Food and Agriculture Organization of the United Nations

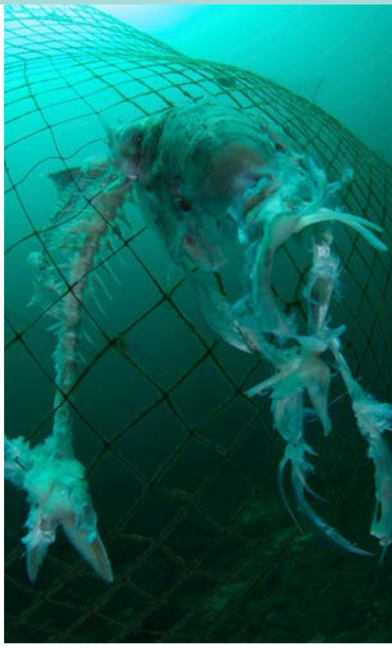
FAO FISHERIES AND AQUACULTURE TECHNICAL PAPER

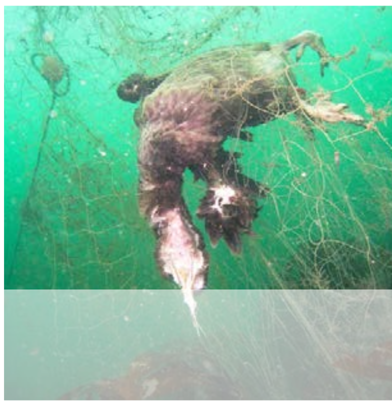
600

ISSN 2070-7010

Abandoned, lost and discarded gillnets and trammel nets

Methods to estimate ghost fishing mortality, and the status of regional monitoring and management





UNEP

Cover photograph:
Top row, left to right: sperm whale entangled in a drift gillnet (Alberto Romero/Marine Photobank); artisanal gillnet fishing vessel, Solomon Islands (Wolcott Henry 2005/Marine Photobank); decomposed trevally caught in a ghost net, Muscat, Damaniyat Islands, Oman (Sijmon de Waal/Marine Photobank).
Bottom row, left to right: removing salmon from a gillnet, Bristol Bay, Alaska, the United States of America (Karen Ducey/NMFS/NOAA Photo Library); derelict gillnet, Oahu, Hawaii, the United States of America (Frank Baersch/Marine Photobank); seabird caught in derelict net (Dave Peake/Marine Photobank).

Abandoned, lost and discarded gillnets and trammel nets

FAO
FISHERIES AND
AQUACULTURE
TECHNICAL
PAPER

600

Methods to estimate ghost fishing mortality, and the status of regional monitoring and management

Eric Gilman
FAO Consultant
Honolulu, the United States of America

Francis Chopin
Fishing Operations and Technology Branch
FAO Fisheries and Aquaculture Department
Rome, Italy

Petri Suuronen
Fishing Operations and Technology Branch
FAO Fisheries and Aquaculture Department
Rome, Italy

and

Blaise Kuemlangan
Development Law Branch
FAO Legal Office
Rome, Italy

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS Rome, 2016

978-92-5-108917-0

Preparation of this document

This publication was produced under a 2014 Letter of Agreement between FAO and the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities, hosted by the United Nations Environment Programme, as Secretariat for the Global Partnership on Marine Litter. The study scope covered abandoned, lost or discarded fishing gear (ALDFG) from marine gillnet and trammel net fisheries. It describes methods to estimate ghost fishing mortality rates and levels, and synthesizes estimates of loss rates, density, duration of fishing efficiency and ghost fishing mortality rates. It also assesses related measures of regional bodies and arrangements for monitoring and managing ALDFG and ghost fishing. Information for the study was obtained through a review of published and grey literature, and consultations with relevant intergovernmental organizations.

Abstract

The ecological and socio-economic problems caused by abandoned, lost and discarded fishing gear (ALDFG) are increasingly of concern. Used primarily by coastal, artisanal, small-scale fisheries worldwide, marine gillnets and trammel nets, which have relatively high ghost fishing potential, account for about one-fifth of global marine fisheries landings. FAO and the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities, hosted by the United Nations Environment Programme, as Secretariat for the Global Partnership on Marine Litter, commissioned this study to identify best practices to estimate ghost fishing mortality rates and levels, priority research needs, and the status of international monitoring and management of ALDFG and ghost fishing by marine gillnet and trammel net fisheries. Accurate estimates of total ghost fishing mortality levels can be made given quality data on the density of ALDFG retaining fishing efficiency, duration of ghost fishing efficiency, and total ghost fishing mortality level of a unit of effort of ALDFG over the full period that the derelict gear retains fishing efficiency. Recommendations to improve estimates of regional and global rates and levels of ghost fishing from ALDFG from marine gillnet and trammel net fisheries were made. An assessment was made and opportunities were identified to improve intergovernmental organizations' data collection protocols and management measures to prevent and remediate ALDFG and ghost fishing by marine gillnets and trammel nets.

FAO. 2016. *Abandoned, lost and discarded gillnets and trammel nets: methods to estimate ghost fishing mortality, and the status of regional monitoring and management,* by Eric Gilman, Francis Chopin, Petri Suuronen and Blaise Kuemlangan. FAO Fisheries and Aquaculture Technical Paper No. 600. Rome. Italy.

Contents

Preparation of this document iii
Abstract iv
Acknowledgements vii
Acronyms and abbreviations viii
Executive summary x

1. Introduction 1
1.1 ALDFG causes and effects 1
1.2 International efforts to address ALDFG 4
1.3 Methods to mitigate ALDFG 6
1.4 Factors affecting ghost fishing efficiency and duration 9
1.5 Study scope and aims 11

2. Catching process, design and operation of marine drift and set gillnets and trammel nets 13
2.1 Gillnets 15
2.2 Trammel nets 17
2.3 Combination gillnets – trammel nets 18

3. Methods and estimates 19
3.1 Methods and results 19
3.2 Discussion 26
3.2.1 Methods and estimates of rates of abandonment, loss and discarding and use in estimating ALDFG density 26
3.2.2 Methods and estimates of the density of ALDFG 28
3.2.3 Methods and estimates of ghost fishing mortality rates and duration of fishing efficiency 30
3.2.4 Research priorities for robust regional and global estimates of gillnet and trammel net ghost fishing mortality levels 36

4. Monitoring and management by regional fishery bodies and arrangements 39
4.1 Introduction, study scope and methods 39
4.2 Results: RFB/A monitoring and management of ALDFG and ghost fishing 41
4.2.1 General Fisheries Commission for the Mediterranean (GFCM) 43
4.2.2 Indian Ocean Tuna Commission (IOTC) 44
4.2.3 International Commission for the Conservation of Atlantic Tunas (ICCAT) 44
4.2.4 Joint Norwegian-Russian Fisheries Commission (JNRFC) 45
4.2.5 North Atlantic Salmon Conservation Organization (NASCO) 46
4.2.6 North Pacific Anadromous Fish Commission (NPAFC) 47
4.2.7 Pacific Salmon Commission (PSC) 48
4.2.8 Regional Commission for Fisheries (RECOFI) 48
4.2.9 Southern Indian Ocean Fisheries Agreement (SIOFA) 49
4.2.10 Western and Central Pacific Fisheries Commission (WCPFC) 49

4.3 Discussion and conclusions 50
4.3.1 RFB/A mandate to monitor and control ALDFG 50
4.3.2 RFB/A logbook and observer data collection protocols on ALDFG 50
4.3.3 RFB/A controls of ALDFG and ghost fishing 51
4.3.4 Monitoring and controlling ALDFG and ghost fishing by bilateral and multilateral arrangements and bodies 53

5. Summary and recommendations 55

6. References 61

Acknowledgements

The authors are grateful for assistance and information provided by: Robin Allen, South Pacific Regional Fisheries Management Organisation; Anthony Beeching, Western and Central Pacific Fisheries Commission; Simon Brockington and David Mattila, International Whaling Commission; Ricardo Federizon, Northwest Atlantic Fisheries Organization; Martin Hall, Inter-American Tropical Tuna Commission; Pilar Hernandez, General Fisheries Commission for the Mediterranean; Miguel Herrera, Indian Ocean Tuna Commission; Peter Hutchinson, North Atlantic Salmon Conservation Organization; Bob Kennedy, Commission for the Conservation of Southern Bluefin Tuna; Bruce Leaman, International Pacific Halibut Commission; Loh-Lee Low, Convention on the Conservation and Management of the Pollock Resources in the Central Bering Sea; Vladimir Radchenko, North Pacific Anadromous Fish Commission; Keith Reid, Commission for the Conservation of Antarctic Marine Living Resources; and Ben van Zyl, South East Atlantic Fisheries Organisation. The report benefited considerably from formal expert peer reviews by: Dr Milani Chaloupka (Ecological Modelling Services and University of Queensland), Joan Drinkwin and Kyle Antonelis (Northwest Straits Foundation), David Laist (Marine Mammal Commission), Graeme Macfadyen (Poseidon), and Heidi Savelli (United Nations Environment Programme).

Acronyms and abbreviations

ALDFG	abandoned, lost or discarded fishing gear
BRD	bycatch reduction device
CCAMLR	Commission for the Conservation of Antarctic Marine Living Resources
CCBSP	Convention on the Conservation and Management of the Pollock Resources in the Central Bering Sea
CCSBT	Commission for the Conservation of Southern Bluefin Tuna
CMM	conservation and management measure
Code	FAO Code of Conduct for Responsible Fisheries
COFI	FAO Committee on Fisheries
CPUE	catch per unit of effort
CV	coefficient of variation
EEZ	exclusive economic zone
FAD	fish aggregating device
FAO	Food and Agriculture Organization of the United Nations
GFCM	General Fisheries Commission for the Mediterranean
GPA	Global Programme of Action for the Protection of the Marine Environment from Land-Based Activities
IATTC	Inter-American Tropical Tuna Commission
IBSFC	International Baltic Sea Fishery Commission
ICCAT	International Convention for the Conservation of Atlantic Tunas
ICES	International Council for the Exploration of the Sea
IGO	intergovernmental organization
IOTC	Indian Ocean Tuna Commission
IMO	International Maritime Organization
IPHC	International Pacific Halibut Commission
IUU	illegal, unreported and unregulated (fishing)
IWC	International Whaling Commission
JNRFC	Joint Norwegian–Russian Fisheries Commission
MARPOL	International Convention for the Prevention of Pollution from Ships
NAFO	Northwest Atlantic Fisheries Organization
NASCO	North Atlantic Salmon Conservation Organization
NEAFC	North East Atlantic Fisheries Commission
NPAFC	North Pacific Anadromous Fish Commission
PSC	Pacific Salmon Commission
PSMA	Agreement on Port State Measures to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing
RECOFI	Regional Commission for Fisheries

RFB/A	regional fishery body and/or arrangement
RFMO	regional fisheries management organization
ROV	remotely operated vehicle
SEM	standard error of the mean
SEAFO	Southeast Atlantic Fisheries Organisation
SIOFA	Southern Indian Ocean Fisheries Agreement
SPRFMO	South Pacific Regional Fisheries Management Organisation
UNCLOS	United Nations Convention on the Law of the Sea of 10 December 1982
UNEP	United Nations Environment Programme
UNFSA	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
UNGA	United Nations General Assembly
WCPFC	Western and Central Pacific Fisheries Commission

Executive summary

Abandoned, lost and discarded fishing gear (ALDFG) causes substantial ecological and socio-economic problems. Ghost fishing, one problem resulting from ALDFG, has received increasing international attention in the past decade. Ghost fishing mortality is infrequently accounted for in fisheries management, potentially compromising the accuracy of population and stock assessment models and the efficacy of harvest strategies. Ghost fishing by ALDFG removes both target and non-target species. Species with relatively low fecundity and other life-history characteristics that make them particularly sensitive to anthropogenic mortality sources are also subject to ghost fishing mortality. These include species of seabirds, sea turtles, marine mammals and elasmobranchs, some of which are endangered, threatened or protected. Ghost fishing mortalities are also a source of wastage, and reduce the sustainable production of fishery resources and economic opportunities for the marine capture sector. There are also social welfare issues relating to ghost fishing mortality of flagship megafauna, as well as the time some organisms caught in ALDFG take to die relative to captures in in-use gear.

Ghost fishing is most problematic in gillnet, entangling trammel net and other passive fishing gear types, where the capture process relies on the movement of organisms into the gear. Used worldwide primarily by coastal, artisanal, small-scale fisheries, about one-fifth of global marine fisheries landings comes from gillnet and trammel net fisheries.

Fishing mortality caused by ALDFG has substantial adverse ecological and socio-economic effects. Marine gillnets and trammel nets have relatively high ghost fishing potential. Recognizing this, FAO and the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities, hosted by the United Nations Environment Programme, as Secretariat for the Global Partnership on Marine Litter, commissioned this study. Its purpose is to: identify best practice methods for estimating ghost fishing rates and levels; determine priority research needs; and assess the status of international monitoring and management of ALDFG and ghost fishing by marine gillnet and trammel net fisheries.[1]

METHODS AND ESTIMATES

This study reviews the methods employed to estimate: rates of gear abandonment, loss and discarding; density of derelict gear in spatially explicit sites; duration of fishing efficiency; and ghost fishing mortality rates by ALDFG. It identifies best practice methods for reducing uncertainty. It synthesizes findings from past studies, providing an understanding of the degree of dispersion in estimates and of the severity of ALDFG and ghost fishing. The study identifies priority information gaps to provide robust estimates of regional and global ghost fishing mortality rates and levels by ALDFG.

At some sites and under certain conditions, ALDFG can result in substantial ghost fishing removals of both market and non-market species, including endangered, threatened and protected species and other species of conservation concern. Relative to some other gear types and to other collateral indirect sources of fishing mortality, there has been good progress in developing methods to estimate the duration of fishing efficiency and ghost fishing mortality rates in gillnets and trammel nets. However, a wide variety of assessment methods and units for reporting results have been employed in the sparse number of relevant studies. This precludes meaningful comparisons of

[1] Hereinafter, to avoid repetition and unless otherwise stated, the text refers to ALDFG and ghost fishing solely by gillnets and trammel nets.

findings between most studies and prevents pooling of datasets to support large-scale temporal and spatial analyses. Studies are largely dated and may not characterize ALDFG and ghost fishing in contemporary fisheries. Studies have been spatially and temporally patchy, with very large dispersion in estimates.

An accurate estimate of the total level of ghost fishing mortality in a spatially explicit site over a selected period can be made given data on: the density of ALDFG (unit amount per unit of area of seafloor and/or per unit volume of water column) retaining fishing efficiency; area of the site; duration of ghost fishing efficiency; and total ghost fishing mortality level of a unit of effort of ALDFG over the full period that the derelict gear continues to retain fishing efficiency. When combined with information on the amount and spatial distribution of fishing effort, information on the rate of abandonment, loss and discarding of fishing gear can be used to estimate the density of ALDFG by gear type in a selected area. Study methods designed to be representative across sites and periods that have variability in potentially significant explanatory factors affecting ALDFG and ghost fishing mortality rates and levels are more likely to characterize a site accurately.

Rates of loss, abandonment and discarding

Fisher surveys have been the most common method to estimate rates of gear loss. They provide a critically important rough order-of-magnitude approximation where previously little or no information was available. Based on a small number (n=10) of comparable estimates from fisher surveys, marine gillnet and trammel net fishers **lose** an average of 1 percent of their gear (e.g. 1 percent of gear is lost per vessel per year), but with very high dispersion in estimates (38 percent coefficient of variation, CV). Few studies have estimated rates of gear abandonment and discarding. Estimates have not been based on data from experiments, observer programmes or logbook programmes, which could validate qualitative estimates derived from fisher surveys and provide more certain findings. Findings are of higher certainty when methods account for the proportion of initially lost gear that was subsequently recovered, the generation of ALDFG from illegal fishing, and the transport of ALDFG into and out of a spatially explicit site.

