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.

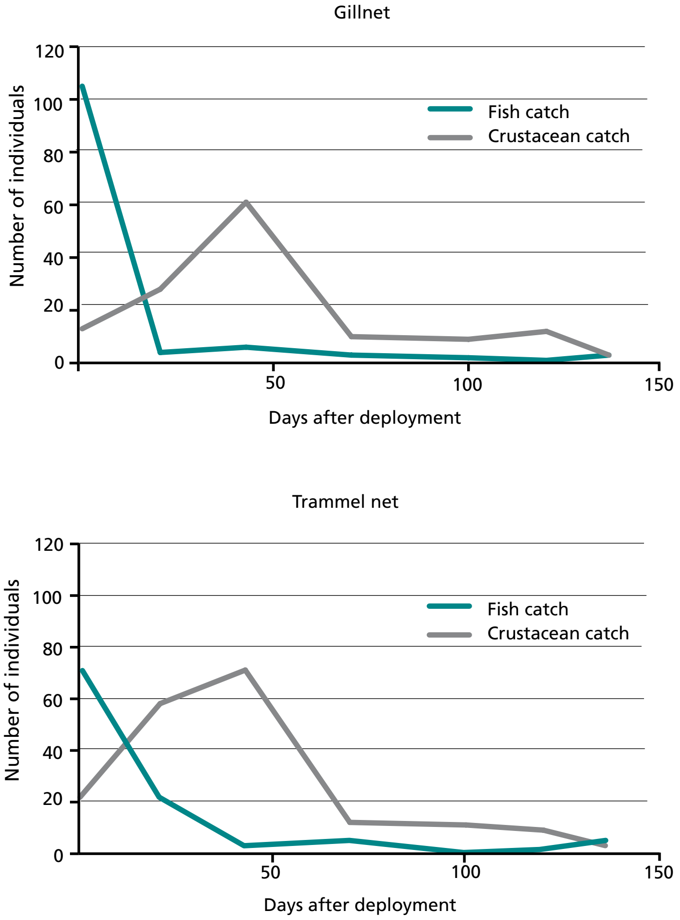
Results of net loss simulations and wreck surveys around the United Kindgom were reported in the FANTARED 2 study, and by Revill and Dunlin (2003). One of the gillnet fleets lost on open ground was virtually intact and appeared to be operating at around 90 percent efficiency after four weeks but contained 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

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[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

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[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.

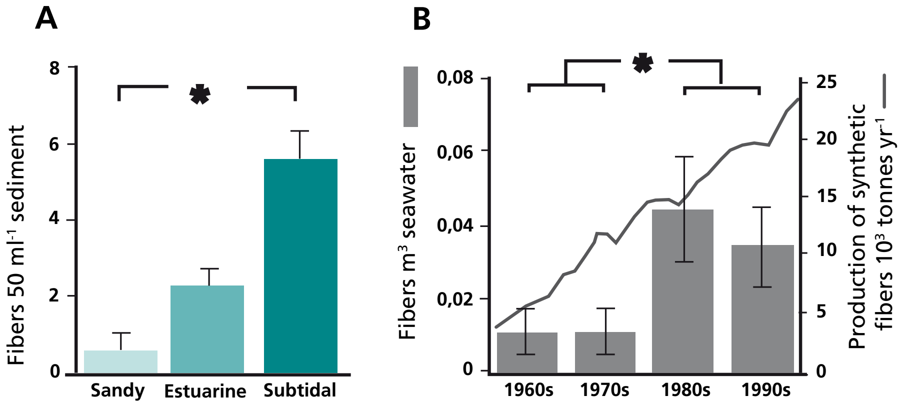
While examining the impact of fishing on the coldwater corals of the northeast Atlantic, although lost longlines were observed on video surveys of coral areas, no evidence of actual damage to reefs was found, although it was supposed that coral branches might be broken off during the retrieval of longlines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

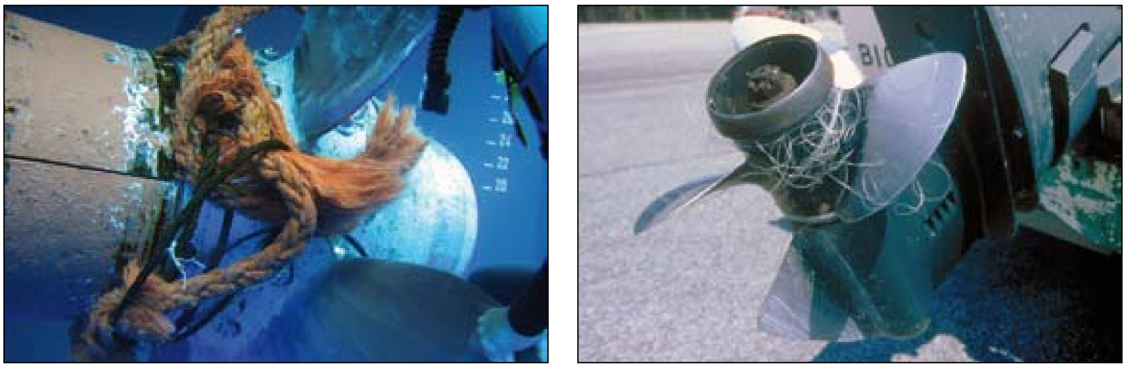
Not all ALDFG is necessarily negative. Box 3 gives examples of the usefulness of ALDFG flotsam in the South Pacific.

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.

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[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.