source: Interview by Poseidon/Luna Matulessy (IFC), personal communication, 2007.

BOX 13

Disposal practices of French/English Western Channel gillnet fishers

Disposal of unwanted gear in France takes place through a number of mechanisms. It can: go to a waste collection centre for sorting and recycling; be returned to a manufacturer; or be collected by municipal trucks from the city, as "big bags" with unwanted gear inside.

In the United Kingdom, nets may be disposed of in skips in harbours (the costs being absorbed by harbor dues), or be disposed of as industrial waste. However, associated charges for industrial waste mean that nets may be either bagged as normal waste and taken to community tips, or "fly-tipped", that is, illegally dumped on land.

In neither France nor the United Kingdom does it appear that fishers discard unwanted nets at sea.

Source: Brown *et al.* (2005), based on interviews with fishers.

SHORESIDE DISPOSAL OF UNWANTED GEAR

The availability, convenience and costs of shoreside collection facilities for unwanted or old gear are critical issues driving the disposal of unwanted gear by fishers. Most forms of fishing gear have a finite life span, after which time they can no longer be used, and must be disposed of. The adequacy or otherwise of shorebased facilities for safe disposal of unwanted fishing gear, and any related costs of disposal when facilities are available, may be an important determinant in reducing the problem of ALDFG. Box 13 notes disposal practices in France and the United Kingdom.

The lack of convenient harbourside collection facilities can result in fishers having to dispose of unwanted gear in municipal waste facilities. This can involve both time (with associated costs) and charges imposed for disposal, if indeed such disposal is permitted at all. Therefore, incentives may be strong to deliberately discard gear at sea, or to illegally dump it at other land-based locations (see Box 14). Even where convenient shoreside facilities are provided for collection and disposal of unwanted gear, while the principle of "user pays" should be supported, if costs are set "too" high there may still be some economic incentive for fishers to discard unwanted gear at sea.

BOX 14

Deliberate discarding of unwanted gear at sea by vessels in the North Atlantic Fisheries Organization (NAFO)

"As a general rule, for European vessels operating in NAFO, the most common cause of ALDFG was simply loss from snagging on the sea bed. This was purely accidental and greatly regretted by the fishers. However, on return journeys in the mid-Atlantic, I do remember seeing old gear being dumped. I think that dumping in the mid-Atlantic was not an uncommon practice, although not done by all vessels, and I can't quantify it in any way. I know it did occur, though. Dumping seldom took place on fishing grounds as this would be self-defeating, and nets were generally dumped in the open ocean on return to port. However, sometimes gear was deliberately dumped between good patches of fishing ground where vessels knew fishing conditions to be so bad that no one fished there, as on very rough, craggy, boulder-strewn seabed and/or where there were strong deep sea currents. I remember a couple of times vessels going to rough patches of sea bed on the Banks and Flemish Cap expressly to dump gear."

Source: Patrick Boyle (ex-senior fisheries observer), NAFO, personal communication, 2007.

ILLEGAL, UNREGULATED AND UNREPORTED (IUU) FISHING

Deliberate discarding or abandonment of fishing gear may also result from IUU fishing for a range of reasons, which by definition are not well documented or reported, but which are likely to be based around the attempt of fishers not to be caught. These may include:

- a failure to mark/identify gear so as to prevent its association with particular vessels, or failure to mark gear may itself be a form of IUU fishing;
- an unwillingness to communicate with other fishers about activities, thereby increasing the risk of ALDFG from gear conflicts;
- increased risks of losing gear if fishing in poor weather or at night in an attempt to conceal IUU activity; and
- an unwillingness to be apprehended by inspections authorities if vessel has been identified at sea as engaging in IUU.

VANDALISM AND THEFT

ALDFG as a result of deliberate vandalism and/or theft is probably only a minor cause of ALDFG in some specific fisheries, typically pot fisheries. Intentional cutting of buoy lines by vandals is reported as a cause of gear loss in the blue crab fishery in the Gulf of Mexico (Perry *et al.*, 2003), and in pot fisheries in the southwest and northeast of England and on the west coast of Scotland (Swarbrick and Arkley, 2002). Theft and vandalism are most likely to take place, if at all, in inshore areas where fixed/static gear or aquaculture production systems conflict with recreational marine use, or where some fishers engage in such activities to the detriment of their peers.

SUMMARY OF WHY FISHING GEAR IS ABANDONED, LOST OR DISCARDED

ALDFG may be unintentional or intentional. There are a wide range of causes of ALDFG that can work together to increase the extent of ALDFG, such as operational factors combined with fishing in poor weather. Gear loss from such factors can potentially be reduced through technical gear developments/changes, through codes of conduct and improved communication between fishers, and through spatial and temporal management of fishing activity.

ALDFG resulting from poor weather, especially in the case of fixed/unattended gears and aquaculture, may be almost impossible to eliminate, but could be minimized with improved severe weather warning systems. Given the increases in aquaculture production globally, and the increased frequency of severe weather events as a result of global warming, gear loss may be expected to increase in the future. Some degree of ALDFG is therefore inevitable and it cannot be expected that the problem will ever be completely eliminated. However, other causes of ALDFG may be intentional and preventable through a range of measures and solutions (if appropriately funded and enforced), as discussed in Chapter 6.

There is limited literature on the causes of ALDFG, which is a potentially significant omission, because it is important to understand in detail what the causes of ALDFG are before one can propose and implement appropriate measures to reduce it. As noted in the text above, there are potentially a wide range of causes (some rather technical in nature) and a high degree of specificity of causes across different fishing methods and fisheries. And in any one fishery there may be multiple causes of gear loss. This means that while some generalized and international measures are certainly appropriate and necessary, it is also likely that great care needs to be taken in specifying solutions to ALDFG that adapt and tailor possible measures to the specificities of the particular fishery concerned.

5. Review of existing measures to reduce ALDFG

ADDRESSING THE PROBLEM

As earlier chapters of this report illustrate, although the precise magnitude and impacts of ALDFG are yet to be fully quantified and validated, the international community recognizes that the problems ALDFG create are significant enough to warrant action.

Measures implemented to date are often part of activities to address the wider problem of marine litter. A summary of measures being taken under the UNEP Regional Seas Programme on Marine Litter and Abandoned Fishing Gear is presented in the report by the Regional Seas Coordinating Office (UNEP, 2005). The report recognizes that lost and abandoned fishing gear is only one aspect (or component) of the global marine litter problem but it needs to be separately addressed.

Specific measures to address ALDFG are discussed in more detail below. These can be broadly divided between measures that ***prevent*** (avoiding the occurrence of ALDFG in the environment); ***mitigate*** (reducing the impact of ALDFG in the environment) and ***cure*** (removing ALDFG from the environment). The examples presented also illustrate that many of these measures can be applied at a variety of levels (internationally, nationally, regionally, locally) and through a variety of mechanisms from legal requirement through to voluntary schemes.

PREVENTATIVE MEASURES

Gear marking

The informal marking of fishing gear is a centuries-old practice to clarify ownership and avoid intra-fishery conflict. The mandatory marking of specific gear to enable identification by competent authorities remains far less widespread.

FAO convened an expert consultation in 1991 through which Guidelines for the Application of a System for the Marking of Fishing Gear were developed. The Guidelines set out the marking system and the responsibilities of owners of gear and fisheries authorities. They also cover the recovery of lost and abandoned gear, salvage and the role of gear manufacturers. In addition liabilities, penalties and control are discussed. (FAO Fisheries Report No. 485, 1991).

Following the expert consultation, FAO produced a set of technical recommendations for the marking of fishing gear (FAO Fisheries Report No. 485 Supplement, 1993) with regard to a standardized system for the type and location of unique identifying marks on tags for each gear type as well as rules to be observed in marking gear so that its presence and extent is obvious to other seafarers.

In 1994, at an expert consultation on the FAO Code of Conduct for Responsible Fisheries in relation to fishing operations, an item on the marking of fishing vessels was included in the debate. The experts offered, *inter alia,* the following solutions:

- reporting of all lost gear in terms of numbers and location to national management entities. Industry and government should consider efforts and means to recover ghost fishing gear; and
- regulatory framework to deal with violators.

They recommended that:

- all fishing gear should be marked, as appropriate, in such a way so as to uniquely identify the ownership of the gear.

Section 8.2.4 of the Code states that "fishing gear should be marked in accordance with national legislation in order that the owner of the gear can be identified. Gear marking requirements should take into account uniform and internationally recognizable gear marking systems" (FAO, 1995). Many FAO Members have gear marking requirements for static gear to support enforcement of licences or for reasons of navigational safety, i.e. marker buoys are labeled rather than the gear itself.

At the RFMO level, the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) has an active programme to combat marine debris, including debris from fishing activities such as large-scale trawl fisheries for krill and longline fishing for Patagonian toothfish (NRC, 2008). Conservation Measure 10-01 on the Marking of Fishing Gear requires all fishing gear such as pots, marker buoys and floats to be marked with the vessel name, call sign and flag state.

ICCAT does not have measures concerning ALD fishing gear, but Contracting Parties have to ensure that fishing gear is marked in accordance with generally accepted standards. Some nations have, however, already introduced gear marking requirements with explicit recognition of ALDFG issues. Canadian regulations, for example, require static gear to be appropriately marked with operator identifiers: "All types of shrimp traps or ring nets must be marked with the name of the person fishing the gear, i.e. the operator." (DFO, 1993).

The Republic of Korea introduced a gear-marking initiative in 2006 as part of its National Integrated Management Strategy for Marine Litter, which has encouraged fellow member countries of UNEP's Northwest Pacific Area Action Plan (NOWPAP) to adopt similar actions: "Develop and use marked fishing gear to identify its owner or user that will contribute to preventing fisheries-related marine litter being abandoned" (UNEP, 2007).

Generally, the marking of gear remains the choice of individual operators with guidance from authorities focusing on navigational safety rather than ALDFG purposes. For example, in the United Kingdom, advice is provided on the marking of fishing gear by the Maritime and Coastguard Agency (MCA, 2000) and is intended to reduce navigational risk of static gear to vessel operators. See also the FAO technical guidelines on the marking of fishing gear (FAO, 1993).

Even where tagging schemes are introduced, such as in the Australian Northern prawn fleet, tags tend to be attached to headropes and groundropes rather than directly to sections of net or line. This is understandable given the practicalities of implementing such a scheme, but does not assist in the identification of most ALDFG as this is predominantly made up of nets and lines.

Coded wire tags can be implanted into netting and scanned for identifying data when required. Alternatively rogue yarn (a yarn of different twist or color from the rest) can be inserted into multistrand twines. This has been used in Japan to distinguish gear from fishers based in specific management areas.

In 2006, the EC introduced regulations requiring the marking of passive gears (static longlines, gillnets and trammel nets) and beam trawls with the vessels' port licence number as a clear identifier. This applies to all vessels fishing this gear in Community waters outside of member state territorial waters (EC, 2006). To date most Member States have not introduced similar gear identification regulations for vessels fishing within their territorial waters.

Currently there are few examples of national requirements for gear marking intended to address the problem of ALDFG, i.e. marking to prohibit the deliberate abandonment of gear through enabling identification of ownership.

On-board technology to avoid or locate gear

The increasing use of GPS and sea-bed mapping technology by fishing vessels affords benefits in terms of both reducing initial loss and improving the location and subsequent recovery of lost gear. Acoustic instruments that use a combination of two echoes returned from the bottom, offer this possibility. The accuracy of navigation in modern fishing vessels is currently very high when using a GPS system (in the range of ±3 m).

With improvements in sea-bed imaging technology, some mobile gear can be towed close to the sea bed or known obstacles, enabling reduced direct impact/contact with the sea bed or these obstacles, thereby reducing the risk of gear snagging and loss. For static gear, technology can also enable the more accurate setting and subsequent location and retrieval of gear.

The main determinant of successful recovery appears to be the reason for the initial loss of fishing gear; fishers report that where nets are trawled away, it is virtually impossible to recover them at sea (although Danish trawlers catching lost nets are reported to deliver them to the harbour, where they can be identified through tags with vessel number) (Brown *et al.,* 2005).

Transponders are now a common feature in many large-scale fisheries with the satellite tracking of vessels for safety and MCS purposes, and the use of transponders on gear such as marker buoys or floats is becoming more readily available. The fitting of transponders to gear improves the ability to locate gear in the water. This is an added cost to the fisher and is therefore most likely to be used by fishing operations where gear tends to be larger and more expensive than in artisanal fisheries. Large vessels operating mobile gear may already use transponders or sensors attached to the gear to aid net deployment and operation. These large vessels are also more likely to have the capacity to locate and retrieve gear if it is lost.

The use of transponders in coastal fisheries or by small-scale fleets is limited due to cost and technology constraints. For coastal fisheries it is often assumed that the combination of an inshore location where landmarks can be used for bearings and more affordable GPS means that the use of transponders is unnecessary for gear location purposes. But in many fisheries their wider adoption would provide an additional method of location to reduce gear loss through misplacement at minimal additional cost.

Port State measures

Port State measures are seen to be critical in addressing IUU fishing, which is a significant contributor to ALDFG problems as illegal fishers are unlikely to comply with regulation including any measures to reduce ALDFG. Those engaged in IUU fishing are also assumed to be key contributors to abandoned gear prompted by MCS activity.

In 2001, FAO Members, recognizing the threat of IUU fishing, developed within the framework of the 1995 FAO Code of Conduct for Responsible Fisheries, an International Plan of Action (IPOA) to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing (IPOA-IUU). Port state control, or rather the weakness or absence of it, is often quoted as one of the weak links in the chain that facilitates IUU fishing (FAO, 2004). If effective, port State measures can help ensure ALDFG caused by vessels registered under a port state flag or using a state's port facilities is addressed.

A model scheme was devised to address IUU fishing at the port state level. In addition to a reduction in IUU fishing having a positive influence on reducing ALDFG in general, the model scheme proposes port inspections that will enable "examination of any areas of the fishing vessel that is required, including …the nets and any other gear, equipment…to verify compliance with relevant conservation and management measures". Port State measures can therefore contribute to the implementation and enforcement of preventative measures.