Density

Fisher surveys have also been used to estimate the density of ALDFG in a spatially explicit area. However, surveys of fishing grounds are a more accurate method, including via towing “creeper” grappling devices and various *in situ* survey methods such as observations by divers, and by sonar, video and photography deployed from marine vessels, towed structures, crewed submersibles and underwater remotely operated vehicles. Estimates obtained from surveys of a subset of a fishing ground can be extrapolated to a larger area of interest, such as an entire fishing ground. Some studies have explicitly accounted for an estimate of error of the survey method (the proportion of derelict gear present in a study site that the survey method did not identify). There was high variability in estimates of the density of ALDFG from gillnet and trammel net fisheries. Four studies that used comparable units, of unit length of nets per unit area of surveyed fishing grounds, found a mean of 4.4 km of nets per square kilometre of fishing grounds, with extremely high variability (86 percent CV).

Ghost fishing mortality rates, duration of ghost fishing efficiency

A wide variety of methods have been employed to estimate ghost fishing mortality rates and the duration of ghost fishing efficiency in ALDFG, or in experimental nets deployed to simulate derelict gear. Study designs using simulated derelict gear will be more likely to characterize ghost fishing rates and levels in the commercial fishery if using typical gear designs and methods, including selecting study sites within typical fishing grounds.

Short-period ghost fishing mortality rates have been estimated by counting the number of organisms that became newly captured since a previous observation. Monitoring has been conducted *in situ* and via repeated net retrieval. There are several sources of uncertainty associated with the each of the methods used to estimate short-term catch rates in derelict nets, which should be accounted for to improve the accuracy of estimates. For example, organisms caught in between two monitoring events that are completely removed from the net by predators or scavengers, or that escape and later die due to injuries resulting from the interaction before the net is subsequently monitored, may not be accounted for in ghost fishing mortality estimates. Estimates made through periodic retrieval of a subset of derelict nets may also underestimate ghost fishing mortality rates, as a proportion of catch may drop out during net retrieval.

Exponential regression decay models have been fitted to time series of short-period ghost fishing catch rate data to estimate the duration of fishing efficiency and the total ghost fishing mortality level for the estimated duration of fishing efficiency. The duration of fishing efficiency has been estimated via periodic monitoring of derelict or simulated derelict gear until the gear is observed to no longer retain any catching capacity, no longer catches main market species, or retains a small proportion of species-specific or total catch capacity relative to its initial fishing efficiency or relative to in-use gear deployed in the same area and time. There was high dispersion in estimates of ghost fishing mortality rates. The mean number of ghost-caught fishes per unit area of nets for the full duration of fishing efficiency or to reach 5 percent of initial catch efficiency was 92.8 fish per 100 m^2 of net (51 percent CV) based on a small number of studies using comparable units (n=5). There was moderate variability in estimates of the duration of ghost fishing efficiency that used units of time to cease catch efficiency of all organisms, or to decline to a small percentage of fishing efficiency: The mean of 11 study findings was 35.0 weeks (18 percent CV). Very few studies have assessed ghost fishing by driftnets. Estimates of the duration of driftnet fishing efficiency have ranged from less than a day for small, 50–100 m length nets, to three months for 2 km length nets. This suggests that anchored gillnets and trammel nets pose larger problems from ghost fishing relative to driftnets. Most studies designed to estimate ghost fishing mortality rates and the duration of fishing efficiency by ALDFG have studied simulated derelict demersal nets set at coastal sites within commercial fishing grounds at relatively shallow depths.

The large dispersion in estimates of ghost fishing mortality rates and duration of ghost fishing efficiency is probably a result of extremely small sample sizes as well as from pooling data from studies employing variable methods, studying ALDFG with variable gear designs and materials, and at sites with variable environmental and physiographic conditions (e.g. flat substrate in shallow water with strong currents and abundant biofouling organisms, debris and particulate matter vs entangled on three-dimensional objects in deep water with weak current and limited biofoulers, debris and particulate matter; site with active towed fishing gear vs site lacking active gear fishing effort).

Research needs and recommendations

Several information gaps were identified that are critical to producing robust estimates of regional and global rates and levels of ghost fishing from ALDFG. There were small sample sizes in available estimates of rates of producing derelict gear, density of derelict gear, ghost fishing mortality rates and levels, with under-representation by region and gear type. Many estimates are dated and may not characterize ALDFG and ghost fishing in contemporary fisheries. Large sources of uncertainty were introduced in some of these studies. The use of variable units to report estimates prevents pooling of some records, reducing sample sizes available to estimate means. There are no available databases estimating regional and global levels of gillnet and trammel net fishing effort.

As a result of these deficiencies, there would be very high uncertainty in estimates of regionally and globally averaged ghost fishing mortality rates and levels, especially for taxa that are rare-event captures, such as marine megafauna. Recommendations were made to address these deficiencies:

- Domestic and regional authorities should harmonize logbook and observer programme data fields, data collection protocols, and database formats on ALDFG where they are in place, and fill gaps where currently programmes to monitor ALDFG are not in place. This would produce larger sample sizes of records of rates of generating ALDFG, and rates of fishing vessel encounters with ALDFG, collected using standardized methods. Standardizing data fields, data collection protocols and database formats facilitates comparisons between regions, enables pooling of data necessary to support large spatial scale analyses within and across regions, and enables global standardization of training materials and courses.
- More research is needed, using identified best practice methods to minimize uncertainty, to estimate ghost fishing mortality rates and levels. These studies should be balanced spatially, temporally and by type of gillnet and trammel net fishing gear and method.
- Studies designed to estimate ghost fishing mortality rates and levels should employ standardized units to report estimates in order to facilitate pooling.
- Meta-analyses of data from relevant compiled studies should be conducted to produce estimates of generating ALDFG, density of ALDFG, and ghost fishing mortality rates with increased precision, accuracy and statistical power over estimates from individual studies.
- Robust estimates of regional and global gillnet and trammel net fishing effort should be developed.

MONITORING AND MANAGEMENT BY BILATERAL AND MULTILATERAL FISHERY BODIES AND ARRANGEMENTS

The past decade has seen increasing international recognition of the need for multilateral efforts to address effectively the transboundary problems resulting from ALDFG, including ghost fishing. To benchmark regional measures for monitoring and mitigating ALDFG and ghost fishing, this study assessed the data collection protocols and management measures to prevent and remediate ALDFG and ghost fishing of ten bilateral and regional bodies and arrangements with the competence to establish binding management measures for regional marine capture fisheries, and that have competence over fishery resources that are captured in an active gillnet or trammel net fishery.

Monitoring and management

Of the ten assessed fishery bodies and arrangements, three collect data via logbook or observer programmes related to ALDFG. Only one of the assessed bodies/arrangements is explicitly mandated by its convention or agreement text to monitor and control ALDFG and ghost fishing. More than half of assessed bodies/arrangements have adopted binding measures that directly or indirectly contribute to avoiding or remediating ALDFG. However, the six bodies/arrangements with controls in place do not take advantage of the full range of available tools. Five of 18 categories of methods identified as being of potential use in preventing and remediating ALDFG and ghost fishing were used by the 10 bodies/arrangements. Five methods used exclusively to mitigate ALDFG and ghost fishing are not implemented by any of the bodies/arrangements. Prohibiting the use of gillnet and trammel net gear in part or all of the area of competence of a body/arrangement, which contributes to reduced ALDFG and ghost fishing, was the most commonly employed measure. Gear marking to identify ownership and to increase passive surface gear visibility was the second-most commonly employed method. Both forms of gear marking contribute to reducing ALDFG.

Recommendations

Findings identify opportunities to improve regional monitoring and management of ALDFG and ghost fishing:

- Bilateral and multilateral fishery bodies and arrangements can harmonize ALDFG logbook and observer data collection and reporting protocols where they are in place, and fill gaps in bodies and arrangements lacking procedures to collect and report this information.
- For bodies and arrangements lacking binding measures to manage ALDFG and ghost fishing, members can raise awareness of the impacts of ALDFG and ghost fishing, and learn from the experiences of bodies and arrangements that have made progress in adopting relevant measures, with an aim to harmonize management systems to achieve consistency and compatibility.
- Through consideration of the full suite of complementary methods, members of fishery bodies and arrangements should consider adopting management measures that directly and indirectly prevent and remediate ALDFG and associated ghost fishing. These methods include, *inter alia*:
  - **Preventive methods:**
    - Gear marking systems to identify ownership and to increase surface gear visibility, where adoption of a global standard for gear marking would facilitate consistent implementation regionally and nationally.
    - Technology to avoid unwanted gear contact with the sea bed.
    - Technology to track gear position and gear used to mark passive gear location that is designed to minimize the risk of loss owing to contact by passing vessels.
    - Gear designs and materials that reduce the risk of gear loss.
    - Input controls, including limits on gear soak time.
    - Periodic or constant attendance by fishers while the gear is soaking.
    - Marine spatial and temporal planning, including to separate passive and mobile gears to avoid gear conflicts and concomitant gear loss, and to phase out gillnet and trammel net fishing at sites with high risk of gear snagging on submerged features.
    - Deterrents of illegal, unreported and unregulated (IUU) fishing.
    - Raised member awareness and incentives for compliance with the prohibition on intentional abandonment and discarding of fishing gear at sea under the International Convention for the Prevention of Pollution from Ships.
    - Economic incentives for proper disposal of unwanted gear and disincentives for fishers to generate ALDFG.
    - Raised member awareness that adequate (affordable and accessible) port reception and recycling facilities for unwanted "retired" fishing gear contributes to preventing ALDFG.
    - Programmes to train new fishery entrants to minimize the likelihood of gear loss and augment capacity to recover lost and abandoned gear.
  - **Remedial methods:**
    - Raised member awareness that adequate port reception and recycling facilities incentives the reporting, retrieval and delivery to these facilities of ALDFG encountered at sea.
    - Programmes for ALDFG detection, reporting and safe retrieval.
    - Programmes to disable the ghost fishing efficiency of ALDFG.
    - Gear designs and fishing practices that reduce ghost fishing catch and mortality rates of species of conservation concern.
    - Less-durable and degradable gear to reduce ghost fishing duration, if determined to outweigh costs of increased introduction of synthetic compounds into marine ecosystems and increased rates of gear loss and retirement.

1. Introduction

1.1 ALDFG CAUSES AND EFFECTS

Abandoned, lost and discarded fishing gear (ALDFG), also called derelict fishing gear, cause substantial ecological and socio-economic problems. An estimated 6.4 million tonnes of marine debris are added to global seas annually (UNEP, 2005a). ALDFG is estimated to compose less than 10 percent of total marine debris by volume at a global scale but the composition of marine debris and density of ALDFG is highly variable at small spatial scales (Macfadyen, Huntington and Cappel, 2009; Pham *et al.*, 2014). The amount, distribution and effects of ALDFG have risen substantially in past decades with the rapid expansion of fishing effort and fishing grounds, and the transition to synthetic, more durable and more buoyant materials used for fishing gear (Derraik, 2002; Macfadyen, Huntington and Cappel, 2009; Gilardi *et al.*, 2010).

There are numerous causes, both intentional and unintentional, for fishing gear to be abandoned, lost or discarded. Losses occur when gear that has been set for fishing is unintentionally left at sea. All or a portion of lost gear may later be found and retrieved. Fishers may lose gear when there is contact with passing vessels or with active gear. For example, gear conflicts occur when passive gear is inadvertently, or intentionally, towed away or marker buoy moorings are cut by trawlers or dredgers (Laist, 1995, 1997; Santos *et al.*, 2003a; Hareide *et al.*, 2005; Antonelis, 2012, 2013). For example, gillnet loss has been documented to be frequent at fishing grounds that also have high bottom trawling effort, where trawl gear moves or cuts the nets or buoy lines (MacMullen *et al.*, 2003; Suuronen *et al.*, 2012). There is also evidence of damage to anchored gillnets and trammel nets from entanglement with passive gear, including demersal longlines and traps (Erzini *et al.*, 1997; MacMullen *et al.*, 2003). Loss of fish aggregating devices (FADs) due to interactions with gillnet fisheries has also been documented (Atapattu, 1991). Fishers may lose gear due to the removal of marker buoys, which can occur when surface gear is cut by passing vessels and by sea ice in poleward regions, and due to the breakage or malfunction of tracking systems. Considerable gear loss can occur during natural hazard events, such as hurricanes (e.g. O'Hare, 2001). High wind and strong currents can push marker buoys under water, causing fishers to lose the gear. Gear can also be lost and abandoned when the gear becomes snagged on wrecks and natural submerged features (Breen, 1990; Pawson, 2003; Cho, 2009; Ayaz *et al.*, 2010; FAO, 2010a). Damage by marine organisms can also lead to gear loss (Vanderlaan, Smedbol and Taggart, 2011). Improper designs and materials can lead to gear loss, such as from not properly maintaining gear and not replacing worn components used to locate the gear. Improper fishing methods can also lead to gear loss, such as new entrants setting passive gear in areas where it is likely to snag submerged features, setting gear at grounds where there is a high probability of interaction with mobile gear, long soak times during which anchored gear moves from its original position, and where strong currents are prevalent (MacMullen *et al.*, 2003; Antonelis, 2012, 2013). Gear can also be lost owing to inclement weather or strong currents.

Abandoned fishing gear results when gear that has been set for fishing is intentionally left at sea and not retrieved. In addition to causing gear to be lost, bad weather may also result in gear abandonment, if it becomes too dangerous to retrieve the gear. Fishers may abandon gear when operating illegally and a risk of detection occurs (e.g. Imamura, 2011). For example, since the United Nations moratorium on large-scale pelagic drift-nets over 2.5 km long in international waters, illegal, unreported and unregulated (IUU) high seas driftnetting has been an ongoing problem in some regions

(UNGA, 1991; Pramod *et al.*, 2008). Fishers may opt to abandon gear, or to refrain from attempting to locate and retrieve lost gear, when there is insufficient time, or when it would be too difficult to retrieve the gear, such as when the gear is snagged on submerged features (MacMullen *et al.*, 2003; Santos *et al.*, 2003a).

Discarded fishing gear is produced when fishers intentionally throw unwanted gear overboard at sea. Crew may discard unwanted components of gear at sea when deemed more practical or economical than disposal on shore, especially where port reception facilities are unavailable. Setting excessive gear can also result in discarding gear. For example, there may be insufficient room on board for all of the gear, such as when the space used to store nets when starting a trip is subsequently used as the fish hold (Hareide *et al.*, 2005; Macfadyen, Huntington and Cappel, 2009).

Achieving sustainable marine fisheries requires reliably estimating and accounting for all main sources of fishing mortality (FAO, 1995, 2003, 2011a). However, several components of fishing mortality, including that caused by ALDFG and other indirect collateral sources that are largely not manifest or readily detectable, are not routinely accounted for in fisheries management owing to a lack of both adequate data and accurate estimation methods (Chopin and Arimoto, 1995; ICES, 1995, 2005; Chopin *et al.* 1996; Chopin, Inoue and Arimoto, 1996; Gilman *et al.*, 2013). Errors can result when population and stock assessment models do not account for total fishing mortality, including from direct and collateral removals caused by ALDFG. This unaccounted fishing mortality has the potential to compromise the efficacy of fisheries harvest strategies and the sustainable production of fishery resources, irreparably harm affected populations and stocks, and cause broader community- and ecosystem-level effects (Hall, 1996; Punt *et al.*, 2006; Coggins *et al.*, 2007). Mortalities from ghost fishing by ALDFG are also a source of wastage and reduce economic opportunities for the marine capture sector (Goñi, 1998; Gilardi *et al.*, 2010; Antonelis *et al.*, 2011). For example, ghost fishing has been estimated to remove between 0.5 percent and 30 percent of landed catches of market species in various European and North American fisheries (Laist, 1995, 1997; Sancho *et al.*, 2003; Santos *et al.*, 2003b; Brown and Macfadyen, 2007). There are also social welfare issues related to ghost fishing mortality of flagship charismatic marine megafauna, and related to the duration that it takes organisms caught in ALDFG to die relative to in-use gear (Akiyama, Saito and Watanabe, 2007; IWC, 2013a; WSPA, 2014).

Ghost fishing occurs when ALDFG continues to catch and kill organisms (Kaiser *et al.*, 1996; FAO, 2010b; Uhlmann and Broadhurst, 2013; Wilcox *et al.*, 2013). Long-term "automated re-baiting" occurs when moribund and decomposing organisms caught in the derelict gear attract scavengers. Feeding by scavengers, in turn, releases odours that augment attraction to the ALDFG. Some of these scavengers become caught and eventually decompose, providing a continual source of "bait" until the ALDFG loses its fishing efficiency. This automated re-baiting can augment the ghost fishing efficiency of some gear types for some species (Breen, 1990; Kaiser *et al.*, 1996; Matsuoka, Nakashima and Nagasawa, 2005; FAO, 2010a; Gilman *et al.*, 2013). While some species are repelled by dead conspecifics (organisms of the same species), others are attracted to live conspecifics caught in the derelict gear. Moreover, the structure of ALDFG acts as a FAD, increasing the local abundance of organisms, which increases ghost fishing efficiency (Breen, 1990; MacMullen *et al.*, 2003).

Ghost fishing mortality is of particular concern for marine megafauna with K-selected life-history strategies (long life span, slow growth, late sexual maturity, low fecundity, and low natural mortality rates of subadult and adult age classes), including seabirds, sea turtles, marine mammals, elasmobranchs (sharks and their relatives) and some bony fishes (Laist, 1995, 1997; Kaiser *et al.*, 1996; Donohue *et al.*, 2001; Good *et al.*, 2009, 2010; IWC, 2013a). Mortality in marine capture fisheries, including from ghost fishing, can contribute to compromising the viability of some populations in these groups. Owing to their life-history characteristics, they can decline over short temporal scales (decades and shorter) and are slow to recover from large declines (Musick, 1999a, 1999b; Hall, Alverson and Metuzal, 2000; Lewison *et al.*, 2004; Gilman, Owens and Kraft, 2013c). However, even populations of fecund, widespread species can be at risk of extirpation (local extinction) owing to unsustainable fishing mortality and other anthropogenic stressors (Casey and Myers, 1998; Dulvy *et al.*, 2004; Gilman *et al.*, 2011).

Floating ALDFG and other marine debris can obstruct navigation. Floating derelict gear can entangle or clog a vessel's water intake valves, propellers, propeller shaft and rudder, so stranding vessels and placing vessels and crew in danger. ALDFG can also foul in-use fishing gear, which may require costly repairs and lost fishing time, and can result in additional gear loss (Macfadyen *et al.*, 2009; FAO, 2010a). In addition, floating marine debris can accumulate as mass concentrations in pelagic ecosystems at ocean convergence zones for extended periods of time, potentially altering community structure and processes (Derraik, 2002; Macfadyen, Huntington and Cappel, 2009; FAO, 2010a).

Derelict fishing gear that sinks to the sea bed can adversely affect benthic habitats of deep-water and shallow coastal areas, including altering microhabitats such as by obstructing reef crevices.[1] For example, ALDFG can entrap fine sediment, smothering benthic communities, and can obstruct water flow, creating anoxic areas, which, if prolonged, can cause substantial mortalities (Parker, 1990; Hall, Alverson and Metuzal, 2000; Levin *et al.*, 2009; Macfadyen, Huntington and Cappel, 2009). When dragged by currents and wind or during retrieval, it can scour and abrade the sea bed and associated communities, including vulnerable and ecologically and biologically significant marine areas such as coastal seagrass beds and coral reefs, and benthic cold water coral reefs and sponge fields (Rose *et al.*, 2000; Donohue *et al.*, 2001; FAO, 2010a).

Collateral effects of fishing are those that are indirectly caused by various ecological effects of fishing (ICES, 2005; Gilman *et al.*, 2013). Collateral indirect effects of fishing, including from ALDFG, are complex and difficult to quantify, in part, because there is high uncertainty in inferring what factors significantly explain mortalities (Gilman *et al.*, 2013). For example, ALDFG and other marine debris may transport invasive alien species, which can disrupt community structure and processes, including causing niche contraction, declines in abundance and local extirpations of native species (Mack *et al.*, 2000; Longpierre *et al.*, 2005; Galil, 2007; FAO, 2010a). Organisms entangled in ALDFG may experience sublethal effects, including reduced mobility. This can compromise foraging ability and lead to starvation, reduce their ability to avoid predators, increasing the probability of mortality, and cause lacerations and subsequent infection, which through synergistic and cumulative effects might eventually lead to the organism's demise (Chopin and Arimoto 1995; Suuronen and Erickson, 2010; Gilman *et al.*, 2013; Uhlmann and Broadhurst, 2013). The ALDFG may be located in critical habitat where it poses a hazard to wildlife, including in foraging areas, fish spawning grounds, turtle nesting areas and migration routes (Gilman *et al.*, 2010). It may provide an unnatural food source for species that remove catch from the derelict gear that are not typical components of their diet (Gilman *et al.*, 2010). Another collateral effect of fishing is that synthetic compounds, including microscopic plastic material and toxic chemicals derived from fishing gear and other marine debris, and from lead in fishing weights, accumulate in marine food webs (Derraik, 2002; Moore, 2008; Arthur, Baker and Bamford, 2009; Hammer, Kraak and Parsons, 2012).

Based on preliminary findings of research on artificial drifting FADs (Marsac, Fonteneau and Ménard, 2000; Hallier and Gaertner, 2008; Dagorn *et al.*, 2013),

[1] An estimated 70 percent of total marine debris sinks to the sea bed (FAO, 2010a). Estimates of the proportion of ALDFG from different gear types that eventually sink are unavailable.

drifting rafts of marine debris, a proportion of which is ALDFG, might aggregate marine organisms from a surrounding area and alter their survival probability. The drifting debris may alter associated organisms' spatial distributions over hundreds of kilometres, transporting them to areas outside of their normal distribution, modifying their diet composition, and changing their behaviour, such as horizontal movements, vertical habitat use and diel vertical migration cycles. In some regions, FADs also have the potential to bring organisms to areas of low productivity (Dagorn *et al.*, 2013). The lack of regional monitoring and controls on the number, density, locations and designs of FADs (the fishing gear is largely unregulated and unreported) contributes to this potential collateral effect of drifting rafts of debris (Gilman, 2011).

1.2 INTERNATIONAL EFFORTS TO ADDRESS ALDFG

In the past decade, there has been increasing international recognition of the need for multilateral efforts to address effectively the transboundary problems resulting from marine debris including ALDFG (Macfadyen, Huntington and Cappel, 2009; Kuemlangan, Chopin and d'Offay, 2011). Since 2004, several United Nations General Assembly (UNGA) resolutions have explicitly recognized problems resulting from ALDFG, and called upon States and international organizations to take steps to mitigate these problems. Through its resolutions, UNGA provides mandates for ALDFG to be addressed globally and by specific intergovernmental organizations (IGOs). International organizations identified in these UNGA resolutions have included the International Maritime Organization (IMO), Food and Agriculture Organization of the United Nations (FAO), FAO Committee on Fisheries (COFI), Regional Seas Programme of the United Nations Environment Programme (UNEP) and regional fisheries management organizations (RFMOs). The UNGA's recommended actions have included: collecting data on gear loss, economic costs, and effects on marine ecosystems; taking preventive and remedial measures; integrating the issue into relevant national and regional strategies; and having relevant international organizations adopt and improve existing measures (UNGA, 2004, 2006a, 2006b, 2007a, 2007b, 2009a, 2009b, 2010a, 2010b, 2011, 2012a, 2012b, 2013a, 2013b, 2014a, 2014b).

In 2011, COFI endorsed FAO's International Guidelines on Bycatch Management and Reduction of Discards (FAO, 2011a). The Guidelines included recommendations for member States to identify, quantify and reduce impacts of mortality from ghost fishing by identifying this as an objective in fisheries management plans, improving scientific information on the magnitude and causes of these mortality sources, and developing technology for assessment and mitigation (FAO, 2011a). COFI had previously highlighted the importance of ALDFG, including fishing gear marking, reporting and recovering lost gear, and a regulatory framework to deal with violators (FAO, 2007a).

In July 2011, IMO, a specialized agency of the United Nations that sets global standards for the safety, security and environmental performance of international shipping, adopted amendments to the International Convention for the Prevention of Pollution from Ships (MARPOL) Annex V Regulations for the Prevention of Pollution by Garbage from Ships. The amendments entered into force on 1 January 2013 (IMO, 2011). Annex V Regulation 3 prohibits the disposal of all plastics, including fishing gear, into the sea in all locations (IMO, 2011, 2012). Regulation 7 defines exceptions to the prohibitions during emergency and non-routine situations, where exceptions are allowed when discharging is necessary to secure the safety of a ship and those on board, or to save life at sea. Fishing vessel operators are required to record the discharge or loss of fishing gear in a garbage record book or ship's log as specified within regulations 7.1 and 10.3.4 of MARPOL Annex V. Moreover, under Annex V Regulation 10.6, fishing vessel operators are required to report the accidental loss or discharge of fishing gear, "which poses a significant threat to the marine environment and navigation," as determined by each member State's government,[2] and provide these reports to the flag State and, if relevant, also to the coastal State in whose jurisdiction the ALDFG occurred (IMO, 2011, 2012). Annex V Regulation 8 obligates governments to provide adequate port reception facilities for garbage from ships and to facilitate and promote their use (IMO, 2012).

Members of FAO and the UNGA have mandated FAO to conduct research, provide technical advice, support regional fishery bodies (RFBs) including RFMOs, and provide advocacy to address ALDFG. Article 8 of the FAO Code of Conduct for Responsible Fishing (the Code) specifically addresses MARPOL requirements, encouraging States to minimize ghost fishing mortality, mark fishing gear to enable identification of the owner and provide waste reception facilities for fishing gear (FAO, 1995).

The Regional Seas Programme's UNEP Global Initiative on Marine Litter assisted regional seas conventions and action plans to organize and implement regional activities on marine litter, including ALDFG (UNEP, 2012). UNEP launched its Regional Seas Programme in 1974 by encouraging groups of countries sharing common seas to find regional solutions to their particular problems. Currently, 143 countries participate in 13 regional seas conventions and action plans and in 5 partner programmes, making it one of the most globally comprehensive initiatives for the protection of marine and coastal environments.

Under the United Nations Fish Stocks Agreement (UNFSA), a set of recommended minimum criteria were produced for RFMO performance assessment. One criterion includes assessing whether measures are in place to minimize ghost fishing: "Extent to which the RFMO has adopted measures to minimize … catch by lost or abandoned gear" (United Nations, 2007 [Annex II]).

The Fifth International Marine Debris Conference, held in 2011, resulted in the Honolulu Commitment and the Honolulu Strategy: A Global Framework for Prevention and Management of Marine Debris. The Honolulu Strategy defined strategies and actions to reduce adverse effects of marine debris, including to reduce the amount and impacts of ALDFG (UNEP and NOAA, 2012). In 2012, the Manila Declaration on Furthering the Implementation of the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities was adopted at the Third Intergovernmental Review of the Implementation of the Global Programme of Action for the Protection of the Marine Environment from Land-Based Activities (GPA). The Manila Declaration recommended the establishment of the Global Partnership on Marine Litter, which was launched later in 2012, and focuses on implementing the Honolulu Strategy by preventing impacts from both land- and sea-based sources of marine litter (UNEP, 2012). Chapter 4 synthesizes conservation and management measures (CMMs) related to preventing, remediating and monitoring ALDFG and ghost fishing from gillnets and trammel nets that have been adopted by bilateral and regional fishery bodies and arrangements (RFB/As), including RFMOs.

Despite the existence of strong international policy and legal frameworks on ALDFG and binding measures to mitigate ALDFG and ghost fishing, past performance

---

[2] The IMO 2012 Guidelines for the Implementation of MARPOL Annex V clarify that Party's governments should determine if accidentally lost and discharged fishing gear is required to be reported under Annex V Regulation 10.6 by considering factors including: (i) the amount of lost and discharged gear; (ii) the conditions of the marine environment where it was lost or discharged; (iii) the characteristics of the lost gear, including types, weight and/or length, quantity, material, and buoyancy; and (iv) the vulnerability of habitat and protected species to gear interactions in the location where the gear was lost/discharged, e.g. was the gear lost or discharged in a sensitive area such as coral reefs, or in a protected species' foraging or breeding area (IMO, 2012). The IMO guidelines use the example of "whole or nearly whole large fishing gear or other large portions of gear" as lost or abandoned fishing gear that could be considered to meet the Annex V Regulation 10.6 definition of posing "a significant threat to the marine environment and navigation" (IMO, 2012).

assessments have concluded that there are substantial governance deficits, including in monitoring, surveillance and enforcement, indicating low compliance with international mandates to prevent and remediate ALDFG (Macfadyen, Huntington and Cappel, 2009; Gilman, Passfield and Nakamura, 2013b; Gilman, 2015).

1.3 METHODS TO MITIGATE ALDFG

Table 1 summarizes preventive methods to reduce the incidence of fishing gear from becoming abandoned, lost and discarded, and remedial methods to reduce the duration that ALDFG remains in the marine environment. Preventive methods are understood to be more cost-effective than remedial methods (Macfadyen, Huntington and Cappel, 2009). Moreover, because some remedial methods can compromise economic viability and practicality, such as the use of biodegradable materials and other methods to disable ALDFG, efforts focusing on preventive methods and quick recovery of ALDFG are likely to be more effective (Matsushita *et al.*, 2008; Suuronen *et al.*, 2012). Many of these methods have broad fisheries management purposes unrelated to ALDFG and ghost fishing, such as managing fishing mortality of market species and mitigating bycatch of vulnerable taxa in in-use gear (Figure 1). However, their implementation nonetheless contributes to mitigating ALDFG and ghost fishing.

TABLE 1
Preventive methods to avoid and minimize fishing gear from becoming abandoned, lost and discarded, and curative or remedial methods to reduce the longevity of ALDFG

Method	Description
Preventive	
Gear marking to identify ownership, and to increase visibility[1]	Requirements for marking fishing gear enable competent authorities to identify the owner or user of ALDFG, which can create a disincentive for the deliberate abandonment and discarding of unwanted gear and incentive to report abandoned and lost gear (Convention on Conduct of Fishing Operations in the North Atlantic, 1967; IMO, 1978; Caddy, 1996; FAO, 1991, 1993, 2011a). Gear marking to increase the visibility of passive gear has also been prescribed by management authorities in order to reduce the navigational risk to vessel operators, which could contribute to avoiding accidental gear loss when damaged by passing vessels or active gear (FAO, 1993). A global standard for marking fishing gear to determine ownership and indicate position has been proposed but to date has not been endorsed (FAO, 1991, 1993).
Technology to avoid unwanted gear contact with seabed[1]	Global Positioning System (GPS) and seabed mapping technology help to reduce the likelihood of gear loss from to unintended contact with the seabed, reducing the probability of accidental gear loss (FAO, 2010a).
Technology to track gear position[1]	Attaching radar reflectors and radio buoys to fishing gear reduces the risk of losing gear, avoids interactions with towed gear, and aids in locating lost gear (MacMullen *et al.*, 2003; FAO, 2010a). Setting gear used to mark the location of passive gear below the sea surface can reduce the risk of loss from being cut by passing vessels (Macfadyen, Huntington and Cappel, 2009).
Gear technology to reduce the incidence of gear loss[1]	Changes in fishing gear designs or materials might reduce the incidence of loss. For example, an alternative design was developed for drift and anchored gillnet floats in an attempt to reduce the probability of loss of buoys from the nets (Chaves and Silveira, 2014).
Input controls, including limit on soak time[1]	Limiting the amount of fishing effort or capacity can reduce the quantity of ALDFG. Input controls include limiting vessel numbers of a specified size, prohibiting new entrants, instituting buy-back schemes, capping the number of fishing days or sets per year, and eliminating subsidies that contribute to overcapacity (Gilman, Passfield and Nakamura, 2012). Limiting the length of gear soak time and requiring the retrieval of gear during closed periods can reduce the probability of gear loss (Macfadyen, Huntington and Cappel, 2009; FAO, 2011a).
Periodic or constant observation of passive gear[1]	Requiring passive gear to be under periodic or constant observation, a recommended practice to increase the probability of sea turtles caught in gear being released alive (Gilman, 2009), can also reduce the probability of gear loss.
Spatial and temporal restrictions on fishing[1]	Separating passive and mobile gear sectors temporally and/or spatially to avoid gear conflicts (i.e. passive gear is towed away by mobile gear), and not using fishing methods in areas where there is a high probability of loss on submerged features, can reduce the probability of gear loss (MacMullen *et al.*, 2003; Macfadyen, Huntington and Cappel, 2009; FAO, 2010a). Some intergovernmental bodies and agreements have adopted measures banning the use of gillnet and trammel net gear, in some cases for the explicit purpose of avoiding ghost fishing (Chapter 4; Gilman, 2015).