FAO is encouraging the strengthening of port State measures in order to combat IUU. In part this is being accomplished through workshops to increase national capacity in inspection and promote regional cooperation. One of the inspection processes being proposed (relating to gear inspection and the marking of gear) is integral to this. Gear inventories for vessels in international waters are also proposed; how a flag state manages its own vessels in its own waters would remain a national issue (J. Fitzpatrick, FAO, personal communication.).

The 27th Session of COFI in 2007 acknowledged the urgent need for a comprehensive suite of port State measures, and strong support was provided for the proposal to develop a new legally binding instrument based on the Model Scheme on Port State Measures to Combat IUU Fishing and the IPOA-IUU.

Onshore collection/reception and/or payment for old/retrieved gear

The provision of appropriate collection facilities is a preventative measure, as it can reduce the likelihood that a fisher will discard unwanted gear at sea. Justification for this provision is provided in the earlier chapter on the causes of ALDFG.

MARPOL Annex V Regulation 7 requires that "the Government of each Party to the Convention undertakes to ensure the provision of facilities at ports and terminals for the reception of garbage, without causing undue delay to ships, and according to the needs of the ships using them." (IMO, 2006). There has, however, been international recognition that there are scale and capacity issues that have prevented the provision of adequate reception facilities at small ports and harbours, many of which are fishing harbours. For Pacific Island States, a lack of port reception facilities for fishing operations (90 percent of which are foreign) resulted in the South Pacific Regional Environment Programme (SPREP) identifying solid waste management as the number one issue facing Pacific Island States (Kiessling, 2004). While in the United States, the recent NRC report notes that "the United States Coast Guard's (USCG) Certificate of Adequacy (COA) program bases its certification not on whether the ports actually accept shipborne garbage, but on whether they are capable of accepting garbage or can demonstrate that they have service providers on-call who can accept the garbage. While vessel crews docking at these berths well understand that such a service is not usually provided free of charge, vessel crews, ready and willing to pay for disposal services either directly from the facility or via independent entities, are not always able to secure these services, even from those ports with COAs." (NRC, 2008).

The long-term initiative to address the port waste reception problem by FAO and IMO under the BOBP (see heading "International recognition of the ALDFG problem" page 1) initially quantified and categorized the waste problem in fishery harbours in various countries within the Bay of Bengal before developing readily understandable guidelines for the operation of fishery harbours.

The Chennai Declaration was produced from an FAO expert consultation in 1999; it included a number of recommendations to be adopted by national administrations. One recommendation was "the charging of tariffs for services provided by fishery harbors and landing sites and incorporation of effective mechanisms for collection in order to generate revenue, which should be used in the management and maintenance of fishery harbors and landing sites" (FAO, 2000). Although "rational" tariffs are recommended, any additional tariff for reception of waste such as fishing gear may be a disincentive to fishers compared to burning or dumping at no immediate direct cost.

Numerous initiatives have since been developed that provide free waste reception facilities for solid waste such as fishing gear, or these costs are incorporated into general berthing charges or landing fees. In the Baltic gillnet fishery for cod, when nets have reached the end of their useful life, they are generally disposed of in containers in the harbour, with the costs of disposal already contained as part of port fees, so there appears little economic incentive for fishers to deliberately discard nets at sea to avoid onshore costs of doing so. In Greece, net fishers report that they tend to strip the old net off the ropes, and dispose of it in the municipal tip. There is therefore no cost involved and no incentive to discard nets at sea (Brown *et al.*, 2005).

Where recreational fishing is a significant sector, the discarding of monofilament line can be a major contributor to ALDFG. Individually, small amounts tend to be discarded, but the numbers of participants mean that this becomes a significant problem where enforcement of regulations is unlikely to be cost effective and education combined with reception facilities is seen to be a more appropriate route. The safe disposal of monofilament line by United States recreational fishers is encouraged by pier-side reception facilities in several states.

In some circumstances where ALDFG gear is perceived to be a particular problem, authorities have created positive incentives through reward schemes for disposal of old and unwanted gear in appropriate facilities. Box 15 describes a highly targeted project that was in part prompted by the tragic sinking of a passenger ferry after it became entangled in discarded fishing gear. The Korean Government Department, Ministry of Maritime Affairs and Fisheries (MOMAF), purchases waste fishing gear returned to port by fishers; this is reported to be highly effective in terms of recovery and disposal of gear, but there is no evidence that cost–benefit analysis has been undertaken for a scheme that is dependent on significant public funding.

Elsewhere fishing sector schemes target marine litter in general. For example, the Fishing-for-Litter project implemented in the North Sea was originally started by the North Sea Directorate of the Dutch Government in cooperation with the Dutch Fisheries Association in March 2000. The aim of the project was to clear the North Sea from litter by bringing ashore the litter that is trawled up as part of fishing activities and disposing of it on land. The project then rolled out the scheme to other ports around the North Sea. By the end of the three-year project in 2004, 54 boats were involved in four countries, and 450 tonnes of litter had been collected. Without direct

BOX 15

The Korean Waste Fishing Gear Buy-back Project

The Waste Fishing Gear Buy-back project has been implemented successfully in the Republic of Korea since 2003, aiming at collecting fisheries-related marine litter (such as fishing nets, traps, lines, floats) deposited in the sea and on the sea bed. Since fishers used to collect waste fishing gear during fishing operation and throw it back into the sea, the buy-back project is especially designed to encourage fishers to bring ashore the litter collected, as part of fishing activities. This is achieved by providing large, hardwearing bags to the boats so that litter can be easily collected and deposited on the quayside.

An economic incentive is also given to fishers: when they bring back waste fishing gear collected during fishing operation to the designated place, it is purchased at the cost of approximately US$10 per 100 litre bag. The budget for this programme is shared between central and local governments.

Annual amount of litter collected and annual budget or Waste Fishing Gear Buy-back Project

	2003	2004	2005	2006
Litter collected *(tonnes)*	578	2 453	3 076	5 137
Budget (US%)	730 000	2 127 000	2 601 000	3 678 000

Source: Cho in APEC (2004).

financial benefit for fishers involved in the Fishing-for-Litter project, the cooperation of the vessels and their crews is on a voluntary basis, like voluntary participation in beach clean-ups.

Reduced fishing effort

Reducing overall fishing effort (e.g. by limiting fishing time or the amount of gear per vessel) is a fisheries management measure that can also be expected to affect rates of ALDFG. The effect on ALDFG is likely to be a subsidiary impact rather than the primary driver for applying effort reduction measures in a fishery. Effort reduction measures can affect the causes and levels of ALDFG in different ways, depending on the type of input restriction.

For static gear, the amount of gear in the water and the time it is left in the water (soak time), both influence the probability that gear will be lost or discarded, with greater gear use and longer soak times increasing the chances of lost gear.

Many fisheries already limit fishing efforts by monitoring use of pots or number of net hours where soak time is included as a key variable. For example, management of the crab fishery in the CCAMLR region requires an accurate reporting of location data, number of pots set, spacing of pots on the line, number of pots lost, depth, soak time and bait type (CCAMLR, 2006). However, this amounts to soak time's contributing to an overall limit of effort rather than a limit imposed on soak time specifically.

Some fisheries with high catch values and low gear costs create a financial incentive for vessels to fish with large amounts of gear, even if a proportion of that gear is likely to be lost or used only once and then discarded. Vessels may therefore shoot gear, accepting that a proportion will not be recovered. The findings from the DeepNet project illustrate how a lack of regulation may result in a situation where problems of ALDFG arise (Hareide *et al.,* 2005; see Box 16).

A further measure associated with effort limitation is a limit to the soak time for static gear, that is how long it can be left in the water. Leaving gear in the water for longer increases its catch potential, but also increases the likelihood of losing the gear

BOX 16

The DeepNet Project

Since the mid-1990s, a fleet of up to 50 vessels has been conducting a gillnet fishery on the continental slopes to the west of the British Isles, North of Shetland, and at Rockall and the Hatton Bank. Vessels currently participating in the fishery are reported to use up to 250 km of gear, and the nets are left fishing unattended and hauled every three to ten days with trip lengths varying between four and eight weeks. The total amount of nets constantly fishing by the fleet at the same time is conservatively estimated at between 5 800 km and 8 700 km, and the vessels leave their gear fishing while they land their fish.

The vessels are not capable of carrying their nets back to port and only the headline and footropes are brought ashore while the net sheets are discarded; they are either bagged on board, burnt or dumped at sea. These vessels are competing on the same grounds as demersal trawlers and longliners, and this gear conflict is adding to the amount of lost nets. The total amount of loss and discarding of nets is not known, although anecdotal evidence suggests that up to 30 kms of gear are routinely discarded per vessel per trip, which in deepwater locations are known to continue catching for two to three years after loss. The long soak times in this fishery also result in a high proportion of the catch being unfit for human consumption, with on average 65 percent of the monkfish being discarded from nets with four to ten day soak times.

Source: Hareide *et al.* (2005).

as bad weather or other fishers remove the gear. Fishers operating large amounts of gear may also simply forget where some sets of gear are located, which is more likely the longer the gear is left. Such abandonment or discarding of gear is in violation of MARPOL Annex V and as such should be addressed by the flag state of the vessels engaged in the fishery.

The EC banned the use of deep-sea gillnets in some areas in waters deeper than 600 m and only permitted their use at other depths under conditions designed to avoid ghost fishing. The ban (introduced in the TAC and Quota Regulation that was adopted at the Council in December 2005) applies to all nets greater than 200 m, with the exception of the hake and monk fishery, which has additional limits on soak time and maximum length of nets that can be deployed. Norway adopted specific regulations on fishing with gillnets and it raised the issue of ALD fishing gear and marine debris in the North East Atlantic Fisheries Commission (NEAFC), which led to several prohibitions for use of gillnets in deepwater. Vessels in the NEAFC Regulatory Area were prohibited from deploying gillnets, entangling nets or trammel nets in waters deeper than 200 m until regulatory measures were adopted, and all such nets were to be removed by February 2006.

As Box 16 notes, a long soak time will also significantly reduce catch quality. Regulatory measures have therefore been implemented through codes of good practice to improve or assure overall catch quality from a fishery, with the additional benefit that ALDFG may also be reduced. A maximum soak time of 48 hours is already in place in Sweden (Brown *et al.,* 2005).

Output or catch restrictions (e.g. a quota allocated per vessel) can also have positive side effects with respect to ALDFG. The International Pacific Halibut Commission (IPHC) reports that overall gear losses have decreased markedly since the introduction of individual transferable quotas. With the removal of a "race for fish", fishers can better manage their own effort; operating less gear per vessel and having more time for retrieval over a longer operational season (Barlow and Baake, undated). Output restrictions could, however, contribute to ALDFG in some circumstances if, for example, a fisher is deemed to be contravening quota restrictions through recovery of all his gear (and its associated catch).

Spatial management (zoning schemes)

Spatial management can avoid ALDFG by actively segregating marine users or, more commonly, by better ensuring that other marine users are aware of the likely presence of fishing gear in the waters. This reduces the navigational hazard of fishing gear to other marine users and thus reduces the likelihood that gear is damaged or moved.

Spatial management is also applied more specifically to the fisheries sector through the zoning of areas and the establishment of agreements between fishers, which can both serve to reduce ALDFG, often through reduction of gear conflict (a key cause of ALDFG), and can reduce its impact by avoiding fishing activities in sensitive habitats.

There are some successful examples of fishers' agreements between sectors, such as the agreements established between English inshore static gear fishers and French trawlers (Woodhatch and Crean, 1999). Some of these agreements were initially facilitated by the United Kingdom National Federation of Fishermen's Organisations (NFFO), but have remained operational without a need for more formal management measures. In the few instances where there has been a persistent breaking of an agreement, local fisheries management by-laws have been implemented.

Spatial management at a local level may also reduce ALDFG through fostering a stewardship approach to an area. In Malaysia, the establishment of Fishermen Economic Groups (FEG) as co-management mechanisms have given a sense of ownership to fishers, who rightly feel that the FADs and artificial reefs now belong to them and should be properly used, preserved and protected (Nasir, 2002).

MITIGATING (REDUCING IMPACT) MEASURES

Technology can be used to reduce the impacts of ALDFG, particularly through alterations to the gear itself to minimize the potential to ghost fish, but also through ways to better manage gear in the water. These areas are discussed in more detail below.

Reduced ghost catches through the use of biodegradable nets and pots

A number of shellfish fisheries are required to use degradable escape panels in traps. For example, Florida's spiny lobster fishery has had such a requirement since 1982 (Matthews and Donahue, 1996). The fisheries management plan for king and tanner crab in the Bering Sea states that "an escape mechanism is required on all pots; this mechanism will terminate a pots catching and holding ability in case the pot is lost". Despite these requirements, trap recovery programmes have identified that significant proportions of the traps recovered do not have the requisite "rot cord" for reducing catching capacity if lost. Forty percent of commercial traps recovered in Port Susan, Washington State, did not have rot cords (Natural Resources Consultants, Inc., 2007). This highlights the importance of monitoring and enforcement to support any mitigation measures that are implemented.

In Canada, recreational fishing traps require features "to ensure that if the trap is lost, the section secured by the cord will rot, allowing captive crabs to escape and to prevent the trap from continuing to fish". (DFO, 2007). Also in Canada, the Pacific Region Integrated Fisheries Management Plan for crab by traps, 2008, includes various requirements related to biodegradable escape mechanisms (see www-ops2.pac.dfo-mpo.gc.ca/xnet/content/MPLANS/plans08/crab08pl.pdf). The use of biodegradable materials is less evident in net fisheries.

There have been some efforts to develop biodegradable and oxy-degradable plastics for use in the fishing industry. For example, the Australian and New Zealand Environment Conservation Council (ANZECC) was instrumental in promoting a national approach towards the use of biodegradable materials in bait bag manufacture (Kiessling, 2003). A biodegradable bait bag has been developed for use by recreational fishers in Queensland and is likely to be introduced to western Australia. Trials have now begun for the development of biodegradable ice bags.

FIGURE 11
Crab trap with rot cord

Source: Fisheries and Oceans, Canada.

BOX 17
Passive pinger wins a prize for the United Kingdom in the WWF Smart Gear Competition

An innovative device which could significantly reduce the number of harbour porpoises and other cetaceans caught in fishing nets has won a prize the for the United Kingdom in the International Smart Gear Competition organized by WWF.

Since the 1990s, acoustic pingers have been effective in reducing cetacean bycatch. However, their relatively high cost has hindered their wider implementation, as have concerns over reliability and whether they cause noise pollution to the animal's environment in the long term. Developed by Aquatec Group Ltd, the Passive Porpoise Deterrent alerts porpoises to the presence of fishing nets using resonant acoustic reflectors that increase the net's "acoustic visibility", and do so in a less complicated way than the currently used pingers. When a porpoise emits a click, the reflectors transmit back a stronger echo, making the reflectors appear to the porpoise to be much larger objects than they are, and thus alerting them to danger.

Source: www.Seafish.org, United Kingdom news release, 15 November 2007.

Reduced ghost catches of incidental catch species

Fishing gears with the potential to capture significant bycatch of non-target species (cetaceans, pinnipeds, turtles, seabirds) when actively fishing, also have the potential to result in non-target species bycatch once gear is abandoned, lost or discarded. Mitigating against such ghost fishing of bycatch can be effected by using the same measures as in active fishery, such as acoustic beacons ("pingers"), reflectors in gillnet and set net fishing gears. But it should be recognized that the effectiveness of such measures can rapidly decrease when gear is no longer actively being fished and the pingers run out of power over time.

Of perhaps greater significance to ALDFG reduction are mitigation measures that are effective even when fishing gear is not being actively fished. Trials are progressing with substances that reflect sound, such as barium sulfate, with such substances being added to nylon net during production. The additive does not affect the performance or the look of the net in any way, but it reflects sound waves in ranges used by echo-locating animals (Schueller, 2001). Other developments supported by WWF's International Smart Gear Competition (www.smartgear.org) have produced weak ropes that are operationally sound, but break with the action of marine mammals, and magnets attached to longlines to repel sharks. Innovative solutions such as the passive pinger (see Box 17) should retain effectiveness even when the gear is lost.

EX-POST CLEAN-UP/CURATIVE MEASURES

Locating lost gear

As discussed under heading "On-board technology to avoid or locate gear" (page 58), generally fishers will make every possible attempt to locate and recover their own gear as it has a significant economic cost in most fisheries, although they will consider the time and fuel costs necessary to do so. This chapter addresses locating lost gear and where a survey may be needed to inform subsequent recovery.

Surveys can range from those with low costs, such as land-based beach surveys involving volunteers, to those at sea with high costs, using side scan sonar operated from sophisticated marine research vessels. The type of survey required and/or possible is dependent upon the type of ALDFG expected to be the key issue in the area and upon the resources available. Land-based surveys are common, and may be the most appropriate form of survey where the key impact is onshore entanglement or littering, such as on turtle nesting beaches. The Ocean Conservancy's Marine Debris monitoring program has a widely adopted annual international coastal clean-up that provides guidelines for beach survey and subsequent clean-up (www.oceanconservancy.org).

Sea-based surveys can be used to locate lost fishing gear that may still be ghost fishing or damaging habitats. Where no accurate information on location of gear is available, the use of modeling techniques, local knowledge and anecdotal information to identify potential hotspots is essential in order to better target a survey intended for gear retrieval. Towed-diver surveys of the northwestern Hawaiian Islands were better targeted with the identification of high entanglement risk zones (HERZ) through recognizing oceanographic conditions leading to likely collation of marine debris combined with high densities of sensitive species – in this instance, monk seal nursery areas (Donohue *et al.,* 2001).

Side scan sonar (SSS) is a sea-bed mapping technology that has become more accurate and more affordable in recent years. However, SSS is likely to be applicable where relatively large or readily distinguishable items such as pots or traps are to be located. Figure 12 shows the images from a SSS survey that could enable the accurate location of fishing traps. The sport trap appears as a square shape at the top of the image, and the commercial trap, the circular shape, and the line appear at the bottom of the image.

The NOAA Gulf of Mexico Marine Debris Project has used SSS from survey vessels in its retrieval of large marine debris and is also using an autonomous survey vessel (ASV). The vehicle has a maximum operating depth of 100 m, but it is used primarily for shallow water surveys (depths of less than 50 m). The ASV (Figure 13) is used to detect and map submerged wrecks, rock, and other objects that pose a hazard to navigation for commercial and recreational vessels. Deployment of the ASV must be strictly controlled to ensure it does not itself create a navigational hazard.

In the United States, from 1986 to 2002, the International Coastal Cleanup removed 89 million pounds of debris from more than 130 000 miles of shoreline. Starting in 1995, more than 108 000 divers also collected 2.2 million pounds of trash in over 3 900 miles of underwater habitat (United States Commission on Ocean Policy, 2004).

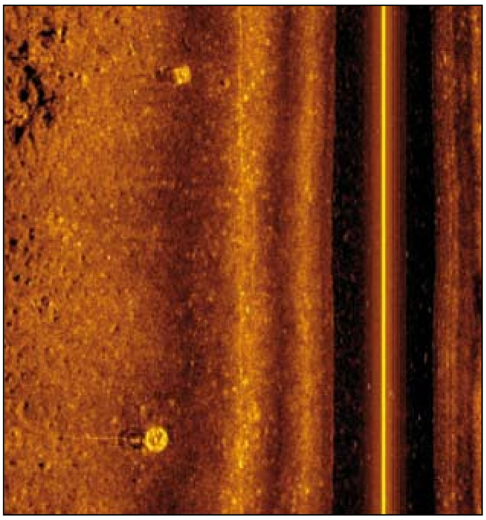
Other possible sources of information might include skipper interviews and the interpretation of VMS plots.

Better reporting of gear loss

Reporting of gear loss may come from the operators of the fishing gear themselves or from other operators that have come across ALDFG. Direct reporting from the operator of the gear should enable more accurate location and identification of the gear, but such reporting is rare.

However, ships (including fishing vessels) over 400 GT and ships certified to carry 15 or more persons, representing a very small fraction of the global fishing fleet, are required under MARPOL to carry a garbage management plan that the crew should follow. Such ships are to be provided with a garbage record book, to include the dumping or loss of fishing gear at sea as well as discharging gear to reception facilities. The garbage record book is subject to inspection by the appropriate administration, usually on an annual basis, but it is also subject to random inspections by the coast guard and fisheries monitoring, control and surveillance officers and port state officers. Therefore, if smaller vessels were to be required by regulations in the shipping or fisheries acts to meet the same conditions that apply to the larger vessels, the record book would be subject to the same inspection procedures. A number of national maritime administrations (such as the Icelandic Maritime Administration) provide guidelines in relation to fishing vessels together with the record book on the reporting

FIGURE 12
Side scan sonar image of ALD traps



Source: Innerspace Exploration Team, United States (from Natural Resources Consultants, Inc., 2007).

FIGURE 13
Autonomous survey vessel used in the Gulf of Mexico

Source: NOAA Marine Debris Program.

of fishing gear lost at sea or incinerated. The form of a garbage record book is given in the Appendix to Annex V of MARPOL.

There are varied approaches and differing national capacities to record and report gear loss. Malaysia established a national inventory of net types and other fishing gear and Latvia obtained data on gear losses and economical casualties to fisheries through a fisheries data collection system and specific questionnaires sent to fishers. Namibia expressed the need for both technical and financial assistance to study and develop a data collection system on gear loss (UNEP, 2005).

In the United States, the California Lost Fishing Gear Recovery Project provides an online reporting form and a free phone number for any marine user to report

FIGURE 14
Creeper gear for recovery of gillnets on board the MFV *India Rose*

Source: Hareide *et al.*, 2005.

the location of ALD gear. The NOAA Fisheries Service has also adopted a set of federal regulations that apply to foreign fishing vessels fishing in the United States Exclusive Economic Zone (EEZ). In addition to requiring foreign vessels to have permits, on-board observers and recordkeeping, and to facilitate enforcement, the regulations contain an express prohibition of the disposal or abandonment of fishing gear, and foreign fishing vessels are also required to report accidental loss or emergency jettisoning of gear to the United States Coast Guard.

The Norwegians have a mandatory reporting procedure that is effective – it is estimated that in excess of 80 percent of losses are reported (Norman Graham, personal communication, 2008). Even though many gear recovery programmes promote a "no blame" approach to lost gear reporting (as advocated by the Northwest Straits Derelict Fishing Gear Removal Project in the northwest of Washington State, United States), there are issues to overcome both in terms of confidentiality relating to precise fishing locations, and of professional pride in admitting gear loss. It is therefore the reporting of ALDFG by other marine users that is most common. In many instances it is recreational users who report lost gear to authorities. Reporting to specific gear programmes by the public has proved to be a useful information source if facilitated (e.g. with online reporting or free phone numbers) and advertised appropriately. This has been significantly assisted by the widespread adoption of GPS technology to enable an accurate logging of location.

Gear recovery programmes

Curative measures often take the form of gear retrieval programmes, which typically entail using a creeper or grapnel (Figure 14) to snag nets. Gear retrieval programmes have been undertaken in net fisheries in Sweden and Poland (Brown and Macfadyen, 2007). Retrieval programmes are also routinely employed by Norway, which led to Norwegian, English and Irish collaborative projects to recover ALDFG from the Northeast deepwater Atlantic gillnet fishery.

The United States has several ongoing gear location and retrieval programmes; many of these are supported by NOAA's Marine Debris Program. For example, the SeaDoc Society at the University of California, Davis Wildlife Health Center, launched the

FIGURE 15
The Gulf States ALD Crab Trap Removal Programme

Source: The Gulf States Marine Fisheries Commission.

California Lost Fishing Gear Recovery Project in July 2005. This project encourages ocean users to report the presence of lost gear, and hires experienced and certified SCUBA divers to remove gear from near-shore waters in a safe and environmentally sensitive manner. Since May 2006, the California Lost Fishing Gear Recovery Project has retrieved nearly 11 tonnes of gear (see www.mehp.vetmed.ucdavis.edu/derelictgear.html).

To better direct gear recovery efforts, some programmes target certain gears such as traps that can be located using remote sensing technology, while others target known hotspots where significant quantities of lost gear may collect or where the habitat is particularly sensitive (as in marine mammal or bird colonies).

The Gulf States Marine Fisheries Commission (GSMFC) produced guidelines for developing ALD trap removal programmes in the Gulf of Mexico. Many elements of the guidelines are transferable to other fisheries and other areas (GSMFC, 2003). Coordinated through GSMFC, a number of states in the United States of America arrange annual voluntary short-term closures and targeted clean-up operations in trap fisheries with assistance from the fishers themselves (see Figure 15). The Louisiana Department of Wildlife and Fisheries reported that "abandoned crab trap closures and clean ups...proved very successful in regards to the total number of retrieved traps, volunteer participation and acceptance by all user groups". Between 2004 and 2007 over 183 boats participated in retrieving nearly 16 000 traps from 1 405 708 acres of coastal waters of the United States (see www.derelictcrabtrap.net/).

The Australian Government has provided AU$2 million (US$1.9 million) in funding to coastal communities in the Gulf of Carpentaria for a project to address ALD fishing nets known as the Carpentaria Ghost Net Programme. Community groups have formed a network to clean up beaches and establish a coordinated information

FIGURE 16
"Ghost net" retrieved by a Scottish trawler in 2004

Source: Directorate of Fisheries, Norway.

recording process to build a picture of the quantities, impacts and likely origins of ghost nets across northern Australian waters.

In addition to targeted surveys or initiatives, some states operate a continual system of gear recovery. In the Sea of Japan, fisheries patrol vessels from the national agency bring any ALDFG identified to shore, as do fishing vessels chartered by fisheries organizations and local government and funded by central government subsidy (Inoue and Yoshioka, 2004).

However, gear recovery programmes may face certain legal constraints and challenges. As the recent NRC report noted, "in the United States, recovery of DFG may be inhibited by prohibitions against tampering with abandoned gear, the application of cabotage laws and burdensome certification requirements for vessels that transport DFG, and fishery regulations that prohibit vessels from carrying gear that is not a gear type permitted under their license endorsement". (NRC, 2008).

Disposal and recycling

There are numerous examples of the reuse and recycling of ALDFG:

- reuse of nets in fencing for agriculture and aquaculture operations in Taiwan Province of China (APEC, 2004);
- use by rangers in northeast Arnhem Land, Australia, of ALD fishing nets found on the coast to harden coastal tracks for vehicles (Kiessling, 2003);
- recycling of monofilament line from quayside collection boxes (mainly from recreational fishers in the United States) (see www.healthebay.org); and
- reuse of recovered nets in some cases for fishing or recycling of recovered nets into soccer nets.

In other cases recovered gear will need to be disposed of (Washington State Department of Fish and Wildlife ALD fishing gear recovery project).

The Honolulu Derelict Net Recycling Program installed a container for reception of ALD nets and material from various origins recovered by the local longline fleet. In the first year, 11 tonnes of material were recovered and transported to the nearby waste-to-energy incinerator. One tonne of such material produces enough electricity to power a home for five months (Yates, 2007). This programme was operated as a public-private partnership, which reduced cost to the public purse and encouraged greater industry participation.

A similar public-private partnership was established with a recycler in Washington State, United States. The Washington ports, located within an hour or so from the recycler, benefited from providing a service to their fishers and from the free hauling and pickup they received when a recycling container was full (reducing their extremely high waste disposal costs). The Alaska communities, which were dealing with quickly filling landfills, heavy equipment entanglement problems and difficulties in burying nets, benefited from the removal of this bulky, troublesome material. Some communities sent baled nets or well-cleaned containers of well-compacted loose net, which could generate revenue or be used for other commodities (such as baled cardboard or metals), to help defray the costs of transport or had the transport donated mainly by freight companies hauling empty barges southward at the end of the fishing season. From an average collection volume of 46 tonnes between 1991 and 1999, collected volumes have been halved as funds for coordination and promotion of the programme have been reduced (Recht and Hendrickson, 2004).

In isolated areas, burning may appear to be a convenient alternative, but this can create further problems. The burning of debris collected north of the Hawaiian Islands region was found to produce a toxic gaseous by-product (Marine Debris Workshop, Hawaii, 2000).

The Japanese national law categorizes plastic objects such as fishing nets and floats as industrial wastes. Industrial wastes are disposed of only in authorized disposal plants or plants operated by local governments. With respect to recycling technology, efforts have been promoted to develop efficient recovery systems for floating styrofoam materials, mainly coming from aquaculture, which has the problem of involving huge transportation costs because of the low density of the materials (Inoue and Yoshioka, 2004).