TABLE 1 (CONTINUED)

Method	Description
IUU deterrents[1]	Effective deterrents of illegal, unreported and unregulated (IUU) fishing can reduce incentives for abandoning gear.
Ban intentional abandonment and discarding of fishing gear at sea[2]	The international prohibition on intentional discarding and abandonment of fishing gear at sea under MARPOL Annex V (IMO, 2011, 2012 [MARPOL Annex V Regulation 3, see Section 1.2]) can be effective if surveillance and enforcement systems elicit strong compliance.
Economic incentives and disincentives[2]	Economic incentives to reduce the incidence of gear becoming abandoned, lost or discarded include creating a mandatory deposit on new gear, which is returned when unwanted gear is delivered to an appropriate port reception facility, and not subsidizing the cost for fishers to replace ALDFG (MacMullen *et al.*, 2003). Or, given sufficient resources for effective monitoring, penalties that are sufficiently onerous to create an incentive to avoid and reduce the incidence of ALDFG could be instituted for abandoned, lost or discarded gear.
Port reception facilities for unwanted gear[2]	Providing accessible and affordable port reception facilities for unwanted fishing gear can reduce the incentive for at-sea discarding (IMO, 1978; FAO, 2010a).
Training for new entrants[1]	Providing training opportunities for new entrants to fisheries with a high probability of gear loss can increase skipper capacity to employ best practice gear designs and fishing methods and minimize the likelihood of gear loss and augment their capacity to recover gear when it is lost or abandoned (MacMullen *et al.*, 2003).
Remedial	
ALDFG port reception and recycling facilities[2]	In addition to reducing the incentive to discarding old "retired" fishing gear at sea, accessible and affordable port reception facilities can encourage the reporting, retrieval and delivery of ALDFG (IMO, 1978; FAO, 2010a; NFWF, 2013). Management authorities have created systems to report ALDFG and have developed incentives for fishing vessels to retrieve derelict gear at sea when it has tangled in their propellers or fishing gear, or that they encounter at their fishing grounds or in transit, deliver it to port reception facilities (Gilman, 2005; Yates, 2007; FAO, 2010a, 2010b, 2011a). There are several programmes designed to create incentives for port disposal of unwanted gear and of ALDFG retrieved at sea. For example, government agencies in the Republic of Korea manage an incentive programme, paying fishers to retrieve marine debris from coastal fishing grounds and deliver it to designated seaports (Cho, 2009). Several ALDFG reception programmes provide opportunities for reuse by the fishing industry, recycling, and conversion to energy (Yates, 2007; FAO, 2010b; Recht, 2010; NFWF, 2013). The National Fish and Wildlife Foundation's Fishing for Energy programme, for example, has established port reception facilities for old, retired and derelict fishing gear, recycling metals and converting non-recyclable materials into energy, and has supported removal and assessment programmes in 41 seaports in ten states in the United States of America (NFWF, 2013). The fishery management authority of the Unites States of America has established a port reception facility for Hawaii longline fishers' own unwanted fishing gear and ALDFG that they collect at sea, which is then incinerated to generate electricity (Gilman, 2005; Yates, 2007; FAO, 2010b).
Detection and removal of ALDFG[2]	Some intergovernmental bodies and agreements have adopted measures requiring fishing vessels to have onboard equipment to retrieve ALDFG, for captains to attempt to retrieve ALDFG generated from their vessel or ALDFG from other vessels that they encounter while at sea, and to report information on lost gear that could not be retrieved (Chapter 4; Gilman, 2015). Mechanisms for fishers to report ALDFG generated from their vessels or that they encounter at sea, including regulatory frameworks that allow "no fault" reporting, eliminating the assessment of penalties for losing gear that would present a disincentive for self-reporting lost gear, can lead to quick identification and retrieval of ALDFG, where derelict gear retrieval programmes exist (Good *et al.*, 2009, 2010). Several government agencies and organizations implement programmes to survey periodically fishing grounds and sensitive marine habitats along coastlines, coastal benthic habitats and pelagic areas in order to locate and then remove ALDFG and other marine debris (e.g. Northwest Straits Foundation, 2007; McElwee and Morishige, 2010; GhostNets Australia, 2012; Suuronen *et al.*, 2012). Methods to search for ALDFG include aerial surveillance, side-scan sonar, remotely operated vehicles (ROVs) and diver surveys and tows (Northwest Straits Foundation, 2007; Murphy, 2011; Natural Resources Consultants, 2013). In shallow waters, inflatable lift bags, winches on vessels, and human-powered collection by scuba diving, hookah and snorkelling have been used to remove ALDFG and other marine debris (Manuel and Koyanagi, 2011; Natural Resources Consultants, 2013). Offshore ALDFG can be recovered by dragging grappling devices along the seabed that are designed to snag the derelict gear ("creepers"), using trawl nets or other fishing gear, using ROVs and removal by divers (MacMullen *et al.*, 2003; FAO, 2005; Good *et al.*, 2009; Jung *et al.*, 2010; Natural Resources Consultants, 2013).
Disablement of ghost fishing efficiency of ALDFG[2]	Programmes periodically use a trawl net or other fishing gear to sweep fishing grounds with unobstructed low-relief substrate with known ALDFG in order to remove or otherwise damage derelict gear sufficiently to discontinue its ghost fishing efficiency (MacMullen *et al.*, 2003; FAO, 2005).

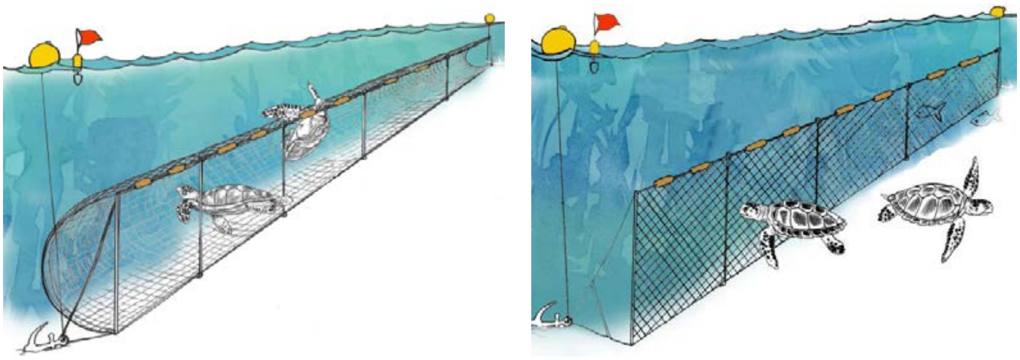
TABLE 1 (CONTINUED)

Method	Description
Gear technology designed for bycatch mitigation in in-use gear that also increases ghost fishing selectivity in ALDFG[1]	Modifications to fishing gear designs to reduce problematic bycatch (bycatch reduction devices [BRDs]) in in-use gear can also reduce ghost fishing rates of vulnerable species in ALDFG from these fisheries. For example, reducing net mesh size, reducing gillnet profile (vertical height), and eliminating or reducing the length of anchored gillnet tiedowns (Figure 1) have been used to reduce turtle capture (Gearhart and Eckert, 2007; Price and Van Salisbury, 2007; Eckert *et al.*, 2008; Gilman *et al.*, 2010). For example, reducing the length or eliminating the use of tiedowns and the amount of webbing in demersal gillnets reduces or eliminates the bag of slack webbing, and this has been found to reduce the incidence of sea turtle entanglement (Gilman *et al.*, 2010), and might reduce sea turtle ghost fishing mortality in ALDFG from set gillnet fisheries (Figure 1). Increasing gillnet filament diameter, modifying the weaves (e.g. using multimonofilament instead of single monofilament), using larger floats on the top rope and heavier weights or lead-core on the bottom rope, and infusing compounds can make the net stiffer (increase net tension), reducing the likelihood of entangling large organisms (Werner *et al.*, 2006; Larsen, Eigaard and Tougaard, 2007; Thorpe and Frierson, 2009). Deploying driftnets 2 m below instead of at the sea surface, and using highly visible netting in the upper portion of a surface drift gillnet reduced seabird catch rates (Hayase and Yatsu, 1993; Melvin, Parrish and Conquest, 2001). Making nets more visible, such as through net colour, thicker twine diameter, and attaching corks or other visual markers within the net, has also been shown to reduce bycatch rates of marine mammals and turtles, but can also reduce target species catch rates (Barlow and Cameron, 2003; Gilman *et al.*, 2010). Attaching materials such as thick polyester rope and chains to fishing nets, and infusing nylon nets with metal compounds such as barium sulphate and iron oxide can reduce cetacean captures. This might occur because the materials increase acoustic reflectivity, increase the net's visibility or increase twine stiffness (Trippel *et al.*, 2003; Koschinski *et al.*, 2006; Werner *et al.*, 2006; Larsen, Eigaard and Tougaard, 2007). Acoustic pingers and alarms are also used to reduce marine mammal bycatch in gillnets and other fishing gear (e.g. Koschinski *et al.*, 2006; Werner *et al.*, 2006), and illuminating nets with chemical or battery-operated lightsticks might reduce bycatch of sea turtles and other vulnerable taxa (Wang, Fisler and Swimmer, 2010), but would be ineffective in reducing ghost fishing mortality once the energy source has drained.
Less-durable and degradable gear to reduce ghost fishing duration[1]	Using less-durable materials (e.g. thinner net twine diameter and weaker material) to produce a breaking strength that allows large organisms to break free of the gear and escape might reduce ghost fishing mortality (Gilman *et al.*, 2010). Gear technology has been developed to reduce the duration of the fishing power of derelict gear via designs that employ degradable materials. For example, degradable FADs have been designed; degradable cotton fibre is still used in some gillnet fisheries; attaching floats using biodegradable materials has been trialled in a demersal gillnet fishery; and degradable escape mechanisms are required in some trap fisheries (Breen, 1990; Carr, Blott and Caruso, 1992; Chopin *et al.*, 1996; Chanrachkij, Siriraksophon and Loog-on, 2008; Matsushita *et al.*, 2008; Antonelis *et al.*, 2011). Degradable escape panels and cords can be used to reduce ghost fishing by traps, which are required in some fisheries (FAO, 2010a). Synthetic gear materials have been developed that can be broken down by microbes and ultraviolet light (Tabata and Kanehiro, 2004). Simulated derelict demersal gillnets constructed of multifilament twine have been observed to have a shorter duration of fishing efficiency than gillnets constructed of monofilament twine (Ayaz *et al.*, 2006). The likelihood that weaker and degradable fishing gear would increase the frequency that gear components require replacement and increase gear loss requires consideration.

[1] Measure might be adopted for a range of fishery management purposes but contributes to avoiding and remediating ALDFG and ghost fishing.
[2] Measure is implemented specifically to mitigate ALDFG and ghost fishing.

Source: Adapted from Macfadyen, Huntington and Cappel, 2009; FAO, 2010a; Suuronen *et al.*, 2012; Gilman, Passfield and Nakamura, 2013.

FIGURE 1
Conventional demersal gillnet (left) and modified net without tiedowns (right)



Source: Original drawing by Jeff Gearhart, re-designed by Manuela D'Antoni (FAO).

1.4 FACTORS AFFECTING GHOST FISHING EFFICIENCY AND DURATION

Gear type is a large, significant explanatory factor in determining species- and size-specific ghost fishing catch rates and levels. Ghost fishing is thought to be most problematic in passive fishing gear that was set and subsequently lost or abandoned. Passive gear types include gillnets, trammel nets, pelagic and demersal longlines, pots and other trap gear, where the capture process relies on the movement of organisms into the gear. The catching process of active gear (e.g. purse seines, trawls) typically ceases when te gear collapses upon detachment from the vessel (Matsuoka, Nakashima and Nagasawa, 2005; SEAFO, 2009; Gilman *et al.*, 2013). However, there is minimal empirical information on ghost fishing in ALDFG from active gear, where effective methods to estimate the frequency of gear loss and the duration and efficiency of ghost fishing by such gear have not been developed (Gilman *et al.*, 2013). Nevertheless, ghost fishing has also been observed in ALDFG from active gear, including in seine nets, and there are observations of marine mammal entanglement in trawl net fragments (Jones, 1995; Donohue *et al.*, 2001; Matsuoka, Nakashima and Nagasawa, 2005). Ghost fishing in derelict FADs used in purse seine and other fisheries has also been documented (Chanrachkij, Siriraksophon and Loog-on, 2008; Filmalter *et al.*, 2013). Ghost fishing mortalities can also occur from discarded bait containing hooks used in both passive and active gear types (Weimerskirch and Jouventin, 1987).

Various factors affect the ability, efficiency and duration of derelict gear to ghost fish. The condition of the gear upon being lost/abandoned/discarded is an important explanatory variable, including whether it was set for fishing or otherwise discarded and therefore less likely to ghost fish. The location of ALDFG, including the depth, substrate material, degree of protection from wave energy, presence of features upon which the gear can become entangled, relative abundance of organisms that are susceptible to capture in the ALDFG, and relative abundance of biofouling organisms, debris and particulate matter can all be significant explanatory factors determining ghost fishing mortality rate and duration. For example, these factors can determine whether derelict gear is subsequently disabled by a passing vessel or fishing gear, and the degree of exposure to environmental forces (storms, currents) that eventually disable the derelict gear (Erzini *et al.*, 1997; Pawson, 2003; Revill and Dunlin, 2003; Sancho *et al.*, 2003; Akiyama, Saito and Watanabe, 2007; FAO, 2010a).

For example, studies have observed that when gillnet and entangling nets are deployed on a flat substrate in relatively shallow water, their ghost fishing catching efficiency and longevity declines rapidly over the initial few days of release, and declines to within about 5 percent of initial catching efficiency within weeks to months. While exhibiting a rapid reduction in fishing efficiency, a derelict net that retains 5 percent of its original catching efficiency that persists for years results in a large level of ghost fishing mortalities. The gear quickly loses its profile owing to the weight of captured organisms. Also, as meshes become obstructed owing to the accumulation of debris and particulate matter and from biofouling (encrusting by biological organisms), this increases the net's visibility, and reduces its profile and surface area (Kaiser *et al.*, 1996; Erzini *et al.*, 1997; Nakashima and Matsuoka, 2004, 2005; Akiyama, Saito and Watanabe, 2007). In some studies, physical damage to derelict gear occurred from interactions with other fishing gear, usually trawlers and other towed gear, but in some cases by passive gear (e.g. Erzini *et al.*, 1997; MacMullen *et al.*, 2003). When a derelict net occurs on open, flat substrate, some studies have found that the gear initially causes ghost fishing mortality primarily of demersal fishes over the first few days to weeks of deployment. Then, once most of the net area has collapsed, the remaining loose horizontal sheets of netting primarily catch scavenging crustaceans and molluscs until the net structure is no longer intact or is buried (Kaiser *et al.*, 1996; Pawson, 2003; Revill and Dunlin, 2003; Akiyama, Saito and Watanabe, 2007).