AWARENESS RAISING

Raising awareness of the ALDFG problem is a cross-cutting measure that can aid the development and implementation of the measures previously described. It can target fishers themselves, port operators, marine users or the general public through local, national, regional or international campaigns.

Graphic images of entangled marine species are often used to publicize the dangers resulting from ALDFG, but care must be taken that this does not act as a disincentive to fishers to report ALDFG despite the "no blame" approach advocated by various gear recovery programmes.

To raise awareness effectively, the specific problem needs to be understood so that actions can be appropriately targeted. For example, net identification on northern Australia's beaches found that 80 percent of nets originated from outside Australian waters (Kiessling, 2005). As a result of this knowledge, it was understood that engagement at a wider regional level was necessary to tackle the problem.

Increasing the awareness of fishers to issues, including ALDFG, is being addressed at an international level through training materials such as the 2001 version of the joint FAO, ILO and IMO publication *Training and Certification of Fishing Vessel Personnel 2001*. This publication also addresses the FAO Code of Conduct for Responsible Fisheries and deals with lost fishing gear, including discarded fishing gear. However, there remains a need to inform fishers who may not have access to formal training or certification courses for fishing vessel personnel about the ALDFG issue. In such cases, administrations would have to provide additional training to extension services, particularly in relation to the small-scale fisheries sector, in order to reach fishers and fishing communities.

The effective education of stakeholders and facilitation of a change in behaviour can become self-policing and extend beyond those directly targeted to change behaviour in society as a whole. For example, the International Coastal Cleanup (ICC) Program has coordinated volunteer-based marine litter campaigns for several years. The international network has expanded, with several new countries joining the programme in 2006, and many countries had notable increases in participation over 2005, while the training of ICC national coordinators has enabled the establishment of a network of clean-up operations that span the globe (Ocean Conservancy, 2007).

A recent regional workshop in the Caribbean resulted in a decision to undertake a study to describe and quantify the problem of ALD fishing gear in the Wider Caribbean, within the context of fisheries management and the prevention of loss of fishing gear, and to propose solutions to prevent the loss of fishing gear. The study should include solutions for the prevention or reduction of the loss of fishing gear. In particular, it was suggested that the prevention or reduction of loss of fishing gear should be a component of fisheries management plans and that the fisheries administrations in each country should take the lead role in this exercise at the national level. The WECAFC Secretariat and the CRFM will coordinate the study with the assistance of NOAA (Bisessar Chakalall, FAOSLAC, personal communication, 2008).

Raising awareness can also be achieved, and indeed requires, good long-term monitoring programmes to collect data on ALDFG over time, so as to assess trends. Monitoring marine debris and its impacts is a permanent agenda item of CCAMLR and its scientific committee. Members submit yearly surveys of debris on beaches and in seabird colonies, of marine wildlife entanglements, and of hydrocarbon soiling of mammals and seabirds. The secretariat maintains a marine debris database from 12 index sites on the Antarctic Peninsula and on Antarctic and subantarctic islands.

EFFECTIVENESS OF MEASURES

Various measures have emerged to tackle the ALDFG problem as it becomes better understood, including the situations and motivations that result in ALDFG. Some of these measures appear to be possible in theory, but may not be effective in practice. It is therefore important to understand why certain measures are effective in certain situations and why others are not. There have, however, been very few studies to date on the effectiveness of measures. Where parties have attempted to tackle ALDFG, only one or two approaches have been adopted. Comparative analysis is therefore difficult, beyond identifying common features in the situations encountered and the measures adopted.

A measure's "effectiveness" has to date been based on expert judgment, as there are few situations where a baseline is available showing the scale of the problem and enabling targets to be set. For example, results from the DeepNet project led to crude estimates of 1 254 km of gear being lost in the fishery each year (Hareide *et al.*, 2005). A follow-up retrieval programme led by Irish authorities resulted in the recovery of approximately 35 km to 40 km of lost gear, amounting to around 3 percent of estimated annual gear losses. An ALD fishing gear recovery programme carried out in Port Susan, United States, in 2006 identified 403 items from a side scan sonar survey of approximately 95 percent of the known coastal fishing grounds. Seventy-three percent of those items could be investigated by diver and 174 items or 43 percent of the total items identified were removed. These two gear retrieval examples illustrate that levels of effectiveness are likely to differ markedly between measures and between fisheries. It will be possible to determine if these are effective levels of retrieval for the fisheries concerned only through repeated operations. The ability to assess effectiveness of measures should therefore improve as more research is done, as the ALDFG problem becomes better understood and as there are more reports on measures taken to enable comparison.

In the absence of accurate baseline information, determining the effectiveness of a measure is likely to be based on aspects such as acceptability of the measure by stakeholders and associated with this, the measure's enforceability. If fishers feel that a measure is imposing unacceptable restrictions or costs on them, compliance is likely to be low. Low levels of compliance are also likely when a measure is difficult to enforce in practice.

Expert workshops held as part of the EC ghost fishing project (Brown *et al.*, 2005) identified that the perceived effectiveness of proposed measures varied between fisheries, suggesting that a "one size fits all" approach would not work in addressing ALDFG. Table 8 shows the different views of the expert working groups on the effectiveness of measures to tackle ALDFG in the Baltic and the (English) Western Channel. While there was general agreement on which measures are relevant, differences are particularly evident in what the experts believed is acceptable or enforceable in these fisheries. There are, however, areas of commonality. Measures such as acoustic detection systems, biodegradable nets and alternative gears are considered unacceptable by fishers in both fisheries.

As Table 9 shows, many measures are difficult to monitor and enforce without a comprehensive observer programme. Observer programmes can be effective in MCS of offshore fisheries, but are costly to implement and it is a cost often borne by nation

TABLE 8
Assessment of measures to address ALDFG in the Baltic Sea and the English Western Channel
Key: red+ low effectiveness; amber ++ medium effectiveness; green +++ high effectiveness

Management Option	Relevance		Effectiveness		Acceptability		Enforceability	
	Baltic	Channel	Baltic	Channel	Baltic	Channel	Baltic	Channel
Identification marking	+++	+++	+	++	+++	++	+	+++
Reporting losses	+++	+++	++	+++	+++	+++	++	++
Acoustic detection	+++	+	+++	+	+	+	+++	+
Zoning schemes	+++	+++	+++	+++	++	+++	++	+++
Biodegradable nets	++	+	?	++	?	+	?	++
Gear use limits	+++	+++	+++	+++	+++	++	++	++
Soak time limits	+++	+++	+++	+++	+++	++	+++	+
Retrieval programmes	+++	+++	++	+++	+++	+++	++	++
Alternative gears	++	+++	++	+++	+	+	+++	++
Mandatory return of nets	+++		+++		++		+	
Incentive schemes		+++		+++		+++		+++

Source: Poseidon, adapted from expert workshop outputs in Brown *et al.*, 2005.

TABLE 9
Potential management measures proposed by the DeepNet Project

Recommendation	Positives	Negatives
The introduction of restrictions on the length of gear deployed at a given time either by overall length or by fleet of nets. Such restrictions were introduced in NE Altantic driftnet fisheries for albacore tuna.	Reduce fishing effort	Difficult to enforce and to monitor, although VMS does provide a level of control
The certification of fishing gear through labelling	Provide better information on fishing effort	Legal responsibility, problems with damaged or repaired gear, and potentially easy to circumvent
A requirement that vessels cannot leave gear at sea while landing	Reduces discarding through extended soak times	Difficult to enforce and to monitor, although a combination of VMS and adequate marking of gear will provide a level of control
Mesh sizes for fixed gears in region 3 to be harmonized with regions 1 and 2, in particular for hake and monkfish	Stop the use of small mesh sizes in regions 1 and 2	None
A requirement that all gears be marked clearly at either end	Reduce the amount of lost gear and also reduce hazard to other fishing vessels	Difficult to enforce; original EU proposals were too complex to be enforceable
The introduction of measures that stop the stripping of the headline and leadline and dumping of used netting at sea	Reduce the dumping of nets at sea	Difficult to enforce and potentially could have the opposite effect
The spatial management of effort by gear sectors, separating towed and static gears	A proven method of reducing the gear conflict and net loss	Probably difficult to administer and enforce in offshore areas and international waters
Closed areas to protect ecologically sensitive habitats, such as hydrothermal vents, deepwater corals, or other characteristic habitats, such as seamounts	Reduce the amount of lost gear and protect sensitive habitats	Difficult to monitor and enforce if areas are too small, but VMS will allow monitoring of bigger areas. Widespread objection from other sectors of the industry

Source: Hareide *et al.*, 2005.

states rather than by those targeting the fishery. It is also apparent that the suitability of measures varies significantly between fisheries.

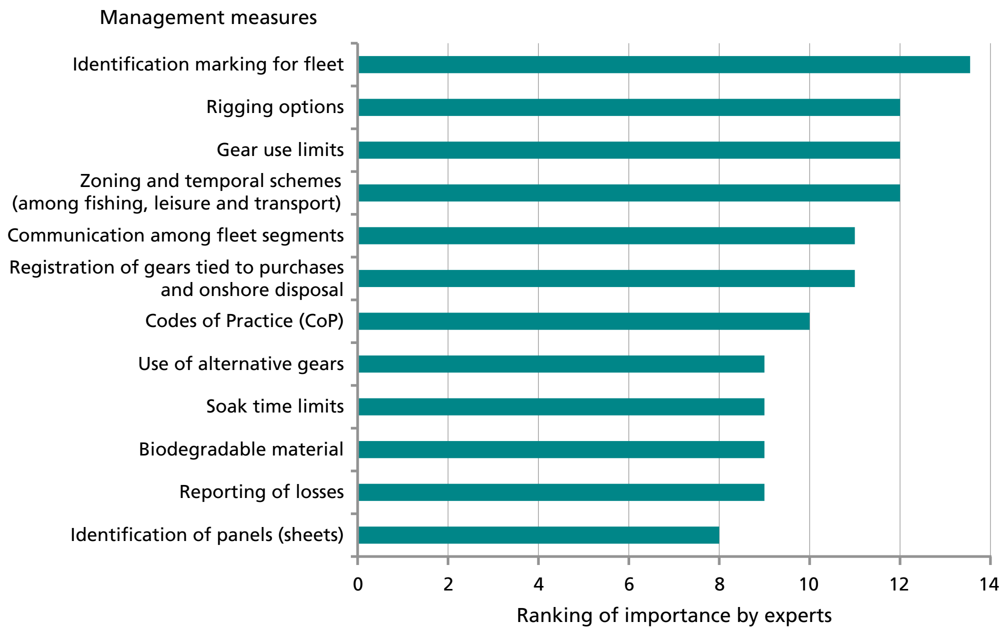
Figure 17 presents potential management measures to reduce gear loss and ghost fishing within the eastern Mediterranean net fisheries, as reported in Brown *et al.*, 2005. Here gear identification was the main priority because of its perceived effectiveness.

COST-EFFECTIVENESS OF MEASURES

The cost-effectiveness of ALDFG measures can be considered by comparing their costs against the (estimated) benefits. The costs associated with ALDFG are discussed under heading "Costs of ALDFG", page 42, but to date few ALDFG programmes have reported the cost-effectiveness of measures, and quantification is often limited to the volume of gear recovered. This is to some extent the result of the difficulty in putting quantifiable estimates on some types of costs. But where cost–benefit analysis has been undertaken, even with the accepted limits to estimations, some have shown a positive cost–benefit ratio. Box 18 shows that recovery programmes can be cost-effective in relation to the direct costs of ALDFG in terms of the value of commercial species lost to ghost fishing. The positive cost–benefit ratio would be far greater with the inclusion of indirect and intangible costs such as human safety and avoidance of the mortality of non-target species, especially if threatened or vulnerable.

However, in certain circumstances a gear recovery programme may not prove to be cost-effective. Brown and Macfadyen (2007) identified that by the time a retrieval

FIGURE 17
Prioritization of management measures for the eastern Mediterranean



Source: Poll output of expert working groups reported in Brown *et al.,* (2005). Bottom axis refers to relative ranking of importance across the expert opinion.

programme is implemented, ghost nets may only be making very small ghost catches due to the rapid decline in catch rates over time. The benefits of preventing this ghost catch may therefore be minimal unless very large quantities of netting are being lost and/or nets are lost in deepwater with little current/tidal activity, thereby reducing the rate of decline in catch rates.

Additionally, the benefits of retrieval programmes may be limited where nets are lost in areas of high trawl activity, because in such cases trawlers can be expected either to pick up or ball up a large proportion of lost nets, resulting in reduced ghost fishing catches in comparison to active catches. Gear retrieval programmes are therefore likely to prove most cost-effective compared to "do nothing", where gear can be located and retrieved quickly (otherwise much of the measurable damage is done), and/or where a significant amount of gear is lost that cannot be recovered by regular fishing activity itself.

A cost–benefit model developed by Brown and Macfadyen (2007) suggests that (a) gear retrieval programmes may only be cost-effective in fisheries where the actual costs of ghost fishing are high; and (b) preventative measures are likely to be preferable to curative ones (see Box 18). Measures that prevent gear loss, can avoid the potentially high costs associated with ghost catches immediately after gear loss, which retrieval programmes are unlikely to be able to do, and they avoid the cost of time spent searching for that gear. However, even in highly regulated fisheries where gear loss is minimized, there may be some need for gear retrieval (Norman Graham, personal communication, 2008).

One of the few attempts to date to compare cost-effectiveness of various gear retrieval methods was by Wiig (2004). Through applying a "hazard hierarchy" in order of killing intensity and cost per tonne removed, he sought the maximum environmental benefit for the minimum cost. He concluded that while certain clean-up programmes (beach clean-ups) are far less expensive than ghost net retrieval at sea – and certain types of debris (crab pots and snagged net) are more hazardous – the ghost net programme

BOX 18
Cost–benefit analysis of ALD fishing gear removal in Puget Sound, United States of America

Information collected over the past four years (from 2004 to 2007) during the Northwest Straits Initiative's ALD fishing gear survey and removal programme in Puget Sound, Washington State, was used to estimate costs and directly measurable benefits of ALD fishing gear removal.