However, when derelict nets become entangled on three-dimensional objects and/or are in a location where environmental conditions, such as currents and weather, and interactions with other fishing gear do not damage the gear, including in very deep water, gill and entangling nets can maintain high ghost fishing catch rates for relatively long periods (several months to several years) (Kaiser *et al.*, 1996; Erzini *et al.*, 1997; Matsuoka, Nakashima and Nagasawa, 2005; Brown and Macfadyen, 2007; Good *et al.*, 2010). In one study, a FAD entangled with a gillnet was observed to have a higher number of fish aggregated around the device relative to an aggregation device of the same design but without an entangled gillnet (Nakashima and Matsuoka, 2005), suggesting that when entangled on three-dimensional objects, derelict nets can augment the fish aggregating capacity of the submerged feature, enhancing the ghost fishing catch rate. Organisms caught in derelict fishing gear can attract scavengers, which subsequently are caught, contributing to long-term ghost fishing efficiency owing to this self-baiting (Kaiser *et al.*, 1996; Matsuoka, Nakashima and Nagasawa, 2005; FAO, 2010a; Gilman *et al.*, 2013).

The depth at which the derelict gear occurs affects its species-specific ghost fishing selectivity (Brown and Macfadyen, 2007). For example, to catch seabirds, a derelict net must be at or near the sea surface (Hayase and Yatsu, 1993; Kaiser *et al.*, 1996).

Gear design and materials are other potentially significant explanatory factors of ghost fishing. Gear designs that affect detection and mechanisms for escape will affect ghost fishing ability, efficiency and duration. A few examples follow.

- Gillnet mesh size has been shown to affect gear selectivity (Price and Van Salisbury, 2007).
- The height or profile of demersal and surface gillnets has been shown to affect sea turtle bycatch rates significantly, perhaps because of the effect on the net stiffness and proportion of the water column that is fished (Gearhart and Eckert, 2007; Price and Van Salisbury, 2007; Eckert *et al.*, 2008; Gilman *et al.*, 2010).
- In demersal gillnet fisheries, tiedowns are typically used to maximize the catch of demersal fish species, discussed in Section 2.1. The shorter the length of tiedowns, the deeper the webbing pocket is, and the higher the probability of capturing non-target species including sea turtles (Figure 1) (Price and Van Salisbury, 2007).
- Mesh, floats, and float and lead line characteristics will also have effects on species-specific catch rates and ghost fishing mortality. For example, mesh characteristics, including embedded luminescent materials and infusing nylon nets with metal compounds, affect a net's species-specific detectability or affects species-specific susceptibility to capture in the net, and concomitant catch and ghost fishing mortality rates (Melvin, Parrish and Conquest, 2001; Bjordal, 2002; Trippel *et al.*, 2003; Werner *et al.*, 2006; Larsen *et al.*, 2007).
- Using alternative net materials (thinner twine and weaker material) to produce a breaking strength that allows large organisms to break free of the gear and escape might reduce ghost fishing mortality (Gilman *et al.*, 2010).
- Gear materials, in combination with local mechanical action and the rate of physical abrasion, water chemistry, and light penetration, affect ALDFG duration of ghost fishing. For example, discussed in Table 1, degradable materials have been tested and are now in use in a few fisheries (Carr, Blott and Caruso, 1992; Chanrachkij, Siriraksophon and Loog-on, 2008; FAO, 2010a, 2010b, 2011a).
- Gear components that affect the depth and weight of the gear affect the ability and energy required for caught air-breathing organisms to reach the surface and the time period for possible escape (Gilman *et al.*, 2013).
- Characteristics of derelict fishing gear that become attached to organisms affect the probability of mortality (e.g. the length of trailing line, Swimmer and Gilman, 2012; Gilman *et al.*, 2013).

1.5 STUDY SCOPE AND AIMS

Recognizing that substantial ecological and socio-economic adverse effects result from fishing mortality caused by ALDFG, that marine gillnets and trammel nets are globally important gear types, and that gillnets and entangling nets have relatively high ghost fishing potential (Pawson, 2003; Matsuoka, Nakashima and Nagasawa, 2005; Macfadyen, Huntington and Cappel, 2009), FAO and UNEP commissioned this study to identify best practice methods for estimating ghost fishing rates and levels, priority research needs, and the status of international monitoring and management of ALDFG and ghost fishing by marine gillnet and trammel net fisheries. This report supplements the broad overview of the magnitude, composition, impacts, causes and approaches to reduce ALDFG provided in UNEP Regional Seas Reports and Studies No. 185 / FAO Fisheries and Aquaculture Technical Paper No. 523 (Macfadyen, Huntington and Cappel, 2009).

Study aims were to: (i) identify best practice methods to estimate ghost fishing mortality levels by ALDFG from marine gillnet and trammel net fisheries; (ii) identify priority information gaps, including research priorities to support robust estimates of global ghost fishing mortality levels by gillnets and trammel nets; and (iii) benchmark international monitoring and management of ALDFG and ghost fishing from marine gillnet and trammel net fisheries.[3] To accomplish the first two aims, a review was conducted of methods and findings of terms to estimate total ghost fishing mortality in an explicit spatial area over a fixed time period. This included reviewing methods and findings on: rates of abandonment, loss and discarding of fishing gear; density of ALDFG (unit amount per unit of area of seafloor and/or per unit volume of water column); and the duration of ghost fishing efficiency and ghost fishing mortality rates of ALDFG. To implement the third aim, an assessment was conducted of the data collection protocols and management measures to prevent and remediate ALDFG and ghost fishing of ten regional bodies and arrangements with the competence to establish binding controls for regional marine capture fisheries, and that have competence over fishery resources that are captured in an active gillnet or trammel net fishery.

[3] Hereinafter, to avoid repetition and unless otherwise stated, the text refers to ALDFG and ghost fishing solely by gillnets and trammel nets.

2. Catching process, design and operation of marine drift and set gillnets and trammel nets

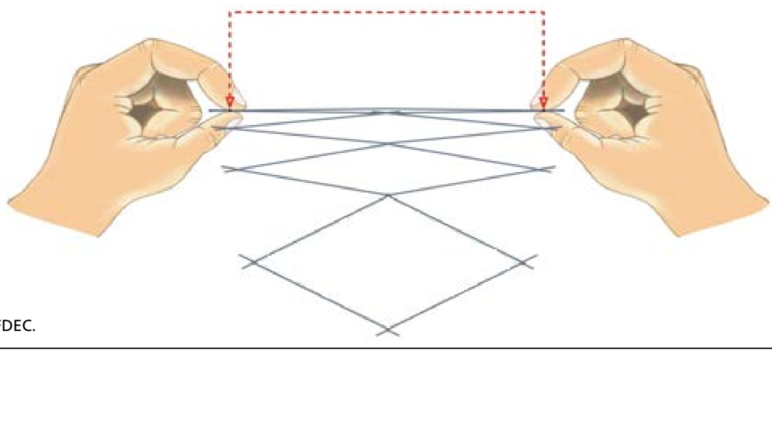
Now used worldwide, gillnets and trammel nets are types of passive fishing gear where the capture process relies on the movement of organisms into the gear, where it becomes gilled, enmeshed or entangled (Bjordal, 2002). An estimated 19 percent of global marine fisheries landings comes from gillnet and trammel net fisheries (SAUP, 2011). There are both extensive industrial and artisanal, small-scale, household-based gillnet and trammel net fisheries (Hubert, 1983; Shester and Micheli, 2011). Artisanal, small-scale fisheries typically use passive gear (Bjordal, 2002; MacMullen *et al.*, 2003). In 2006, the Russian Federation (Pacific coast), Myanmar, India, Viet Nam, and Indonesia (eastern) had the five highest reported landings from marine gillnet fisheries that occurred in their exclusive economic zones (EEZs) (SAUP, 2011). The five countries for which landings from marine gillnet fisheries accounted for the largest proportion of total marine fisheries landings from their EEZs in 2006 were Timor-Leste (94 percent), Bangladesh (91 percent), Somalia (88 percent), Myanmar (86 percent) and Viet Nam (79 percent) (SAUP, 2011).

Explained in Section 1.4, various gillnet and trammel net gear designs and fishing methods can have significant effects on ghost fishing ability, catch rates and duration of fishing efficiency. This chapter provides an overview of the catching process, designs and methods of operation of different types of marine gillnets and trammel nets, which are factors that have the potential to influence ghost fishing catch rates.

Gillnets and trammel nets can be anchored and stationary on a variety of substrates of flat open ground and on the edges and slopes of canyons, and on reefs, wrecks and other structures. Gillnets can also be drifting at the sea surface, mid-water or near or on the sea bed (MacMullen *et al.*, 2003). Because they rely on target species swimming into the net, gillnets and trammel nets are designed to minimize their visibility and might be used in areas with low light levels or high turbidity (Bjordal, 2002).

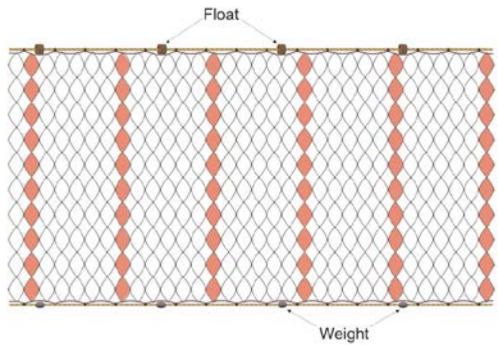
Since the 1960s, nets have been made with synthetic twine usually of nylon (polyamide), either as multifilament thread or monofilament or mutlimonofilament line, which is much less visible, more durable and requires less maintenance than nets made of non-synthetic fibre (Moore, 2008; Macfadyen, Huntington and Cappel, 2009). Mesh size is typically measured as the length of a whole stretched mesh (Figure 2), or

FIGURE 2
Measuring mesh size as the length of a whole stretched mesh



Source: SEAFDEC.

FIGURE 3
Net with a mesh count of ten, determined by counting the number of meshes between the float and lead lines



Source: SEAFDEC.

as the half-length (bar-length). Figure 3 illustrates the method for counting the number of meshes in a net.

To maintain a roughly vertical profile, gillnets, trammel nets and combination set gillnet/trammel nets, described below, have floats, typically made of plastic or cork, attached along the top rope (float line, cork line, headline or headrope), and weights attached along the bottom rope (sinker, lead line, footline or groundrope), or a bottom rope made with a lead core (Hubert, 1983; Nedelec and Prado, 1990; Bjordal, 2002). Wreck nets might include metal rings to the leadline to avoid snagging on the wreck (Rose *et al.*, 2000). Commercial vessels might use hydraulic-driven haulers and net drums to set and haul driftnets and to haul set nets, while artisanal vessels typically set and haul drift and set gillnets, trammel nets and combination gillnets/trammel nets by hand (Nedelec and Prado, 1990). After hauling, the catch is removed from the net by hand.

Depending in part on the target species and size, and environmental characteristics of the fishing grounds, there can be large variability in the designs and methods of deployment of gillnets and trammel nets. Parameters that can vary include (Hubert, 1983; Bjordal, 2002; Hall *et al.*, 2009):

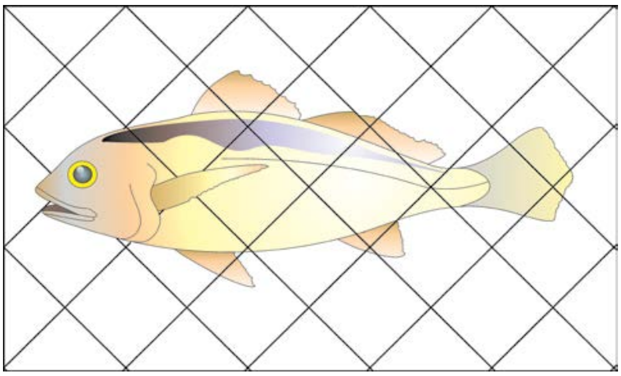
- whether a net is drifting, anchored or sweeping;
- whether a net is at the sea surface, midwater, slightly above the substrate, or at the substrate;
- the hanging ratio, a measure of how tightly the net is stretched, is the length of a rope on which a panel is mounted divided by the length of stretched netting on the rope. Low hanging ratios have meshes with narrow openings with a tall mesh height and narrow lateral opening, while large hanging ratios have a low mesh height and wide lateral opening;
- the length of each panel, number of panels (a series of connected panels is referred to as a "fleet"), and total fleet length;
- mesh size;
- twine diameter and material, and concomitant breaking strength;
- total surface area;
- mesh characteristics (mesh size, twine material, diameter, colour);
- float line characteristics (material, diameter, colour);
- float characteristics (number per unit length of float line, material, colour, dimensions, shape);
- whether floats are set at or below the surface;
- lead line characteristics (material, diameter, colour, weight per unit length of lead line, mass of each weight);
- whether bait is placed in net;

- the angle of the net in relation to the coastline;
- the time of day and season of gear soak;
- for demersal nets, whether tie downs are used and their height;
- whether nets are patrolled or otherwise left unattended during the soak.

2.1 GILLNETS

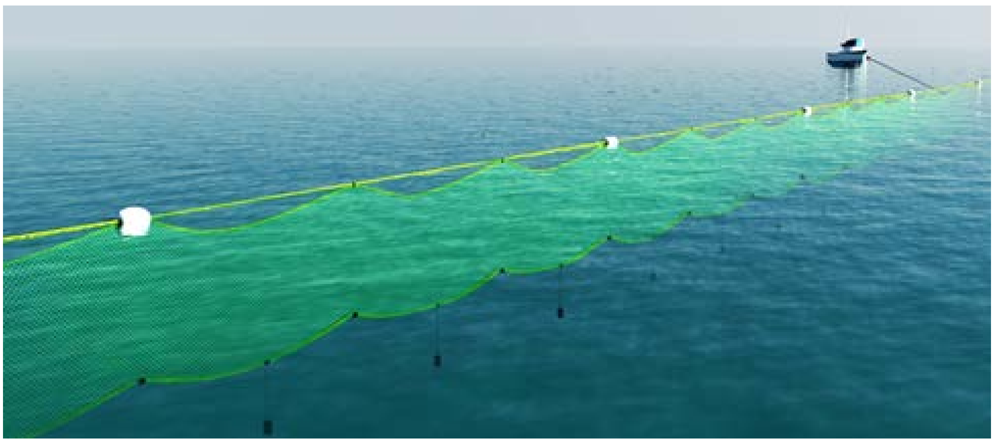
A fleet of gillnets is constructed of a series of connected single panels of meshes made from fine thread, with reinforcing ropes along the sides. Gillnets typically have a hanging ratio ≥ 0.5 (Uhlmann and Broadhurst, 2013). Gillnets are relatively size-selective for finfish, but can have poor species selectivity, depending on the species composition at individual fishing grounds (Valdemarsen and Suuronen, 2003; Suuronen *et al.*, 2012). The catching process in gillnets entails fish being caught in one of the meshes in the gill region of its body (between its head and body) (Figure 4) (Bjordal, 2002). A fish can become caught in a gillnet when it swims part way through a mesh, struggles to free itself, and the twine of the mesh slips under the fish's opercula (gill covers) preventing escape, i.e. the fish becomes "gilled" (Bjordal, 2002) (Figure 4). Less frequently, a fish may also become wedged around its body inside a gillnet mesh, or parts of its body (fins, teeth, or other projection) may become entangled in the twine (Murphy and Willis, 1996; Price and Van Salisbury, 2007).

FIGURE 4
Catching process in gillnets where a fish becomes caught in one of the meshes in the gill region of its body



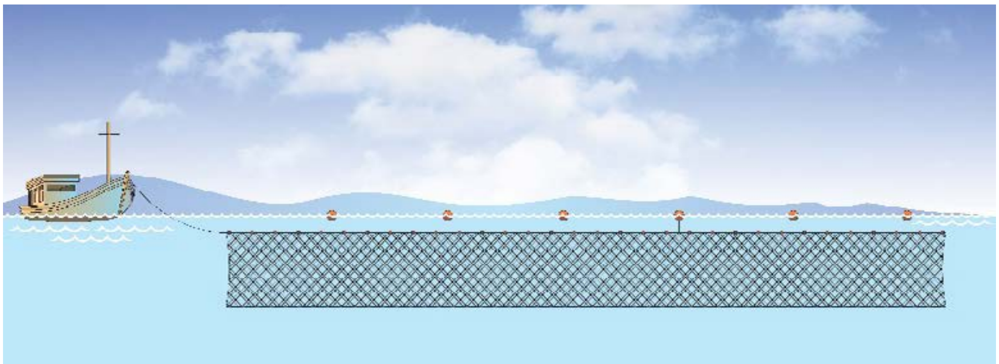
Source: SEAFDEC.

FIGURE 5
Drift gillnet (driftnet) set at the surface, connected to a fishing vessel and drifting with the current



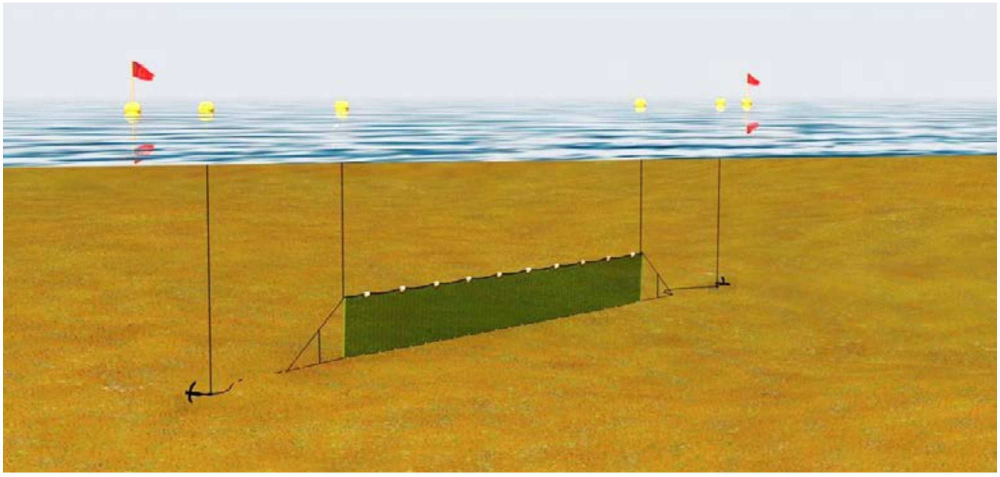
Source: SEAFDEC.

FIGURE 6
Drift gillnet (driftnet) deployed subsurface/midwater, attached to a vessel and drifting with the current



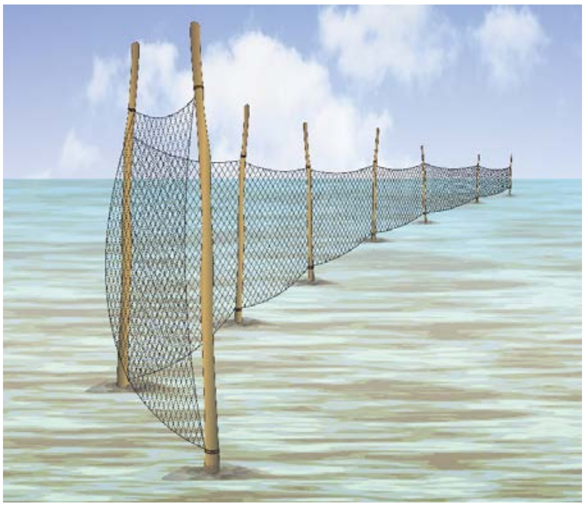
Source: Nedelec and Prado (1990); redrawn by SEAFDEC.

FIGURE 7
Bottom set (anchored) gillnet



Source: SEAFDEC.

FIGURE 8
Staked set gillnet



Source: Nedelec and Prado (1990); redrawn by SEAFDEC.

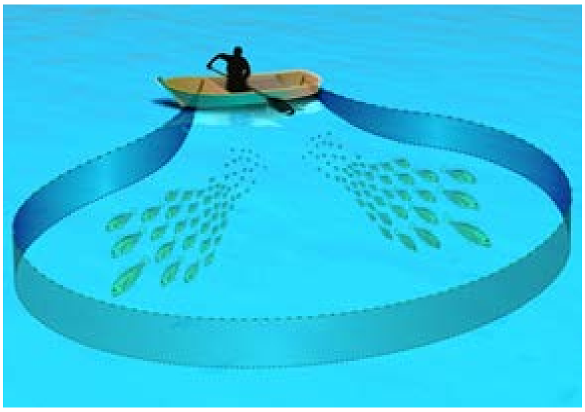
Drift gillnets (driftnets), set at or below the sea surface, can be connected to a fishing vessel and drift with the current (Figures 5 and 6).

Set or anchored gillnets are a type of static gear deployed at or near the sea bed. Set gillnets can be kept stationary using anchors or weights at both ends (Figure 7). Tiedowns may be used in set gillnets. Tiedowns are lines that are shorter than the fishing height of the net and connect the float and lead lines at regular intervals along the entire length of the net. Tiedowns create a bag of slack webbing which aids in entangling, rather than gilling, demersal fish species (Figure 1) (Price and Van Salisbury, 2007).

Gillnets with panels stretched between two or more stakes are also deployed primarily in the intertidal zone in locations with a large tidal range (Figure 8) (Nedelec and Prado, 1990). Staked gillnets are left to soak for several days, with the catch collected at low tide (Nedelec and Prado, 1990).

Encircling gillnets are used in shallow, nearshore waters (Figure 9) (Nedelec and Prado, 1990). Typically, groups of small-scale fishers, or in some cases one fisher, using small open boats or canoes will encircle a school of fish in shallow water, and will then use various methods to disturb and scare the fish to swim into the net. Methods to scare the fish include making noise by slapping the surface of the water with sticks or a paddle, and having a group of people move towards the school (Nedelec and Prado, 1990).

FIGURE 9
Encircling gillnet

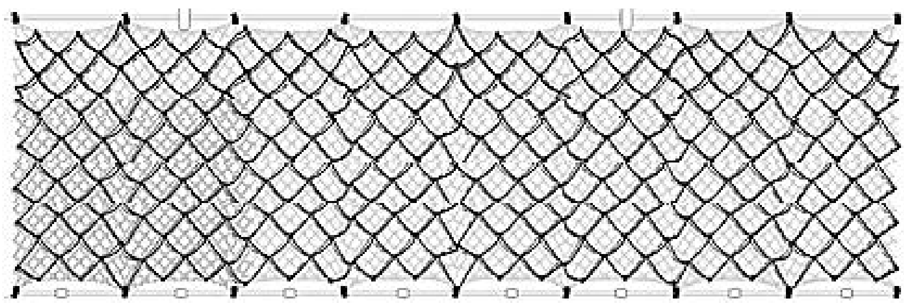


Source: SEAFDEC.

2.2 TRAMMEL NETS

Trammel nets usually have three panels of meshes, but occasionally can have two layers (Figure 10) (Bjordal, 2002; Hall *et al.*, 2009). The middle panel is slack and has small-sized meshes. The two outer panels have larger meshes. When a fish comes into contact with a trammel net, it pushes the small mesh through an adjacent larger mesh and becomes entangled (Figure 11). As a result of this catching process, trammel nets are less size-selective relative to gillnets (Bjordal, 2002), and as gillnets are not species selective (e.g. Goncalves *et al.*, 2008). Trammel nets typically have a hanging ratio < 0.5 (Uhlmann and Broadhurst, 2013).

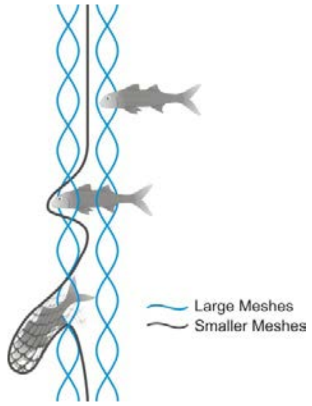
FIGURE 10
Trammel net



Source: SEAFDEC.

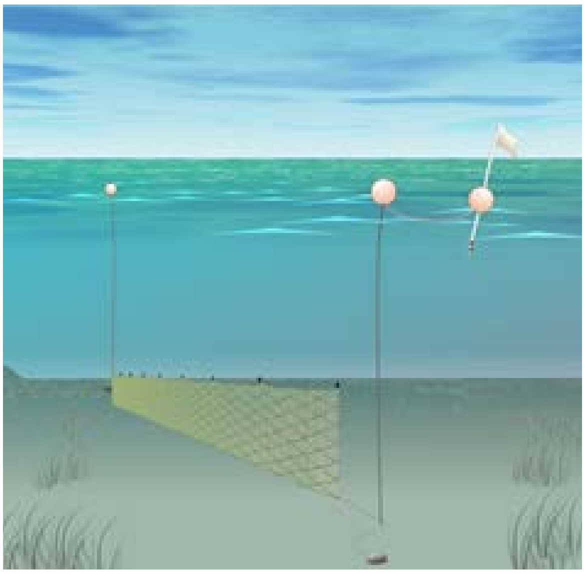
Like set gillnets, trammel nets are usually used to target benthic and demersal species. They are typically deployed anchored on the substrate in shallow nearshore areas (Figure 12). Drift trammel nets are also used near the substrate (Nedelec and Prado, 1990; Bjordal, 2002). They may be set as a single panel or occasionally in fleets of a string of connected panels (Nedelec and Prado, 1990).

FIGURE 11
Catching process in a trammel net with three panels of meshes, where a fish pushes the small mesh of a centre panel through an adjacent larger mesh of an outer panel and becomes entangled



Source: SEAFDEC.

FIGURE 12
Anchored trammel net

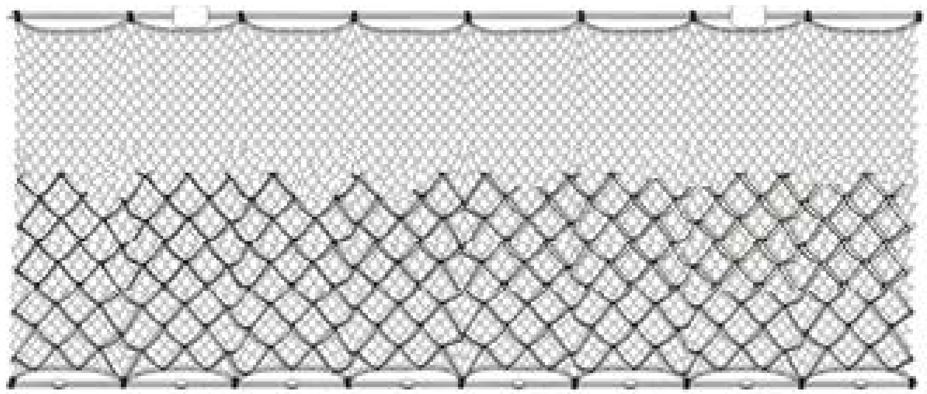


Source: SEAFDEC.

2.3 COMBINATION GILLNETS – TRAMMEL NETS

Originating in the Mediterranean and now used in many parts of the world, gear employing a gillnet in the upper portion and trammel net in the lower portion are typically set on the substrate as set gillnets and trammel nets (Figure 13) (Nedelec and Prado, 1990). The gillnet portion might target pelagic and/or semi-demersal species, while the trammel net portion targets demersal species.

FIGURE 13
Combined gillnet – trammel net, with gillnet in the upper section and trammel net at the bottom



Source: SEAFDEC.

3. Methods and estimates

3.1 METHODS AND RESULTS

A sample of studies were reviewed to document the range of methods and findings on: (i) rates of abandonment, loss and discarding of fishing gear; (ii) the density of ALDFG (unit amount per unit of area of seafloor and/or per unit volume of water column); and (iii) ghost fishing mortality rates and duration of ghost fishing efficiency of ALDFG (Table 2). Both structured and unstructured literature searches were conducted to compile relevant literature. The structured search was conducted using various combinations of the following Boolean search terms in Google Scholar: gillnet, gill-net, gill, trammel, entangle, net, ghost, ALDFG, abandoned, lost, discarded, derelict, fishing, and gear. An unstructured literature search was conducted by reviewing reference lists of relevant publications and reports and then searching for identified relevant citations, posting a query on ResearchGate.net and via an informal network of fisheries professionals requesting suggestions of relevant publications. Literature compilation was conducted from February to June 2014. The aim of the literature search was to obtain adequate sample sizes for each of the three study categories to characterize the range of methods employed and findings, and to include studies across regions. For each record included in Table 2, the UNEP Regional Seas Convention and Action Plan region and FAO Major Marine Fishing Areas in which the study area was located was identified (FAO, 2014; UNEP, 2014).

These three categories of studies were included in the review because they provide information on factors needed to estimate total ghost fishing mortality in an explicit spatial area over a fixed time period. To produce accurate estimates of the total level of ghost fishing removals that occurs in a fishing ground during a fixed time period, accurate information is required on the amount of derelict gear present in the area and the mean ghost fishing catch rate of the derelict gear in the area at a point in time (Matsuoka, Nakashima and Nagasawa, 2005). Robust estimates of the total ghost fishing mortality level that an individual derelict net will cause require information on the duration of ghost fishing efficiency of that net, and the change (likely exponential decay) in species-specific catch rate during the period when the net retains some fishing efficiency (Kaiser *et al.*, 1996; Erzini *et al.*, 1997; Sancho *et al.*, 2003; Nakashima and Matsuoka, 2004; Ayaz *et al.*, 2006).

The purposes for reviewing this sample of relevant studies were to: provide an understanding of the dispersion in methods and findings; document the potentially significant explanatory effect of identified factors; and determine the state of understanding of the severity of adverse ecological effects from gillnet and trammel net ALDFG. The assessment also enabled the identification of general best practice estimation methods to reduce uncertainty and identification of priority gaps in information needed to produce robust estimates of regional and global ghost fishing mortality rates and levels by ALDFG.

TABLE 2

Synthesis of methods and estimates of: (a) rates of abandonment, loss and discarding of fishing gear; (b) density of ALDFG; and (c) ghost fishing mortality rates and duration of ghost fishing efficiency of ALDFG

TABLE 2A

Methods and estimates of rates of abandonment, loss and discarding of fishing gear from gillnet and trammel net fisheries

UNEP Regional Seas[1]	FAO Major Marine Fishing Area[2]	Fishery or study site location	Method[3]	Rate of abandonment, loss and/or discarding	Citation
Baltic	27	Swedish Baltic Sea south coast, Hano Bay and east coast demersal gillnet cod and turbot fisheries	a	0.08% of nets set were lost and not retrieved (25.5 km of 28 021 km length of nets set per year were lost, of which 3.35 km was retrieved by the vessel that temporarily lost it). This is equivalent to a mean of 3.7 nets (108 m average length per net) per vessel per year.	MacMullen *et al.*, 2003
East Asian Seas and North-West Pacific	61	Coastal gillnet fisheries of the Republic of Korea	a,b	38 535 tonnes gillnets per year abandoned, lost or discarded in coastal waters of the Republic of Korea. On average, a gillnet vessel abandons, loses or discards 9.64 units of gillnets per year; one unit weighs an average of 478.4 kg.	Kim, Lee and Moon, 2014
Mediter-ranean	37	Section of the Gokova Special Environmental Protection Area off Turkey, eastern Mediterranean Sea, demersal gillnet and trammel net fisheries	a	0.8% and 3.4% of demersal gillnets and trammel nets, respectively, are lost per year	Ayaz *et al.*, 2010
Mediter-ranean	37	Spanish Cantabrian region demersal gillnet red mullet and hake fisheries and coastal demersal trammel net mixed species fishery	a	12.7 nets per vessel per year are lost and not retrieved (13.3 nets per vessel per year were lost of which 0.58 nets per vessel were retrieved by the vessel that temporarily lost it). Information was not presented to determine the percentage of total gear set that was lost and not recovered.	MacMullen *et al.*, 2003
North-East Atlantic	27	United Kingdom, German and Panamanian deep-water anchored gillnet monkfish and shark fishery, United Kingdom and Ireland EEZs and adjacent high seas, west of the British Isles, north of Shetland, on the continental slopes from south of Porcupine Bank to Tampen, and at Rockall and the Hatton Bank	c	600 50 m-long panels of gillnet (30 km total length) per vessel per trip are discarded.	Hareide *et al.*, 2005
North-East Atlantic	27	Southern Norwegian coastal anchored gillnet cod fishery	a	0% of nets set were lost and not retrieved (10 of 170 000 nets were lost, and all were retrieved by the vessel that temporarily lost it).	MacMullen *et al.*, 2003
North-East Atlantic	27	Southern Norwegian coastal anchored gillnet Greenland halibut fishery	a	0.09% of nets set were lost and not retrieved (5 of 5 350 nets set were lost and none was retrieved by the vessel that temporarily lost it).	MacMullen *et al.*, 2003
North-East Atlantic	27	Southern Norwegian coastal anchored deep-sea gillnet saithe fishery	a	0.18% of nets set were lost and not retrieved (275 of 152 550 nets set were lost and none was retrieved by the vessel that temporarily lost it).	MacMullen *et al.*, 2003
North-East Atlantic	27	Southern Norwegian anchored gillnet blue ling and ling fishery	a	0.5% of nets set were lost and not retrieved (159 of 12 135 nets set were lost of which 97 were retrieved by the vessel that temporarily lost it).	MacMullen *et al.*, 2003
North-East Atlantic	27	Algarve, Portugal, demersal trammel net and gillnet fisheries	a	Local fishery: 17.3 panels lost/vessel/year, of which 3.2 panels are not recovered. Coastal fishery: 27.0 panels lost/vessel/year, of which 6.0 panels are not recovered. Hake fishery: 33.6 panels lost/vessel/year, of which 7.4 panels are not recovered.	MacMullen *et al.*, 2003