Costs of the ALD net survey and removal totaled US$4 960 per acre of net removed. Costs of survey and removal of ALD pots/traps totaled US$193 per pot/trap. Directly measurable monetized benefits of ALD fishing gear removal were based on the commercial ex-vessel value of species saved from mortality over a one-year period for ALD pots/traps, totaling US$248 per pot/trap and a ten-year period for ALD nets, totaling US$6 285 per net. The cost–benefit ratio was positive and similar for the removal of both gear types, measuring 1:1.28 for pots/traps and 1:1.27 for ALD nets.

Although indirect benefit values of human safety, unimpeded vessel navigation, habitat restoration, reduction in mortality of non-commercial and protected or endangered species and pollution removal were not monetized, ALD fishing gear removal compared favorably in cost-effectiveness with habitat restoration and wildlife rehabilitation projects. Given the expected long-term life span of these mainly synthetic-based ALD gears, negative impacts may continue for many years or decades beyond the ten-year period used in the cost–benefit analysis. The cumulative costs of not removing the ALD gear now will likely be much higher in the future.

Source: Natural Resources Consultants, Inc., 2007.

will be more cost-efficient in reducing marine animal deaths caused by marine debris. This research was, however, hindered by a lack of available data. The results were based on the circumstances found in the specific United States programmes being considered, where the damage caused by ghost nets in situ was deemed to be far greater than the damage caused by gear that washed ashore. In other situations, the opposite may be true, such as in the turtle-nesting beaches of Australia's Northern Territory, where the most damaging impacts identified are caused by entanglement ashore.

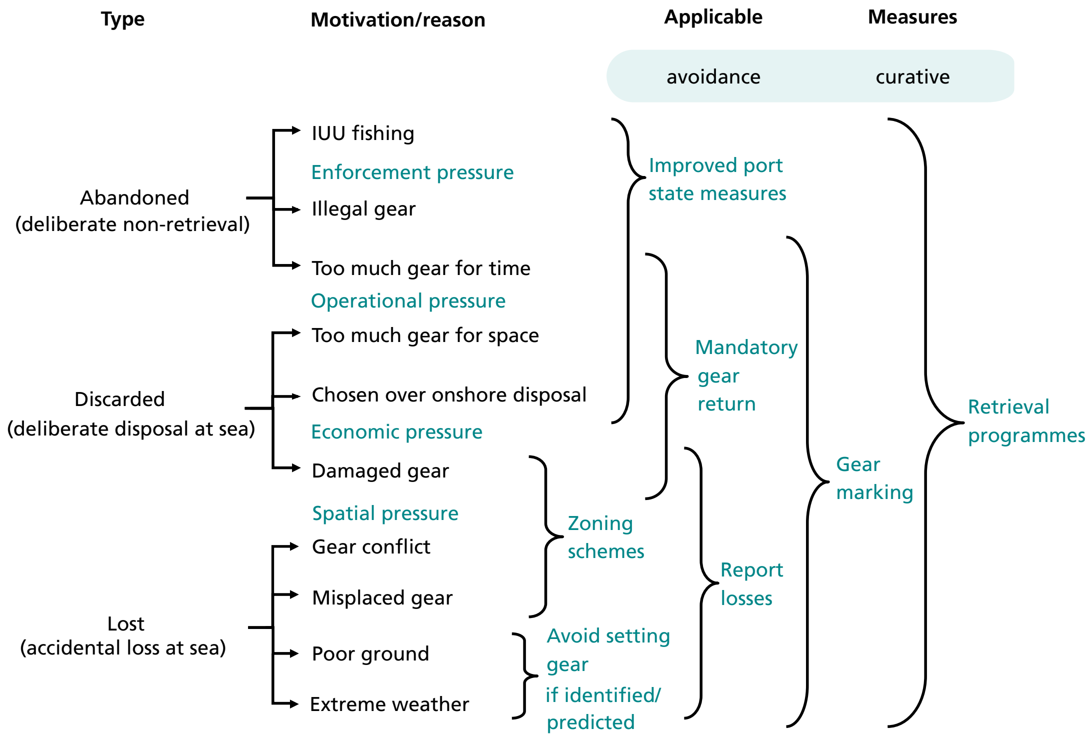
Assessing the effectiveness of curative measures such as gear retrieval is a simpler process than for most preventative measures, where it may be difficult to establish that the retention of fishing gear that would otherwise have been abandoned/lost/discarded, is a result of a particular preventative measure. The impact of preventative measures and awareness-raising initiatives tend to be inferred from surveys of fisher behaviour or opinion.

SUMMARY OF EXISTING MEASURES TO REDUCE ALDFG

A variety of measures aimed at the prevention, mitigation or cure of ALDFG have been identified, with many being implemented across the globe. Some measures, such as gear recovery programmes, are specific measures to tackle ALDFG, while others, such as effort restrictions (pot limits, soak time limits), may be implemented to tackle more general problems of overcapacity, but may have the additional benefit of reducing ALDFG.

The most appropriate measure to tackle ALDFG is more likely to be identified if the type and cause of ALDFG is known for any particular situation. For example, if gear

FIGURE 18
Types of ALDFG, their causes and measures to address



Source: Poseidon, 2008.

conflict is a key cause of lost gear, better spatial management to avoid conflict should reduce the incidence of ALDFG. Where discarding of unwanted or damaged gear at sea is seen to be an issue, a lack of accessible reception facilities may be a key factor and the provision of those facilities should reduce ALDFG.

Figure 18 summarizes the various types of ALDFG and the measures applicable in addressing them. The range of applicable measures move from preventative/avoidance measures (most effective) on the left to curative measures on the right. As the figure indicates, preventative measures are more targeted to specific types of ALDFG, while curative measures can address ALDFG from numerous causes. Fisheries may well experience several types of ALDFG due to a variety of causes.

Many measures are also of limited effectiveness in isolation, and it is therefore suggested that a suite of measures should be implemented. Curative measures could be implemented promptly while preventative measures would be implemented once the causes of ALDFG are known. For example, a comparatively intensive gear retrieval programme may be undertaken initially to remove the immediate problem, but this should be supported by measures to prevent the recurrence of an ALDFG problem in the area, e.g. through awareness-raising, communication between fishers and/or provision of reception facilities.

Measures imposed or taken in isolation may not be effective. For example, gear marking is only likely to make a significant difference if this is supported by an MCS regime that ensures a high level of industry compliance. So too, the provision of waste facilities will only avoid inappropriate disposal if there are incentives (regulatory or economic) applied to encourage their use.

A number of measures to tackle ALDFG remain theoretical rather than applicable in real world situations. Some gear adaptations to reduce or mitigate ALDFG, such as biodegradable nets or lines, are possible, but further testing and cost issues still need to be overcome. Economic incentives are only applied in a small number of cases (such as the payment by Korean authorities to fishers for delivering unwanted or ALD gear). It is difficult to determine the economically optimum level of payment in this instance – particularly because many of the benefits to the marine environment remain difficult to quantify.

A consistent conclusion from a number of recent projects and workshops on ALDFG[19] is that "prevention is better than cure". This is certainly true in environmental terms, but has also been found to hold true in the limited number of cost-effectiveness studies. In general, curative programmes tend to be less effective and more costly than avoidance measures, but they can still be cost-effective when considered against doing nothing. For example, gear retrieval programmes have been shown to be cost-effective when considered against the cost of ghost fishing resulting from leaving ALDFG *in situ*.

[19] See outputs from FANTARED and DeepNet projects and workshop discussions presented in Brown *et al.* (2005).

6. Conclusions and recommendations

The final chapter of this report draws some conclusions and makes some recommendations based on the previous chapters regarding measures to reduce ALDFG.

CROSS-CUTTING RECOMMENDATIONS

The magnitude, impacts and causes of ALDFG are not well known or documented in many fisheries. Thus it is probably unwise, as well as being practically very difficult, to attempt any universal statements about the magnitude, impacts, or causes of ALDFG at the global level, without recognizing the importance of local specificities. However, a precautionary approach would suggest that a lack of complete information is not a reason for inaction. There are numerous examples where the level and impact of ALDFG is sufficiently high to cause concern and warrant action. There are likely to be many additional situations where the problem of ALDFG is present or emerging but is not yet widely reported.

Recommendation 1: Action should be taken immediately to reduce ALDFG, even though better information is still required on various aspects of ALDFG.

Measures to tackle the problem of ALDFG can be preventative, mitigating or curative, but as curative measures generally only remove ALDFG after it has been in the marine environment for some time, preventative measures are likely to be more effective in reducing ALDFG and its impacts. However, to successfully reduce the problem of ALDFG, and its contribution to marine debris more generally, it is likely that actions and solutions will need to address all three types of measures, i.e. preventative, mitigating and curative. (See also recommendation 8).

Recommendation 2: To successfully reduce the problem of ALDFG, and its contribution to marine debris more generally, it is likely that actions and solutions will need to address a wide range of preventative, mitigating, *and* curative measures. However, while all forms of measures to reduce ALDFG may be useful, efforts should focus on preventative measures, except where these are ineffective or where threatened and/or where vulnerable species are at risk.

A number of potential preventative measures such as spatial management and effort reduction are associated with wider fisheries management issues, but can also have positive results in terms of reducing ALDFG. Where such measures already exist, or are being planned, appropriate efforts should be made to specify them so as to integrate specific requirements that may help to reduce ALDFG.

Recommendation 3: Existing fisheries management measures should be reviewed and, where appropriate, adapted to help to address ALDFG.

A large number of research gaps exist in knowledge about ALDFG and the potential solutions. For example, research into the impacts of ALDFG has focused strongly on the potential for ghost fishing of target and non-target species, whereas the contribution of ALDFG to plastics within the environment and the impact of their subsequent incorporation into marine ecosystems have been given less attention. The extent to which FADs contribute to ALDFG is also not well studied, nor are appropriate solutions. And there are many regions of the world for which almost no information is available about the magnitude of ALDFG. However, while further research into the magnitude and impacts of ALDFG are certainly necessary in relation to many different fisheries, reducing ALDFG is likely to be better served by research that focuses on a) the causes of ALDFG and b) appropriate solutions, including their costs/benefits, relevance to specific species and fisheries, effectiveness, acceptability by stakeholders, and enforceability. National and international research and information needs assessments, if fed into research and information plans, would greatly enhance the ability for research and information to inform policy decisions and effective strategies to reduce ALDFG. National and international research and information plans could form part of IPOAs and NPOAs.

Recommendation 4: More research is needed on all aspects of ALDFG including a quantification of the scale involved and the contribution of different fisheries, but particularly into the causes and cost-effectiveness of potential solutions. A useful starting point would be research and information needs assessments at national and international levels, with such assessments used as the basis for specifying research and information plans and priorities.

Like other environmental problems, ALDFG can be addressed and controlled through an effective collaboration of education and outreach programmes, strong laws and policies, governmental and private enforcement, and adequate support infrastructure. Developing effective policies that will reduce this problem requires a comprehensive understanding of the sources and impacts of ALDFG as well as an understanding of human behaviour and how it is affected by economic policies. Economic incentives/measures (taxes, fees, fines, penalties, liability and compensation schemes, subsidies and tradable permit schemes) have a potentially important role to play in addressing the problem, when used as part of an integrated strategy.

There is a need for further action and an examination of relevant economic measures to determine if these could help meet the challenge. For example, a programme that offers attractive "bounties" for fishers to bring abandoned fishing nets to shore requires that these nets and gear be recycled, incinerated and/or otherwise properly disposed of in port. The port waste reception facilities most often are provided on a fee-for-service (user pays) basis. Such an approach can be a barrier to the use of such facilities – since vessel operators may not wish to pay for such fees and instead may opt to illegally dispose of their garbage at sea at no cost (unless they are caught and fined). In some instances, a "general fee" approach has proved more effective. It requires that all vessels using a port pay a standard environmental fee, regardless of whether or not the vessel uses the waste reception facilities. Economic incentives could also be provided to fishers for reporting lost gear.

Recommendation 5: The use of economic incentives and measures to encourage fishers to report lost gear, or bring to port their old, damaged or recovered ALDFG should be studied, developed and implemented.

Awareness about the issue of ALDFG is still not widespread. While care should be taken not to tarnish the fisheries sector with a poor reputation without due consideration of a) the fact that fishing sector marine debris represents only a small proportion of overall marine litter and b) ALDFG may be a very small or unavoidable factor in many fisheries, efforts must be made with relevant stakeholders to increase awareness about the issue. Education has the capacity to provoke positive action to address the ALDFG problem in the first instance and then to enhance the effectiveness of measures. The format for raising awareness needs to be dependent upon the target stakeholder, and type of and reasons for ALDFG in the situation under consideration.

Recommendation 6: Awareness-raising of all stakeholders is needed, with ALDFG measures including an educational element and appropriate reporting to increase awareness.

Measures are likely to be more effective if specified in consultation with the various stakeholders involved, and based on voluntary agreements or economic incentives. Such an approach is likely to better tailor solutions to causes, and to reduce enforcement costs. This in turn requires far better coordination and integration of those seeking to combat ALDFG.

Recommendation 7: Measures to reduce ALDFG should be developed and agreed in close consultation with relevant stakeholders, and they require increased coordination and integration of the efforts of those seeking to reduce ALDFG.

Given that the causes of ALDFG in any particular fishery or region may be multi-faceted, it is likely that a range of different measures may be necessary to reduce ALDFG. This may require a fishery- or region-specific action plan detailing different measures and how they should be applied.

Recommendation 8: Suites of measures should be identified and used to appropriately tackle ALDFG and, where appropriate, specified in an ALDFG action plan.

While it is acknowledged that quantifying many of the costs and benefits of ALDFG and different measures is difficult, measures that have been taken and programmes that have been developed to prevent or reduce ALDFG have to date been poorly evaluated for their effectiveness or cost-efficiency. This prevents objective decision-making about which measures should be prioritized. In order to effectively target activities with measures/solutions that are most successful, and to measure trends in ALDFG, long-term monitoring plans at both national and international level are necessary. These monitoring plans should include quantifiable information based on rigorous methodologies on the sources of ALDFG, its magnitude, and its impacts. This information can then be used in advocacy, and as a baseline to monitor progress in reducing ALDFG and assessing the most effective measures. Enforcement and compliance activities could be a useful source of information for such monitoring plans, along with self-reporting, monitoring of onshore collection compared to new gear purchases, collection/retrieval programmes and targeted scientific research.

Recommendation 9: More monitoring and evaluation is needed of the scale of ALDFG, its impacts and the efficiencies of different measures to reduce ALDFG. Such monitoring and evaluation should form part of national and international monitoring programmes (which could also potentially be included in IPOAs or NPOAs).

RECOMMENDATIONS RELATING TO PREVENTATIVE MEASURES

Gear marking to indicate ownership

Marking gear is gaining prominence due to its potential application in addressing IUU fishing. In pot/trap fisheries individual traps could be adequately tagged, but there are a number of practical hurdles to overcome when considering marking gear for ALDFG purposes, i.e. the most frequently lost or otherwise discarded items of gear are unlikely to retain identifying marks. To be most effective, integral identifiers would need to be added, such as distinct colors or markings within multi-strand twines. Further development is needed to incorporate such technology into monofilament nets and lines (Kiessling, 2003). Marking of FADs could also be used to effectively prevent their loss, abandonment or discarding.

Labelling must be practical and should not restrict performance of the gear. The introduction of gear identifiers during manufacture would, however, be likely to result in higher costs to customers, and to lead to added complexity for statutory regulators as there would be a need to establish and maintain a database of gear ownership. Manufacturers do not always sell direct to vessel owners and therefore the reporting of gear ownership must be at the most appropriate level for the fishery. Should chip

technology be further developed and adopted in the future, it should be applied at the appropriate level and managed within a suite of gear reporting measures.
Recommendation 10: For the available technology in gear marking to be most effective, identification should be made an intrinsic feature of gear at the point of manufacture. This must then be recorded at the most appropriate level in the supply chain, such as the level of manufacturer or chandler.

A clear constraint to gear marking is that vessels engaged in IUU fishing would not easily be incorporated into a gear identification system. Abandonment may occur due to the operator being involved in IUU fishing and in this situation it is highly unlikely that gear will have any traceable identifying marks. Removal and retention of unmarked gear by MCS authorities would be a curative action, but for gear marking to be preventative, port inspection of gear to ensure compliance would be required.
Recommendation 11: Gear marking should be supported by a comprehensive vessel and gear registration system and port inspection.

"Traceability"

All states recognize that there will be accidental loss of fishing gear through a variety of causes. Deliberate abandonment would be difficult to prove and act upon unless done so in combination with gear marking (to identify owner) and reporting requirements (to confirm a lack of compliance).
Recommendation 12: The "findability" of fishing gear should be promoted as a preventative measure by enabling fishers to better find gear that is temporarily lost, rather than as a potentially punitive measure post-recovery.

The use of transponders to aid traceability and reduce ALDFG is most likely to be applicable in large-scale fisheries where the use of technology is commonplace. Even in these fisheries, the extension of this technology may still require some mandatory measures to ensure that use extends to fisheries where ALDFG is thought to be a significant issue and the transponders are of a suitable type and in an appropriate position on the gear to aid immediate or rapid gear recovery. Their use on FADs may be particularly appropriate. GPS technology is becoming increasingly affordable, and given its additional use for vessel navigation, could become widely adopted in marking the position of static gear and assisting mobile gear users to avoid agreed zones of static gear use.
Recommendation 13: Further support should be given to developing affordable transponders and supporting equipment to aid the location of drifting gear and FADs. In addition, GPS technology and assistance in its use should be directed at small-scale fishers so that they can identify the position of static gear.

Spatial management

Closure of an area to specific gears such as mobile gears can avoid gear conflict. If this measure is associated with sea-bed hazards, this zoning is more likely to be accepted and adhered to by the industry as fishers are likely to avoid locations where gear is more likely to be lost, unless good financial returns compensate for this. However, even when static gear sectors are clearly identified, mobile gear is often deliberately towed within these areas, indicating that such zoning must be policed.
Recommendation 14: Spatial management can be an important tool in avoiding gear conflict – an important cause of ALDFG. Measures should be developed with significant industry involvement and subsequently policed.

Onshore collection/disposal

Ensuring that adequate reception facilities are readily available and advertised to port users will aid in the prevention of ALDFG through reducing the problem of disposal and also through raising awareness of the opportunity to dispose of the material safely. The supply of such facilities at a cost deemed to be excessive by users will be a disincentive to dispose of material appropriately. (See also recommendations related to MARPOL Annex V revisions relating to port reception facilities).

Recommendation 15: Nations should ensure that port operators provide adequate, accessible and affordable reception facilities for waste fishing gear. The costs of using these facilities should not deter their use. Where cost recovery is necessary, this might be included in harbour charges rather than as a stand-alone fee.

Projects rewarding or at least facilitating the correct disposal of fishing gear can contribute to changing practices and culture within the fishing sector, provide a mechanism to remove marine litter from the marine environment, and raise awareness among the fishing industry, other sectors and the general public.

Recommendation 16: Disposal equipment should be placed to facilitate easy use.

Reduction of fishing effort through limitations on gear

Many fisheries management regimes contain input restrictions in the form of technical measures, including limiting the quantity of gear that can be used, such as pot or net length limits. The application of gear limits has generally occurred through a need to limit fishing capacity for stock management rather than specifically to reduce ALDFG. But these are likely to have the additional benefit of reducing ALDFG through setting limits at levels where vessels can effectively manage the gear being used.

Management regimes that focus solely on output restrictions such as catch quotas could unwittingly be causing a degree of ALDFG if MCS focus on the catch, as a fisher could be breaking quota limits by recovering all his gear.

Enforcement of a soak time limit would be more difficult than an overall gear limit as circumstances such as poor weather may prevent recovery within a defined timeframe.

Recommendation 17: To reduce gear losses, the amount of gear that can be fished should be limited to that which can be fished effectively. This could be integrated with fishery conservation measures and applied as a condition of licence.

Recommendation 18: Specific effort reduction measures to reduce ALDFG are likely to be most effective when implemented as part of a comprehensive suite of gear measures, including gear marking, recording and monitoring requirements.

RECOMMENDATIONS RELATING TO MITIGATING MEASURES

To date many technical solutions to reduce the impact of lost gear remain in development with few required by legislation. The further development and successful testing of other solutions may lead to the wider adoption of more environmentally benign fishing gear. The greater availability of R&D funding and the introduction of more industry-science partnerships would be positive steps towards more innovative solutions in this area.

For ALDFG purposes, measures targeting reduced bycatch would be beneficial if they remain effective when gear is in a detached or damaged state. For example, twine with improved acoustic reflection could be effective at reducing ghost fishing. Developing measures that are built into the gear, such as biodegradable fastenings to enable escape, is useful for addressing ghost fishing of ALDFG.

The increased costs of many such developments are a barrier to wider adoption, and adopted measures will require enforcement to overcome any real or perceived reduction in operational efficiency and ensure industry compliance. Close cooperation

among the fishing industry, scientists and other stakeholders is therefore necessary in the process of developing and introducing environmentally friendly fishing technology (Valdemarsen and Suuronen, 2001).
Recommendation 19: Support should be given to ensure that ALDFG is a consideration in gear innovation.

Recommendation 20: Where innovations have been tested and found to be practical, industry implementation should be encouraged though grants and ecolabelling/ certification schemes.

RECOMMENDATIONS RELATING TO CURATIVE MEASURES

Locating lost gear

The ability to locate ALDFG is critical to the overall effectiveness of any gear recovery programme; the alternative is undetected gear, and expensive hours at sea can be wasted in chancing upon and recovering lost gear. In many surveys a combination of location methods are used to suit the resources and information available, including VMS track logging data.
Recommendation 21: All available information sources should be used, ranging from fisher information (often initially to identify a search area) to detailed sea-bed imaging and diver surveys.

Diver surveys are known to be more accurate in identifying ALDFG in sea-bed habitat compared to remote operated vehicles (ROVs) and are therefore likely to be superior in identifying ALDFG, but the distance covered by ROV can be far greater and the risk to divers in water where ALDFG is known to be present may be excessive.
Recommendation 22: All divers involved with gear recovery should be properly trained and possess the necessary up-to-date qualifications to undertake such work. Additional guidelines and procedures to further ensure safety in gear recovery operations should be applied (as per California SeaDoc Society).

Reporting lost gear

The early and accurate reporting of lost gear improves the likelihood and effectiveness of recovery. It is therefore important to involve the industry in any such initiatives. A balance should be struck between the benefits of industry reporting lost gear and the administrative burden this may place on vessel operators. Reporting of gear loss could be integrated with catch reporting to additionally provide information on type, extent, position and depth. Therefore, an amendment to MARPOL should require that administrations endeavour to develop strategies to identify the location, source and types of fishing gear lost.
Recommendation 23: Existing reporting requirements such as catch reporting systems (e.g. logbooks) and observer programmes should be extended to include the reporting of ALDFG, possibly as a mandatory requirement. A "no-blame" approach should be incorporated into any such requirements, with respect to liability for losses and their impacts and any related recovery costs.

Recovering lost gear

Gear recovery programmes do not necessarily require high-tech support or significant resources. Where coastal fishing areas are impacted, small-scale fishers may themselves choose to coordinate gear recovery.

Individual actions to recover gear found should also be encouraged as a matter of course through good practice (i.e. retaining on board any marine debris collected while at sea, including ALD gear), but group coordination of gear recovery such as through the local fishers' association or cooperative has the benefit of:

- encouraging an efficient targeted approach;
- ensuring all are contributing to the cost of recovery (lost fishing time and fuel);
- contributing to safer recovery operations with more than one vessel involved; and
- being able to coordinate at the most appropriate time of year, i.e. closed seasons or suitable weather conditions.

Recommendation 24: Co-management or other fisher groups should be encouraged to conduct targeted gear recovery activities. Risk assessment methodologies can be used to prioritize high risk/sensitive areas for ALDFG recovery.

Recycling gear

Where possible, retrieved gear should be reused or recycled. In some instances recycling will not always be practical, as the synthetic material is likely to be mixed with organic debris including the remains of animals entangled, which may raise health issues and odor problems and limit the recycling possibilities to the extent that safe disposal would be more appropriate. Additionally the energy and resources required to collect and transport material to a recycling facility may exceed the benefit derived from recycling it.

Recommendation 25: Simple guidance for the cost-effective, safe and environmentally responsible local-level recycling of ALDFG is required. Where necessary, local-level disposal solutions need to be developed for different gear types and material.

POTENTIAL INTERNATIONAL ACTIONS

The International Maritime Organization (IMO)

While MARPOL has been effective in tackling many areas of marine pollution, more could be done to specifically address marine debris and ALDFG, including more coastal and port state control with better flag state implementation of the convention.

Recommendation 26: IMO should consider disposal of waste from fishing vessels, including ALD gear more specifically, through an expanded action plan on adequacy of port reception facilities. A resulting action should be an investigation and port state reporting into the adequacy of port reception facilities for fisheries waste, including ALD gear.

The International Convention for the Prevention of Pollution from Ships (MARPOL) Annex V

MARPOL Annex V is recognized as a key mechanism in addressing one important aspect of marine pollution – reducing garbage and litter from shipping. It is therefore an important element in tackling ALDFG. As an international convention to tackle marine pollution from shipping in general, MARPOL Annex V cannot be expected to address all ALDFG issues. However, MARPOL and the IMO as an organization are uniquely placed to help address the international problem of ALDFG.

Although the guidelines for the implementation of Annex V of MARPOL addresses ALDFG, there are a number of areas where amendments could be made to the Annex to support wider international ALDFG measures, namely:

- consider a reduction in the 400 GT limit for vessels under Annex V[20];
- develop an addendum to the Annex V guidelines with more detailed guidance on appropriate measures to address ALDFG, for example on what constitutes reasonable precaution with regard to preventing the loss of fishing gear, and on gear marking requirements; and
- provide qualitative and quantitative standards related to port reception facilities.

[20] Setting a new GT limit and extension to domestic vessels will have significant consequences for port and vessel operators. The most appropriate GT limit will need to be determined: it would have to be sufficient to have an impact, but remain workable.

Imposing stricter port measures and recording requirements inappropriately may in fact increase the incidence of disposal of gear at sea.

Recommendation 27: Amend MARPOL Annex V to include reducing the 400 GT minimum tonnage for garbage management plans, providing better guidance on "reasonable losses" and gear marking, and providing quantitative standards related to port reception facilities.

Recommendation 28: Ensure that MARPOL Annex V amendments are appropriate and that non-compliance is not exacerbated (e.g. by undertaking a regulatory impact assessment of proposals).

Recommendation 29: Review MARPOL Annex V to consider that administrations endeavour to develop strategies to identify the location, source and types of fishing gear lost.

International agencies

It is recognized that IUU fishing is a contributor to ALDFG, but most preventative measures will only be effective in dealing with legitimate operators. International action to tackle IUU fishing is also therefore an important factor in the reduction of ALDFG.

Various international agencies are progressing actions within the fisheries or maritime sectors that have direct or indirect consequences for ALDFG. This includes UNEP's marine litter programme and recent FAO actions on port State measures, IUU fishing and a global vessel register.

Recommendation 30: A coordinated/consistent approach to address ALDFG across agencies is necessary. The holding of an expert consultation could lead to further action at an international level and encourage the production of national plans to tackle ALDFG and provide a route to information on ALDFG for regional or national agencies.

A lack of adequate reception facilities is known to contribute to ALDFG. Port states, particularly the Pacific Island States, have identified this is as key issue. The IMO is recognized as the lead organization in addressing port reception facilities, but FAO has experience of developing practical initiatives for fishery harbours through the Bay of Bengal Programme Cleaner Fishery Harbours. This experience may well prove useful in developing guidelines for small-scale ports and harbours hosting domestic fishing fleets.

Recommendation 31: FAO should continue to collaborate with the IMO (in association with RFMOs) in developing a cleaner harbours programme for small-scale ports and harbours, particularly targeting fishing sector waste, including waste gear. This would complement the proposed IMO investigation of the adequacy of port reception facilities for fishing waste, including ALD gear.

The impetus for reducing marine litter has come from IMO, with ALDFG emerging as an FAO-UNEP priority. In order to provide greater consistency and greater emphasis, it is considered that FAO and UNEP work cooperatively towards developing a global plan of action for ALDFG.