TABLE 2A (CONTINUED)

UNEP Regional Seas[1]	FAO Major Marine Fishing Area[2]	Fishery or study site location	Method[3]	Rate of abandonment, loss and/or discarding	Citation
North-East Atlantic	27	United Kingdom demersal trammel net and demersal gillnet hake fisheries	a	Trammel net fishery: 845 m length of nets per vessel per year are lost and not retrieved (1.3 km length of nets per vessel per year were lost of which 0.455 km per vessel was retrieved by the vessel that temporarily lost it). Gillnet fishery: 500 m of net per vessel per year are lost and not retrieved (1 km length of nets per vessel per year were lost of which 0.5 km per vessel was retrieved by the vessel that temporarily lost it). Information was not presented to determine the percent of total gear set that was lost and not recovered.	MacMullen *et al.*, 2003
North-East Atlantic	27	Algarve, Portugal, local, coastal and gillnet hake and trammel net fisheries	a	The average annual number of panels lost per boat was 3.2, 5.1 and 7.4 for the local, coastal and hake fisheries, respectively.	Santos *et al.*, 2003a
North-East Atlantic and Mediter-ranean	27 and 37	French demersal gillnet and trammel net fisheries of the (i) East Channel and North sea coasts, (ii) North and West Brittany coasts, and (iii) Mediterranean coast.	a	East Channel and North sea coasts: 1.6km/vessel/year lost; 1% of the length of nets set per year are lost. North and West Brittany coasts: 2.6km/vessel/year lost; 1% of the length of nets set per year are lost. Mediterranean coast: 0.95km/vessel/year lost; 1.7% of the length of nets set per year are lost.	MacMullen *et al.*, 2003
North-East Pacific	67	United States of America Puget Sound, Washington salmon driftnet fishery.	a,b	2–10% of vessels lose a fragment or entire fleet. Extrapolating this loss rate estimate to the entire fishery, 18–42 driftnet fragments are lost per year.	Antonelis, 2012

[1] UNEP, 2005b, 2014. “None” indicates there is no UNEP Regional Sea Convention or Action Plan in the region for this study.
[2] FAO, 2014.
[3] (a) Survey (remote and/or in-person) of fishers.
(b) Survey (remote and/or in-person) of non-fishers experts.
(c) Method not specified (“anecdotal evidence”).

TABLE 2B
Methods and estimates of the density of ALDFG from gillnet and trammel net fisheries

UNEP Regional Seas[1]	FAO Major Marine Fishing Area[2]	Fishery or study site location	Method[3]	Density of ALDFG (unit amount per unit of area of seafloor and/or per unit volume of water column)	Citation
Baltic	27	Swedish demersal gillnet fishery, south of Gotland, Baltic Sea	a,g	7.5 kg of gillnet/km^2 (35.1 m length of gillnet/km^2)	MacMullen *et al.*, 2003
East Asian Seas and North-West Pacific	61	Eastern Yellow Sea, Republic of Korea	a,b	1 570 kg of fishing nets /km^2	Kang, 2003
Mediter-ranean	37	Section of the Gokova Special Environmental Protection Area off Turkey, eastern Mediterranean Sea, demersal gillnet and trammel net fisheries	c	15 700 m of combined gillnets and trammel nets per km^2	Ayaz *et al.*, 2010
None	21	United States of America Gulf of Maine, Jeffries Ledge and Stellwagen Bank demersal gillnet fishery	d,e,f	Jeffries Ledge: 54 m^2 gillnet /km^2 fishing ground (27 m length gillnet/km^2 fishing ground). Stellwagen Bank: 921 m^2 gillnet /km^2 fishing ground (1 842 m length gillnet/km^2 fishing ground) Extrapolation to total fishing ground: 2 240 gillnets (1.02 km^2 of netting; 1 net = 91 m × 5 m) / 14 042 km^2 fishing ground.	Carr and Cooper, 1987

TABLE 2B (CONTINUED)

UNEP Regional Seas[1]	FAO Major Marine Fishing Area[2]	Fishery or study site location	Method[3]	Density of ALDFG (unit amount per unit of area of seafloor and/or per unit volume of water column)	Citation
None	21	Demersal gillnet cod fishery, Newfoundland, Canada	a	148 demersal gillnet fragments per 48.3 hours of trawling/grappling effort; 167 demersal gillnet fragments per 53.5 hours of trawling/grappling effort.	Way, 1977
North-East Atlantic	27	Deepwater demersal gillnet anglerfish, hake and shark fisheries, Rosemary, Porcupine and Rockall Banks, off the United Kingdom and Ireland	a	CEFAS 2005 survey at Rosemary Bank: 0.011 m^2 of gillnet per km of towed transect. BIM 2005 and 2006 surveys at Rockall and Porcupine Banks: 0.12 km and 0.014 km of gillnet per km of towed transect, respectively. CEFAS 2006 survey at Porcupine Bank: 0.032 km of gillnet per km of towed transect.	Large *et al.*, 2009
North-East Atlantic	27	Norwegian demersal gillnet Greenland halibut fishery	a	0.11 km of gillnet per km of towed grapnel. (The total distance of towed transects was not reported, and was therefore estimated by assuming a mean tow speed of 1.5 knots, and mean haul duration of 2.25 hours was conducted, such that the total distance covered by the survey was 116.3 km, the distance covered by each haul was 1.88 km, and 0.21 km of gillnet was retrieved per haul).	Misund *et al.*, 2006
North-East Atlantic	27	Northeastern United Kingdom wreck gillnet fishery	c	7 of 11 wrecks had some ALDFG from gillnet fisheries. None of the wrecks had ALDFG from gillnets that retained fishing efficiency (0 of 27 gillnets and gillnet fragments retained fishing efficiency).	Revill and Dunlin, 2003
North-East Pacific	67	United States of America Puget Sound, Washington salmon driftnet fishery	b,c,f	Between 3 550 and 6 442 lost fragments or fleets of gillnets were estimated to be in the Washington State waters of the Salish Sea (area of the fishing grounds not reported).	Antonelis, 2013
North-East Pacific	67	United States of America Puget Sound, Washington salmon driftnet fishery	c,f	4 518 fragments or fleets of gillnet was estimated to occur in the Washington State waters of Puget Sound (area of the fishing grounds not reported).	Northwest Straights Foundation, 2007

[1] UNEP, 2005b, 2014. “None” indicates there is no UNEP Regional Sea Convention or Action Plan in the region for this study.
[2] FAO, 2014.
[3] (a) Tow ‘creeper’ grappling device.
(b) Side scan sonar.
(c) Divers (scuba, diver tows).
(d) Manned submersible.
(e) Underwater ROV.
(f) Raised estimate from sampled area to entire fishing grounds.
(g) Raised estimate explicitly accounted for proportion of ALDFG that was estimated not to have been observed.

TABLE 2C

Methods and estimates of ghost fishing mortality rates and duration of ghost fishing efficiency of ALDFG from gillnet and trammel net fisheries

UNEP Regional Seas[1]	FAO Major Marine Fishing Area[2]	Fishery or study site location	Method[3]	Ghost fishing mortality rates	Ghost fishing duration	Citation
Baltic	27	Simulated derelict demersal cod gillnets, Hano Bay, Swedish	a,c,d,e,h,i	NA	Fishing efficiency declined to 5–7% of the initial level after 3 months. Retained some fishing efficiency at 27 months.	Tschernij and Larsson, 2003
Mediter-ranean	37	Simulated derelict demersal gillnets, Izmir Bay, eastern Aegean Sea, Turkey	a,d,f,g,k,l	Multifilament gillnets: 62 fish in three 33 m × 2.8 m gillnets for duration of fish fishing efficiency. Monofilament gillnets: 115 fish in three 33 m × 2.8 m gillnets for duration of fish fishing efficiency.	Multifilament and monofilament gillnets ceased to catch fish at 106 and 112 days after deployment, respectively.	Ayaz *et al.*, 2006
Mediter-ranean	37	Simulated derelict demersal crawfish trammel net and hake and seabass demersal gillnet, St. Tropez Canyon and Cassis harbour, coastal France	a,c,d,e,k	Gillnet open ground: 46 hake and 36 crawfish per 5400 m^2 of net per year. Trammel net open ground: 46.25 crawfish per 2 100 m^2 of net per year.	Nets on open ground retained some catching efficiency at 18 months after deployment. Gillnet and trammel nets set on wrecks no longer retained catch efficiency by 6 months after deployment.	MacMullen *et al.*, 2003
None	21	United States of America Gulf of Maine, Jeffries Ledge and Stellwagen Bank demersal gillnet fishery	b,f,i	15% of fish catch rate of in-use gear.	NA	Carr and Cooper, 1987
None	21	Simulated derelict demersal gillnet, Cape Cod Bay, Gulf of Maine, United States of America	a,c,f	NA	Retained catching efficiency after 74 days.	Carr *et al.*, 1985
None	21	Simulated derelict demersal gillnet, Buzzards Bay, New England, United States of America	a,c,f	NA	Catch efficiency of the control and all experimental treatment nets continued after 2 years.	Carr, Blott and Caruso, 1992
None	71 and 77	Simulated derelict Japanese high seas squid drift gillnets, central Pacific Ocean near the Hawaii archipelago	a,c,d,f,k	NA	Lengths of 50 m and 100 m length nets reduced to < 5% of original in less than 0.5 day. The 350 m length net reduced to <5% of original at 2 days. The 1 km length net reduced to < 5% of original length at 10 days.	Gerrodette, Choy and Hiruki, 1987, 1990
North-East Atlantic	27	Simulated derelict demersal trammel nets, central coast of Portugal	a,c,d,f,i,k	Rocky substrate: 541 organisms per 100 m of net during study period. Sandy substrate: 257 organisms per 100 m of net during study period.	Fishing efficiency < 1% from an in-use net at 10.5 months at the site with rocky substrate, and at 8 months at the site with sandy substrate.	Baeta, Costa and Cabral, 2009
North-East Atlantic	27	Simulated derelict demersal gillnet and trammel net, Algarve, Faro, southern Portugal	a,c,d,f,g,k,l	Gillnet: 314 fish, 0 seabirds, 0 reptiles, 0 mammals per 240 m^2 net for duration of finfish fishing efficiency. Trammel net: 221 fish, 0 seabirds, 0 reptiles, 0 mammals per 190 m^2 net for duration of finfish fishing efficiency.	Duration of fishing efficiency for finfish: 15-20 weeks.	Erzini *et al.*, 1997

TABLE 2C (CONTINUED)

UNEP Regional Seas[1]	FAO Major Marine Fishing Area[2]	Fishery or study site location	Method[3]	Ghost fishing mortality rates	Ghost fishing duration	Citation
North-East Atlantic	27	Simulated derelict deep water demersal Greenland halibut gillnets, Norway	a,c,d,e,h,j	Experiment 1: 67–100 kg halibut per 4 207.5 m^2 net per day once net fishing efficiency declined to 20–30% of original. Experiment 2: 28–43 kg halibut per 4 207.5 m^2 net per day once net fishing efficiency declined to 20–30% of original.	Retained catch efficiency after 68 days. Catch rate reached 20–30% of initial efficiency between 21 and 45 days after setting and remained at that level through the remainder of the study period to 68 days after setting.	Humborstad *et al.*, 2003
North-East Atlantic	27	Simulated derelict demersal gillnet and trammel net, St. Bride's Bay, southwest Wales, United Kingdom	a,c,d,f,g,l	Gillnet: 226 fish, 839 crustaceans per 243 m^2 net for duration of fishing efficiency. Trammel net: 78 fish, 754 crustaceans per 243 m^2 net for duration of fishing efficiency.	The ghost fishing catch rate of number of fish per 24-hour period approached 0 at 70 and 22 days after deployment for the gillnet and trammel net, respectively. Crustaceans continued to be observed to be caught at low rates at 9 months after initial deployment.	Kaiser *et al.*, 1996
North-East Atlantic	27	Simulated derelict demersal hake gillnet, southwest England, United Kingdom	a,c,d	Fleet 1: 39 crustaceans and 2 fish per 400 m net during study period. Fleet 2: 30 crustaceans and 6 fish per 400 m length of net during study period.	Not known; the experimental fleets were lost when checked at 14 weeks after deployment.	MacMullen *et al.*, 2003
North-East Atlantic	27	Simulated derelict demersal gillnet, Bay of Biscay, Spain	a,c,e,h,l	7.38 kg of monkfish per 180 m^2 net for duration of fishing efficiency	Still maintained some demersal fish and invertebrate catch efficiency after 12 months of deployment.	MacMullen *et al.*, 2003
North-East Atlantic	27	Simulated derelict wreck gillnet and demersal trammel net, North Sea off northeast United Kingdom	a,c,d,f,g,k	NA	Wreck gillnet ceased finfish fishing efficiency at 45 weeks and crustacean fishing efficiency at 2 years after being set. Open ground trammel net ceased fishing efficiency at 58 days after being set.	Revill and Dunlin, 2003
North-East Atlantic	27	Simulated derelict demersal monkfish gillnet, Bay of Biscay, Basque Region, Cantabrian Sea, northern Spain	a,c,d,e,h, k,l	4.7 monkfish (17.7 kg) per 360 m^2 net for duration of fishing efficiency.	224 days until ceased to catch monkfish.	Sancho *et al.*, 2003
North-East Atlantic	27	Simulated derelict demersal hake gillnets, Faro, Algarve, Portugal	a,c,d,e,h,i, k,l	May-deployed fleets: 116 organisms (29.8 kg) / 9 hake (20.6 kg) per 620 m^2 net for duration of fishing efficiency. Sept.-deployed fleets: 413 organisms (90.1 kg) / 88 hake (29.9 kg) per 620 m^2 net for duration of fishing efficiency.	Ghost fishing maximum duration was estimated to be 248 days; negligible catch was predicted to be reached after 3 months.	Santos *et al.*, 2003b
North-East Atlantic	27	Simulated derelict demersal hake gillnets, Algarve, Faro, southern Portugal	a,c,d,e,h,i,l	249.9 non-hake organisms (64.4 kg) per 620 m^2 net for duration of fishing efficiency	Retained catching efficiency after 12 months. Estimated fishing capacity would end at 430 days after setting.	Santos, Gaspar and Monteiro, 2009
North-East Pacific	67	United States of America Puget Sound, Washington salmon driftnet fishery	b,f,g	2.119 invertebrates, 0.196 seabirds, 0.275 fish per 3 610 m^2 net per day	NA	Gilardi *et al.*, 2010

TABLE 2C (CONTINUED)