Recommendation 32: Building regional and state awareness of the issues and providing guidance on the potential regulatory and voluntary mechanisms for preventing, mitigating the impact of and recovering ALDFG should be the centrepiece of a global plan of action on ALDFG.

SUMMARY OF RECOMMENDATIONS AND POTENTIAL ACTIONS

Measures to reduce ALDFG may be appropriately taken at the international, regional, national or local level. It is also likely that some measures will need to be legislated and made mandatory, while others need only be voluntary, and indeed may be more effective for being so. For example, while locally specific legislation may be appropriate in some cases, in fisheries where there is potential for local-level arrangements to result in a degree of consensus and agreement between/by participants, measures could be applied voluntarily and/or through the adoption of codes of practice, where improved communication between different fisher groups and preventative measures could be adopted and agreed.

Conversely, due to the transboundary nature of many of the causes and impacts of ALDFG, and the fact that some causes are likely to be universal in nature and require universally applicable measures, regional and international collaboration may be especially appropriate to address some aspects. These may be voluntary or legislated, but their application, support and enforcement may often be necessary at a national/local level, even if based on international conventions or the requirements of a regional fisheries body.

Table 10 provides a summary of the recommendations associated with ALDFG in general, of specific measures, and of the authors' views as to what international agencies could do to help reduce ALDFG. The table also includes a suggestion as to the level at which the recommendations should be addressed, and the extent to which they should be legislated for or made voluntary.

TABLE 10
Suggested route for addressing recommendations

Recommendation	Level and responsibility	Legal status
1–9 Cross-cutting recommendations (see Chapter 6.1)	Can be effective at all levels, and relevant to all stakeholders	Voluntary
Preventative (avoiding the loss of gear) measures (see "Recommendations relating to preventive measures", page 81)		
10. Make gear Identification intrinsic to gear structure	Fishery-specific and therefore could be applied through RFB or national regulations	Mandatory
11. Require port-based marking inspections to reduce IUU-related ALDFG	Fishery-specific and therefore could be applied through RFB or port state regulations	Mandatory
12. Promote lost gear recovery	Fishery-specific and therefore could be applied through RFB or national or local regulations	Voluntary
13. Develop affordable GPS and transponder use	Adoption of technology could be encouraged by initiatives at any level or by certification schemes	Voluntary
14. Promote spatial management	Area-specific and therefore likely to be local	Mandatory & voluntary
15. Facilitate onshore reception and disposal	International action (IMO) to encourage national adoption	Mandatory
16. Facilitate convenient and affordable gear disposal	International action (IMO) to encourage national adoption	Voluntary
17. Set general limits on gear carried	Fishery-specific and therefore could be applied through RFB or national regulations	Mandatory
18. Integrate ALDFG reduction into wider management methods	Fishery-specific and therefore could be applied through RFB or national regulations	Voluntary
Mitigating measures (reducing the impact if lost) (see "Recommendations relating to mitigating measures", page 83)		
19. Promote better gear design to reduce bycatch by lost gear	Fishery-specific and therefore could be applied through RFB or national regulations or local agreements	Mandatory
20. Encourage use of "ALDFG-friendly gear" through grants/ ecolabelling initiatives	Local government/ecolabelling standard development	Voluntary

Recommendation	Level and responsibility	Legal status
Curative measures (removal and clean-up of lost gear) (see "Recommendations relating to curative measures", page 84)		
21. Combine local knowledge and scientific approaches for gear location	Fishery-specific and therefore could be coordinated through RFB, national agency or local agreements	Voluntary
22. Develop minimum requirements for diver safety plus guidelines and procedures to further ensure safety in retrieval	National, but international collaboration useful	Mandatory
23. Incorporate reporting of lost gear with current reporting systems	Fishery-specific: possibly coordinated through RFB, national agency or local agreements	Mandatory
24. Conduct targeted gear recovery	Fishery-specific: possibly coordinated through RFB, national agency or local agreements	Voluntary
25. Provide guidance for cost-effective, safe and responsible disposal	Local coordination, but may be part of wider national or international initiative	Voluntary
International initiatives (see "Potential international actions", page 85)		
26. Develop an action plan on adequacy of port reception facilities for fisheries waste, including ALD gear	IMO	Voluntary
27. Amend Annex V: reduce the 400 GT limit, and provide specific guidance on "reasonable losses", gear marking and port reception facilities	IMO	Mandatory
28. Undertake regulatory impact assessment to ensure measures are appropriate	IMO	Voluntary
29. Expand Guidelines appendix to advise port states on pollution from fishing, including ALDFG	IMO	Voluntary
30. Promote coordinated/consistent approach to address ALDFG across agencies	IMO/FAO	Voluntary
31. Develop cleaner harbours programmes	FAO	voluntary
32. Formulate a global action plan to address ALDFG	UN Agencies	Voluntary

Source: Poseidon, 2008.

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Carpentaria Ghostnets Programme – www.ghostnets.com.au

Derelict fishing gear recovery in California, USA – www.mehp.vetmed.ucdavis.edu/derelictgear.html

Global Marine Litter Information Gateway – www.marine-litter.gpa.unep.org/cases/shipping-fishing.htm

Monofilament line collection and recycling – www.healthebay.org/news/2007/08_02_monofilament/default.asp

SeaNet Program involving outreach to fishing industry on developing technical solutions to improve sustainability – www.oceanwatch.org.au/snindex.htm

Glossary

Term	Explanation
Abandoned fishing gear	Fishing gear that is deliberately left at sea with no intention by fishers to retrieve it, for whatever reason.
ALDFG	Collective term for fishing gear that has been abandoned, lost or otherwise discarded (see separate glossary entries). Often referred to as "derelict fishing gear" in literature.
Creeper	A device used to retrieve abandoned, lost or otherwise discarded fishing gear.
Curative management	Management approach that seeks to reduce the extent of ALDFG (i.e. *ex-post* as opposed to *preventative management* which attempts to prevent gear being abandoned, lost or otherwise discarded *ex-ante*).
Discarded fishing gear	Fishing gear or parts thereof that is deliberately thrown overboard without any intention for further control or recovery.
Drifting longline	Consists of a mainline kept near the surface or at a certain depth by means of regularly spaced floats and with relatively long snoods with baited hooks, evenly spaced on the mainline. Drifting longlines may be of considerable length exceeding 80 km. Mainlines and leader lines are almost exclusively made from synthetic materials.
Fish aggregating device (FAD)	Moored or free-floating structures placed in the open ocean with the primary function of aggregating fish to increase their catchability.
Fishing gear[1]	Tools for the capture of aquatic resources. This definition includes all items/elements onboard fishing vessels that are used for fishing purposes, including fish aggregating devices (FADs).
Fleet (of nets)	Two or more gillnets which are connected.
Fyke net	Normally used in shallow water, consists of a cylindrical or cone-shaped bags mounted on rings or other rigid structures, completely covered by netting and completed by wings or leaders which guide the fish towards the opening of the bags. Fyke nets, fixed on the bottom by anchors, ballast or stakes, may be used separately or in groups.
Gear conflict	An event where one form of fishing activity interferes with another, potentially resulting in the loss of one or both types of fishing gear. For example, this may occur when a towed gear (e.g. trawl) cuts across static gear (e.g. gillnet).

[1] For a detailed description of fishing gears see *FAO Fisheries Technical Paper* No. 222 Rev. 1.

Ghost fishing	The term used to describe the capture of marine organisms by lost, abandoned or otherwise discarded fishing gear or parts thereof. Effectively, the capture of fish and other species that takes place after all control of fishing gear is lost by a fisher[2]. For example, a lost, abandoned or discarded gillnet might continue to fish with consequent mortality to the enmeshed fish. Ghost fishing is often cyclical and the pattern, duration and extent will depend on a large number of factors including the gear type, water depth, currents and local environment.
Gillnets/ entangling nets/ tangle nets	Strings of single, double or triple netting walls, vertical, near the surface, in midwater or at the bottom, in which fish will gill, entangle or enmesh. These nets have floats on the upper line (headrope) and, in general, weights on the ground line (footrope). Several types of nets may be combined in one gear (for example, gillnet combined with trammel net). These nets can be used either alone or, as is more usual, in large numbers placed in line ("fleets" of nets). The gear can be, anchored to the bottom or left drifting, free or connected with the vessel.
Ground	The seabed substrate. Often described as soft or open ground (i.e. sandy or muddy) or hard or rocky ground (substrate with obstructions that might snag or damage fishing gear).
Lost fishing gear	The accidental loss of fishing gear at sea.
Mobile gear	Fishing gear that is towed by a vessel to displace and capture fish. Sometimes called active or towed gear. Examples include trawls and dredges.
Net sheet	A portion of netting typically joined together with other sheets.
Preventative management	Management approach that seeks to prevent the initial loss of gear (i.e. an *ex-ante* measure as opposed to *curative management* that is implemented *ex-post*).
Purse seine	A long wall of netting framed with floatline and leadline (usually, of equal or longer length than the former) and having purse rings hanging from the lower edge of the gear. Through the purse rings runs a purse line made from steel wire or rope which allows the pursing of the net. For most situations, purse seine is the most efficient gear for catching large and small pelagic species that are shoaling.
Retrieval	A process by which ALDFG fishing gear is recovered using towed trawls, grapnels, divers, remotely operated vehicles or other specialist equipment.
Set longline	Consists of a mainline and secondary lines with baited (occasionally un-baited) hooks at intervals. The number of hooks, distance of snoods on the mainline, and length of the snoods depends on the target species, the handling capacity and technology used. Longlines can be set as bottom lines (including on very rough bottom and/or coral reefs) or in midwater or even not far from the surface. Its length can range from a few hundred metres in coastal fisheries to more than 50 km in large-scale mechanized fisheries.

2 Some variation of this definition could be considered in cases where fishers do not abandon, lose or discard gear, but leave it in the water for longer periods than is deemed appropriate to retrieve catch of a marketable quality.

Soak time	The period for which fishing gears are deployed in the water before being removed/recovered.
Static gear	Fishing gear that is placed in one fixed location, usually through anchors and buoys, so that it traps or ensnares passing fish. Static gear includes types of nets, pots and traps. Some gear may be baited to improve fishing efficiency. This gear is sometimes called passive gear, in that no energy is expended during the actual fishing process.
Trammel net	Bottom-set entangling net made with three walls of netting, one or more outer walls being of a larger mesh size than the loosely hung inner netting sheet. The fish get entangled in the inner small meshed wall after passing through the outer wall, thus trapping rather than gilling it.
Traps/pots	Traps, large stationary nets, or barrages or pots, are gears in which the fish are retained or enter voluntarily and are then hampered from escaping. They are designed in such a manner that the entrance operates as a non-return device, allowing the fish to enter the trap but making it impossible to leave the catching chamber. Different materials are used for building a trap or pot; wood, split bamboo, netting, and wire are some examples. Due to the lack of standardization in the literature, the terms “pots” and “traps” are used interchangeably throughout this report.
Trawl	A cone-shaped net (made from two or more sheets of netting), that is towed, by one or two boats, on the bottom or in midwater (pelagic). The cone-shaped body ends in a bag or cod-end. The horizontal opening of the gear while it is towed is maintained by beams, otter boards or by the distance between two towing vessels (pair trawling). Floats and weights and/or hydrodynamic devices provide for the vertical opening. Two parallel trawls might be rigged between two otter boards (twin trawls).
Vertical line (or recreational “hook & line”)	Consists of a line to which is attached sinker and one or several hooks, used in both commercial and recreational fisheries. In commercial fisheries, the lines have usually several hooks. The additional hooks can be fixed on the mainline at short intervals with branch lines of a certain length. A special form of vertical line is a jigger line, mostly used in the fisheries for squid. Special squid jiggers (ripped hooks) are mounted one after the other at a certain distance with a monofilament line. The line weighed down by sinkers can be set up to 200 m in depth and is hauled with jerky movements.

Appendix A

United Nations General Assembly Resolutions related to ALDFG

Resolution A/RES/59/25 Sustainable Fisheries (United Nations, 2004)

> *"60. Calls upon States, the Food and Agriculture Organization of the United Nations, the International Maritime Organization, the United Nations Environment Programme, in particular its Regional Seas programme, regional and subregional fisheries management organizations and arrangements and other appropriate intergovernmental organizations that have not yet done so to take action to address the issue of lost or abandoned fishing gear and related marine debris, including through the collection of data on gear loss, economic costs to fisheries and other sectors, and the impact on marine ecosystems;*
> *61. Requests the Secretary-General, in his next report concerning fisheries, to include information on the actions taken by the Food and Agriculture Organization of the United Nations, the United Nations Environment Programme, in particular its Regional Seas programme, the International Maritime Organization, regional and subregional fisheries management organizations and arrangements, and other appropriate intergovernmental organizations, to give effect to paragraph 60 above;*
> *62. Urges States to ratify and implement relevant international agreements, including annex V to the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto;*
> *63. Calls upon States, where relevant, to establish systems for retrieving lost gear and nets;"*

Resolution A/RES/60/30 - Oceans and the Law of the Sea (United Nations, 2006a)

> *"65. Notes the lack of information and data on marine debris, encourages relevant national and international organizations to undertake further studies on the extent and nature of the problem, also encourages States to develop partnerships with industry and civil society to raise awareness of the extent of the impact of marine debris on the health and productivity of the marine environment and consequent economic loss;*
> *66. Urges States to integrate the issue of marine debris into national strategies dealing with waste management in the coastal zone, ports and maritime industries, including recycling, reuse, reduction and disposal, and to encourage the development of appropriate economic incentives to address this issue, including the development of cost recovery systems that provide an incentive to use port reception facilities and discourage ships from discharging marine debris at sea, and encourages States to cooperate regionally and sub-regionally to develop and implement joint prevention and recovery programs for marine debris;*
> *67. Invites the International Maritime Organization, in consultation with relevant organizations and bodies, to review annex V to the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto, and to assess its effectiveness in addressing sea-based sources of marine debris;*
> *68. Welcomes the continued work of the International Maritime Organization relating to port waste reception facilities, and notes the work done to identify problem areas and to develop an action plan addressing the inadequacy of such facilities;"*

Resolution A/RES/60/31 (United Nations, 2006b)

> *"77. Calls upon States, the Food and Agriculture Organization of the United Nations, the International Maritime Organization, the United Nations Environment Programme, in particular its Regional Seas programme, regional and sub-regional fisheries management*

organizations and arrangements and other appropriate intergovernmental organizations that have not yet done so to take action to address the issue of lost or abandoned fishing gear and related marine debris, including through the collection of data on gear loss, economic costs to fisheries and other sectors, and the impact on marine ecosystems;

78. Encourages close cooperation and coordination, as appropriate, between States, relevant intergovernmental organizations, United Nations programmes and other bodies, such as the Food and Agriculture Organization of the United Nations, the International Maritime Organization, the United Nations Environment Programme, the Global Program of Action, and Regional Seas arrangements, regional and sub-regional fisheries management organizations and arrangements and relevant stakeholders, including non-governmental organizations, to address the issue of lost and discarded fishing gear and related marine debris, through initiatives such as analysis of the implementation and effectiveness of the existing measures relevant to the control and management of derelict fishing gear and related marine debris, the development and implementation of targeted studies to determine the socio-economic, technical and other factors that influence the accidental loss and deliberate disposal of fishing gear at sea, the assessment and implementation of preventive measures, incentives and/or disincentives relating to the loss and disposal of fishing gear at sea, and the development of best management practices;

79. Encourages States, directly and through regional and sub-regional fisheries management organizations and arrangements, and in close cooperation and coordination with relevant stakeholders, to address the issue of lost and discarded fishing gear and related marine debris, through initiatives including developing and implementing joint prevention and recovery programs, establishing a clearinghouse mechanism to facilitate the sharing of information between States on fishing net types and other fishing gear, the regular, long-term collection, collation and dissemination of information on derelict fishing gear, and national inventories of net types and other fishing gear, as appropriate;

80. Encourages States, the United Nations Environment Programme, the Global Program of Action, the Food and Agriculture Organization of the United Nations, the International Maritime Organization, sub-regional and regional fisheries management organizations and arrangements and other relevant intergovernmental organizations and programs to consider the outcomes of the Asia-Pacific Economic Cooperation Education and Outreach Seminar on Derelict Fishing Gear and Related Marine Debris, held in January 2004, and how they may be implemented;

81. Encourages States to raise awareness within their fishing sector and sub-regional and regional fisheries management organizations and arrangements of the issue of derelict fishing gear and related marine debris and to identify options for action;

82. Encourages the Committee on Fisheries to consider the issue of derelict fishing gear and related marine debris at its next meeting in 2007, and in particular the implementation of relevant provisions of the Code;"

Resolution A/RES/61/222 (United Nations, 2007a)

78. Welcomes the activities of the United Nations Environment Programme relating to marine debris carried out in cooperation with relevant United Nations bodies and organizations, and encourages States to further develop partnerships with industry and civil society to raise awareness of the extent of the impact of marine debris on the health and productivity of the marine environment and consequent economic loss;

79. Urges States to integrate the issue of marine debris into national strategies dealing with waste management in the coastal zone, ports and maritime industries, including recycling, reuse, reduction and disposal, and to encourage the development of appropriate economic incentives to address this issue, including the development of cost recovery systems that provide an incentive to use port reception facilities and discourage ships from discharging marine debris at sea, and encourages States to cooperate regionally and sub-regionally to develop and implement joint prevention and recovery programs for marine debris;
80. Welcomes the decision of the International Maritime Organization to review annex V to the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto, 42 to assess its effectiveness in addressing sea-based sources of marine debris, and encourages all relevant organizations and bodies to assist in that process;

Resolution A/RES/61/105 (United Nations, 2007b)

"94. Reaffirms the importance it attaches to paragraphs 77 to 81 of its resolution 60/31 concerning the issue of lost, abandoned, or discarded fishing gear and related marine debris and the adverse impacts such debris and derelict fishing gear have on, inter alia, fish stocks, habitats and other marine species, and urges accelerated progress by States and regional fisheries management organizations and arrangements in implementing those paragraphs of the resolution;95. Further encourages the Committee on Fisheries of the Food and Agriculture Organization of the United Nations to consider the issue of derelict fishing gear and related marine debris at its [next] meeting in 2007, and in particular the implementation of relevant provisions of the Code;"

Appendix B

Survey and personal contacts made during this study

Name	Organization	Survey respondent
Adler, Ellik	UNEP	
Agnew, David	Imperial College London	
Anon.	North East Atlantic Fisheries Commission (NEAFC)	Yes
Breen, Mike	International Council for the Exploration of the Sea (ICES) – Fisheries Research Service (FRS), Aberdeen	
Broadhurst, Ginny	Northwest Straits Commission, USA	
Chakalall, Bisessar	FAO Subregional Office for the Caribbean (SLAC)	
Chopin, Francis	FAO Fishing technology Service (FIIT)	
De Rozarieux, Nathan	Seafood Cornwall, UK	
Donohue, Mary	Sea Grant College Program, University of Hawaii, USA	Yes
Espy, Leigh	National Oceanic and Atmospheric Administration (NOAA)	
Ferro, Dick	Fisheries Research Service (FRS), Aberdeen	
Fitzpatrick, John	FAO Fishing technology Service (FIIT)	
Gilardi, Kirsten	SeaDoc Society, California Fishing Gear Retrieval Programme	
Gillett, Bob	Independent Consultant	
Gregory, Murray	University of Auckland, NZ	
Jeftic, Ljubomir	UNEP Consultant	
Joseph, Leslie	Independent Consultant	
June, Jeff	Natural Resources Consultants, Inc., USA	Yes
Kiessling, Ilse	Department of the Environment & Water Resources, Northern Territory, Australia	
Matulessy, Luna	International Finance Corp. (IFC)	
Moloney, Brett	South Pacific Commission (SPC)	
Morgan, Gary	Regional Organization for the Protection of the Marine Environment (ROPME)	

Parry, Neal	National Oceanic and Atmospheric Administration (NOAA) Marine Debris Program	Yes
Phillips, Michael	Network of Aquaculture Centres in Asia-Pacific (NACA)	
Raaymakers, Steve	Consultant, Australia	
Rihan, Dominic	Bord Iascaigh Mhara (BIM), Ireland	Yes
Rose, Craig	Alaska Fisheries Science Center, USA	Yes
Simonds, Kitty	Western Pacific Fishery Management Council, Hawaii, USA	Yes
Tambunan, Gomal H.	Network of Aquaculture Centres in Asia-Pacific (NACA) – Escolas Técnicas do Estado de São Paulo (ETESP)	
Tietze, Uwe	FAO Fishing Technology Service (FIIT) (retired)	
Valdemarsden, John W.	Institute of Marine Research (IMR), Norway	Yes
Vassilopoulou, Vassiliki	Hellenic Centre for Marine Research (HCMR), Greece	Yes

Appendix C

Summary of survey results

1. Please would you tick the one box below that best describes which sector you work for or in

Answer Options	Response Percent
private sector	0.00%
government	60.00%
international organisation	10.00%
regional organisation	10.00%
representative organisation (e.g. producer organisation)	0.00%
NGO	10.00%
Research	10.00%

2. Please indicate in which region of the world you are based

Answer Options	Response Percent
Europe	50.00%
North America	30.00%
South America	0.00%
Pacific	20.00%
Asia	0.00%
Africa	0.00%
Middle East	0.00%
Other	0.00%

3. Please rank the following gear types in terms of how much ALDFG (in volume terms) you think they generate in your region (e.g. tick 1 for the most important gear type, 2 for the next most important, etc)

Answer Options	1	2	3	5	6	Rating Average
Gill nets	6	1	0	0	0	2
Pots/traps	1	3	3	1	0	2.63
Mobile gear/trawls	2	2	2	0	0	2.5
Longlines	0	3	3	0	0	3
Jigs	0	0	0	2	4	5.67
Aquaculture	0	0	1	5	2	5

4. For each gear type, which of the following impacts of ALDFG on the marine environment do you think are PARTICULARLY significant in your region (you may tick more than one impact for each gear)? (in relation to aquaculture we are thinking of lost cages, etc)

Answer Options	Ghost fishing of target species	Ghost fishing of non-target species	Navigational hazards	Ingestion by other species	Phyiscal impacts on the benthic/bottom environment
Gill nets	7	9	2	1	4
Pots and other forms of traps	6	6	1	0	3
Mobile gear/ trawls	2	5	5	0	7
Longlines	4	4	1	1	0
Jigs	0	0	0	0	0
Aquaculture	0	1	2	1	4

5. For each gear type could you please indicate which you think are the PRINCIPAL causes of ALDFG (you may tick more than one cause for each gear type)?

Answer Options	Gear conflicts	Poor weather	Economic reasons	Lack of port-side collection		IUU fishing	Other
Gill nets	5	7	3	3	1	3	1
Pots/traps	3	8	1	2	1	0	1
Mobile gear/trawls	1	3	3	3	4	3	4
Longlines	5	6	2	2	3	2	1
Jigs	0	2	1	0	0	0	1
Aquaculture	1	4	1	1	1	0	0

6. Which of the following measures to reduce ALDFG are being used in your region, at local, national, or regional level.

Answer Options	Yes	No	Dont know
Gear marking to indicate ownership	6	3	1
Gear modification to reduce loss	5	4	1
Technical – transponders	1	7	2
Technical – biodegradable gear	4	6	0
Requirements to report losses	5	4	1
Port State measures	2	3	5
Effort regulation (e.g. soak times)	7	2	1
Spatial management regulation	9	0	1
Fishermen education/training	7	1	2
Development of codes of practice/conduct	5	3	2
Port-side collection facilities	8	1	1
Economic incentives (e.g. payment for old gear)	0	10	0
Ex-post clean up/recovery	8	2	0
Recycling	6	2	2

7. How effective do you think the following measures could potentially be, or are, in preventing ALDFG in your region

Answer Options	Very effective	Quite effective	Not very effective
Gear marking to indicate ownership	2	5	1
Gear modification to reduce loss	0	7	1
Technical - transponders	2	1	2
Technical - biodegradable gear	3	2	1
Requirements to report losses	4	0	3
Port State measures	2	2	2
Effort regulation (e.g. soak times)	2	2	3
Spatial management regulation	2	5	2
Fishermen education/training	3	4	2
Development of codes of practice/conduct	0	4	2
Port-side collection facilities	4	4	0
Economic incentives (e.g. payment for old gear)	1	3	2
Ex-post clean up/recovery	4	3	0

8. Do you think the following measures should be legislated for i.e. compulsory, or promoted through voluntary approaches? And at what level do you think they would be most appropriately addressed (you may tick more than one level, but if possible we would prefer you to select different levels for different measures). Please also note that if you suggested particular measures would not be effective in question 16, you could leave the rows relating to those measures blank

Answer Options	Legislated/ mandatory	Voluntary	International	Regional
Gear marking	7	1	4	2
Technical gear modification to reduce loss	3	4	3	2
Technical - transponders	1	5	3	1
Technical - biodegradable gear	2	4	3	5
Requirements to report losses	7	0	3	3
Port State measures	5	0	3	3
Effort regulation (e.g. soak times)	7	0	2	4
Spatial management regulation	7	0	1	5
Fishermen education/training	3	5	2	5
Codes of conduct	2	4	3	5
Port-side collection facilities	4	4	4	2
Economic incentives (e.g. payment for old gear)	1	4	1	2
Other	0	0	1	1
Ex-post clean up/recovery	2	5	1	4
Recycling	2	5	3	2

Appendix D

Breakdown of gear retrieval programme costs

TABLE 11
Cost of the Norwegian gear retrieval survey

Budget item	Cost in Kr.	Cost in €
Boat hire and fuel for one month	1.1 million	133 000
Collecting information (Fishermen's survey)	0.12 million	14 520
Survey labour cost, travel, report writing	0.28 million	33 880
Total cost	**1.5 million**	**181 500**

Source: Brown *et al.,* 2005.

TABLE 12
Estimated costs for deep water pilot retrieval survey

Budget item	Total cost in €
Boat hire 20 days at €5 000 day	100 000
Fishermen's survey (consultant time costs)	15 000
Retrieval gear	15 000
Total	**130 000**

Source: Brown *et al.*, 2005.

TABLE 13
Process and costs of the Baltic retrieval programme conducted by Sweden

Gear retrieval steps	Cost in €
Determine areas of net loss with industry. Based on good communications between industry and researchers.	Labour time of fishermen (2 person days) and scientists (2 person days) to discuss appropriate area for survey. Information collected in advance of planned gear retrieval programmes
Hire retrieval vessel (normal commercial vessel rather than a research vessel. Medium-sized stern trawler with 2 net drums)	10 sea days at > €1 100/day (12 000 Kr./day)[3]. Costs depend on time of year – it is cheaper during the summer cod closure, although earlier times of year are favoured
Determine retrieval gear development costs – suitability varies by region, e.g. Norwegian gear not suitable to Baltic conditions	2 years, 3 people part-time (2 person months)
Purchase retrieval gear, e.g. sweeps, hooks, otter doors (of special size)	Approximately €1 000
Dispose of retrieved gear	Costs borne by port authorities in Sweden and Denmark
Maintain retrieval gear	Dependent on frequency of retrieval work and nets recovered, but generally very low – €100/year
Prepare evaluation	5 person days to evaluate the weight and length of netting, weight and length of fish caught in net. Attempts to look at value v total cost of harvest, but many uncertainties. Could look at trends in nets being caught per retrieval effort (net retrieval per unit of effort (NRPUE))

Source: Brown *et al.,* 2005.

[3] Hire costs in other countries may vary considerably depending on differences in vessels needed, and basic differences in costs for similar items between countries.

Abandoned, lost or otherwise discarded fishing gear (ALDFG) is a problem that is increasingly of concern. This report, undertaken by the United Nations Environment Programme (UNEP) and the Food and Agriculture Organization of the United Nations (FAO), reviews the magnitude and composition of ALDFG, and while noting that information is not comprehensive and does not allow for any global estimates, suggests that gillnets and fishing traps/pots may be the most common type of ALDFG. Factors leading to ALDFG as well as their impacts are presented. The report profiles measures already considered to stem the problem and includes a number of recommendations for future action.

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