UNEP Regional Seas[1]	FAO Major Marine Fishing Area[2]	Fishery or study site location	Method[3]	Ghost fishing mortality rates	Ghost fishing duration	Citation
North-East Pacific	67	United States of America Puget Sound, Washington salmon driftnet fishery	b,f,k	NA	Fish and diving seabirds ceased to be caught after about 3 years. Crabs continued to be caught after 6 years.	High, 1985
North-West Pacific	61	Simulated derelict demersal Japanese spiny lobster gillnets, Tateyama Bay, Chiba Prefecture, Japan	a,c,d,f,g,l	Artificial reef experiment 1: 44 crustaceans, 11 gastropods, 2 bony fishes, 2 sand dollars per 9.4 m^2 net during study period. Artificial reef experiment 2: 33 crustaceans, 5 gastropods, 5 bony fishes, 1 sea cucumber per 9.4 m^2 net during study period. Sandy sea bed experiment 1: 8 crustaceans, 4 gastropods, 1 bony fish per 9.4 m^2 net during study period. Sandy sea bed experiment 2: 7 crustaceans, 1 gastropod per 9.4 m^2 net per during study period.	Duration of fishing efficiency derelict gillnet in an artificial reef, experiment 1: 561 days. Duration of fishing efficiency derelict gillnet in an artificial reef, experiment 2: 284 days. Duration of fishing efficiency derelict gillnet on sandy sea bed, experiment 1: 200 days. (Sandy sea bed experiment 2, no significant correlation between soak time and number of caught organisms).	Akiyama, Saito and Watanabe, 2007
North-West Pacific	61	Simulated derelict salmon drift gillnets, northwest Pacific Ocean east of Japan	a,c,d,f,k	NA	< 3 months for nets to form a solid mass.	Mio *et al.*, 1990
North-West Pacific	61	Simulated derelict demersal gillnet, coastal Japan	a,f,g,j,l	455 fish per 165.6 m^2 net until net reached 5% of original fishing efficiency.	142 days to reach 5% of initial fishing efficiency.	Nakashima and Matsuoka, 2004
North-West Pacific	61	Simulated derelict demersal gillnet wrapped on a fish aggregation device, and control fish aggregation device with no tangled gillnet, coastal Japan	a,f,g,j	191 fish per 2.25 m^2 net per year.	No declining trend in ghost fishing catch rate observed during the 1 149 day study period.	Nakashima and Matsuoka, 2005

[1] UNEP, 2005b, 2014. "None" indicates there is no UNEP Regional Sea Convention or Action Plan in the region for this study.
[2] FAO, 2014.
[3] (a) Deployed simulated derelict gillnets and/or trammel nets.
(b) Observed ALDFG from gillnet and/or trammel net fisheries.
(c) Simulated derelict gear used commercial gear design and fishing methods, in some cases modified to simulate derelict conditions.
(d) Simulated derelict gear set at conventional fishing grounds, including cases where the study site was selected in a subset of grounds to avoid disturbance, e.g. from conflict with mobile gear.
(e) Monitored catch and/or changes to gear condition via periodic retrieval of subset of gear.
(f) Monitored catch and/or changes to gear condition via in situ monitoring.
(g) Estimated short-term (hours to weeks) ghost fishing mortalities by counting the number of organisms that became newly captured since a previous observation. Marked catch to enable the identification of new catch in subsequent monitoring event.
(h) Estimated short-term (hours to weeks) ghost fishing mortalities by counting the number of recently captured organisms in 'good condition' observed present at the time of monitoring.
(i) Fishing efficiency of derelict gear/simulated derelict gear at end of study period compared to that of in-use gear during the same period and area as the study gear.
(j) Fishing efficiency of derelict gear/simulated derelict gear at end of study period compared to its initial fishing efficiency.
(k) Monitored ALDFG until cessation of ghost fishing, until cessation of fishing efficiency for target species, or until retained small proportion of initial species-specific or total catch capacity based either on observations of ghost fishing catch rates or on net condition factors that indicate catch capacity.
(l) Fit decay model to short-term ghost fishing catch rate data to: (i) estimate total ghost fishing mortality level over a study period that ended before derelict gear ceased to ghost fish, or for the estimated duration of fishing efficiency; and/or (ii) estimate the duration of fishing efficiency.

3.2 DISCUSSION

3.2.1 Methods and estimates of rates of abandonment, loss and discarding and use in estimating ALDFG density

Information on the rate of abandonment, loss and discarding of fishing gear can provide a requisite input to understand total ghost fishing mortality levels in a spatially explicit area over a given time period. The most common method employed to estimate the rate of abandonment, loss and discarding of fishing gear is to conduct in-person interviews and remote surveys, e.g. via telephone, mail and e-mail, of captains and crew of a fishery and of other experts (Santos *et al.*, 2003a; Antonelis, 2012, 2013; Kim, Lee and Moon, 2014). Surveys of fishers and other experts can provide a critically important first-order qualitative understanding of basic characteristics of a fishery, including rates and density of ALDFG, when previously little or no information was available (Gilman *et al.*, 2010). Data from expert surveys can then be validated through methods that provide more certain results (MacMullen *et al.*, 2003; Ayaz *et al.*, 2010).

Experiments and analyses of observer and logbook programme data can provide more robust estimates of rates of the abandonment, loss and discarding of fishing gear. Long-time series of records of such incidents may be needed to account for potentially high interannual variability as documented to occur in some fisheries (e.g. documented in southern Norwegian coastal anchored gillnet fisheries, MacMullen *et al.*, 2003). One source of error, rates of ALDFG generated from IUU fishing may be substantially different from estimates obtained from legal fisheries if a main cause of ALDFG by the IUU fishers is abandonment of gear when operating illegally and a risk of detection occurs (Imamura, 2011).

Estimates of gear loss rates should be explicit in indicating if they are for initial "gross" gear loss or otherwise if the estimate is for "net" gear loss after accounting for the proportion of the initially lost gear that was recovered (MacMullen *et al.*, 2003; Santos *et al.*, 2003a). Vessels may recover a proportion or all of their lost gear depending on the ability of the captain to locate the exact position where they set the gear, to track the location of gear that moved from its original position, weather conditions, the cause of the gear loss, etc. Lost gear resulting from cut float lines is likely to have a high rate of recovery. If the gear loss was due to gear conflict (e.g. a trawler towed over a set gillnet), then it is possible that only a section of the lost fleet of set gear was towed away, and a large portion of the fleet might be recovered by the vessel. If a storm or currents caused the gear to move position, then the probability of finding the lost gear can be high if tracking technology is used, and otherwise the gear is less likely to be retrieved.

Equation 1 provides a model using information on the rate of abandonment, loss and discarding of fishing gear to estimate the density of ALDFG at a fixed point in time and spatially explicit area.

Equation 1: $$D_{ALDFG} = E^{*}(A_f + L_f + D_f) + ALDFG_c - (ALDFG_r + ALDFG_d)$$

The terms of Equation 1 are defined as follows:

- D_{ALDFG}: The density of ALDFG of a particular gear type, or from a specific fishery, at a single point in time, and explicit spatial area such as the grounds where a fishery operates, where units are: the unit of effort (e.g. length of net, area of net, weight of nets) per area under assessment.
- E: Effort, the mean number of active vessels per year in the fishery in question times the number of years that the fishery in question has been operating.
- A_f, L_f and D_f: The rates of abandonment, loss and discarding of fishing gear by the fishery in question into the study area, respectively, in units of: unit of effort per vessel per selected time period.

- $ALDFG_c$: The rate of inputs of ALDFG into the study area from currents and storms, in the unit of: unit of fishing effort per selected time period as used in the A_f, L_f and D_f terms.
- $ALDFG_r$: The rate of all sources of removals from the study area (transported out of the area by currents and storms, recovered by the vessels of the fishery in question, by vessels of other fisheries, by ALDFG collection programmes, entangled on large marine organisms that migrate out of the study area, etc.) of ALDFG that were introduced by the fishery in question, in the unit of: unit of fishing effort per selected time period as used in the A_f, L_f and D_f terms.
- $ALDFG_d$: The rate of complete decomposition of ALDFG in the study area, in units of: unit of fishing effort per selected time period as used in the A_f, L_f and D_f terms.

When combined with information on amount and spatial distribution of fishing effort, information on the rate of abandonment, loss and discarding of fishing gear can be used to estimate the density of ALDFG by gear type. However, especially in open bodies of water, ALDFG can be carried by currents out of the area where it was abandoned, lost or discarded, and ALDFG can similarly be carried into an area from afar (e.g. Ebbesmeyer *et al.*, 2012). Therefore, information on gear abandonment/loss/discarding rates probably provide a less accurate basis to estimate the current amount of ALDFG in a defined spatial area, such as the fishing grounds for a fishery, relative to other methods for estimating the density of derelict gear, discussed in the following section.

Of the 14 studies reviewed in Table 2a, 13 surveyed a sample of fishers from a fishery, one included marine pollution experts in its survey sample, and one study did not explain the method employed to estimate the rate of abandonment, loss or discarding of fishing gear from gillnet and trammel net fisheries. No studies were found that estimated ALDFG based on data from experiments, observer programmes or logbook programmes. Most of the studied fisheries employed coastal demersal gillnets and trammel nets. Rates of gear loss were reported in units of length or area of nets lost per vessel per year, and percentage of set gear lost. Nine of the 14 studies reporting estimated rates of producing derelict gear were from the Northeast Atlantic, resulting from the European Commission's FANTARED project (Table 2a; MacMullen *et al.*, 2003).

Several units were used to report the rates of abandonment, loss and discarding of gillnets and trammel nets. Of the studies reviewed in Table 2a, the following eight units were used: (i) percentage of total gear set that was lost and not recovered (n=10); (ii) number of net panels per vessel per year that were lost and not recovered (n=8); (iii) number of discarded net panels per vessel per trip (n=1); (iv) length of nets per vessel per year that were lost and not recovered (n=6); (v) length of nets per vessel per set that were either abandoned, lost or discarded (n=1); (vi) weight of discarded nets per vessel per year (n=1); (vii) percentage of vessels in a fishery that lose a fragment of set gear or the entire set gear (n=1); and (viii) number of net fragments that are lost per year by all vessels in a fishery (n=1).

The mean estimated percentage of lost gear from gillnet and trammel net fisheries, where nets were set, lost and not subsequently retrieved by the vessel, was 0.9 percent (± 0.3 SEM, range 0–3.4 percent, n=10) (e.g. 1 percent of gear is lost per vessel per year) (Table 2a). A 38 percent CV (coefficient of variation, the standard deviation of the mean was 38 percent of the mean), with 7 of the 10 estimates falling outside ± one SD from the mean, indicates that there was relatively high variability / low consistency in the 10 study findings. Similar CVs resulted when employing a unit of the number of lost net panels per vessel per year (mean of 11.7 ± 3.0 SEM, 26 percent CV, 6 of 8 estimates falling outside ± one SD from the mean) and length of lost nets per vessel per year (mean of 1.1 km/vessel/year ± 0.4 SEM, 33 percent CV, 4 of 6 estimates falling outside ± one SD from the mean).

In summary, there is high variability in the few available estimates of rates of abandonment, loss and discarding of gear from gillnet and trammel net fisheries, consistent with Macfadyen, Huntington and Cappel (2009). Studies have primarily estimated rates of abandonment, loss and discarding of gear through fishers surveys; estimates have not been based on data from experiments, observer programmes or logbook programmes, which would have higher certainty findings and could be used to validate the first-order estimates from the fishers surveys. Some study findings did not specify whether estimates of loss rates accounted for the proportion of initially lost gear that was recovered by the vessels. There has been inconsistent use of units to report rates of abandonment, loss and discarding, using the length or area of nets lost per vessel per year, and percentage of set gear that was lost. This precludes meaningful comparisons of findings between studies and prevents the pooling of records. There have been some relevant studies, few studies conducted outside of Europe, with most studies having been conducted on coastal demersal gillnets and trammel nets; data sources are dated and patchy spatially, temporally, and by gear type.

3.2.2 Methods and estimates of the density of ALDFG

Two common methods to estimate the density of ALDFG, the unit amount per unit area of seafloor and/or per unit volume of water column, in a spatially explicit site, are: (i) to survey the sea bed of a subset of the area of the total fishing grounds and extrapolate to the total area; and (ii) to conduct interviews to obtain expert opinion of estimates of the amount of derelict gear present in a designated area (e.g. Carr and Cooper, 1987; Northwest Straits Foundation, 2007; Antonelis, 2013). In some studies, survey sites were randomly selected to attempt to characterize the density of ALDFG across the fishing grounds, while in others survey sites were selected based on information from fishers identifying sites where they lost gear or observed ALDFG, in some cases, to attempt to maximize the quantity of ALDFG retrieval (Misund *et al.*, 2006; Large *et al.*, 2009). For example, identifying wrecks as having high concentrations of ALDFG, Revill and Dunlin (2003) surveyed wrecks along a 100 km section of coastline off northeast England, the United Kingdom of Great Britain and Northern Ireland, to observe the number of ALDFG from gillnet fisheries. Northwest Straits Foundation (2007) used a combination of observations of removed ALDFG, reports of ALDFG received through a reporting system, and diver surveys focused on heavily fished areas.

Observations by divers, and by sonar, video and photography deployed from marine vessels, towed structures, manned submersibles and underwater ROVs, have been used to survey for derelict gear (Carr and Cooper, 1987; MacMullen *et al.*, 2003; Revill and Dunlin, 2003; Ayaz *et al.*, 2010). For example, Matsuoka, Nakashima and Nagasawa (2005) estimated the amount of derelict gear in a study area through information derived from a combination of interviews of fishers and from a seabed survey using sidescan sonar. One trial where demersal gillnets were deployed to simulate derelict gear found that towed sidescan sonar equipment was unreliable in detecting the gear when high sea swell prevented maintaining the towed device at a constant depth, the device was too distant from the sea bed or when the vessel speed was too fast (MacMullen *et al.*, 2003). Towing "creeper" grappling devices is another method to estimate the density of ALDFG in a sampled area of a fishing ground (Kang, 2003; Misund *et al.*, 2006; Large *et al.*, 2009).

Estimates of the density of ALDFG at a point in time obtained from surveys of a subset of a fishing ground can then be extrapolated to the entire fishing ground. For example, in an early study to estimate the density of ALDFG at a commercial demersal gillnet fishing ground, Way (1977) trawled with a grappling device and reported the number of derelict gillnet fragments retrieved per number of hours of trawling. Subsequent studies have reported findings in units of the number, length or area of retrieved ALDFG from net fisheries per linear length surveyed (crept), and extrapolated this to the length or area of derelict nets per area of fishing ground (Misund *et al.*, 2006; Large *et al.*, 2009; Ayaz *et al.*, 2010).

Models estimating the density of ALDFG in a total fishing ground based on observations from a sample of the area can include a factor to account explicitly for an estimate of error of the survey method, by accounting for an estimate of the proportion of derelict gear present in the study site that was not observed during a survey (MacMullen *et al.*, 2003). In one experiment testing a new design of creeper, 27 percent of the length of deployed simulated derelict demersal gillnets were retrieved, and some or all of simulated derelict nets were retrieved in half of the tracks in which derelict nets had been set (MacMullen *et al.*, 2003).

Of the 10 studies reviewed in Table 2b, 5 towed a grappling device, 2 used sidescan sonar, 4 used divers, 1 a crewed submersible, and 1 an underwater ROV. Four of the studies raised estimates from a sampled area to a larger fishing ground, one of which accounted for an estimate of error in the sampling method (the proportion of total ALDFG present along tow lines that a towed creeper did not retrieve). There were 5 studies of coastal demersal gillnet and trammel net fisheries, 2 of a coastal driftnet fishery, 1 of a coastal gillnet wreck fishery, 1 of a deep-water gillnet fishery, and 1 study did not determine the source fisheries of retrieved derelict fishing nets (Table 2b). Three of the 10 studies were from the Northeast Atlantic, 2 from the Northwest Atlantic, 2 from the Northeast Pacific, and 1 each from the Baltic, Mediterranean and Northwest Pacific (Table 2b).

Variable units were used to report the density of ALDFG from gillnet and trammel net fisheries: (i) length of derelict net per unit area (n=4); (ii) length of derelict net per unit length of survey transects (n=4); (iii) number of net fragments per unit of sampling effort (n=2); (iv) area of derelict nets per unit area (n=2); (v) number of net fragments per area of a fishing ground (n=2); (vi) weight of derelict nets per unit area (n=1); (vii) area of derelict nets per unit length of survey transects (n=1); and (viii) proportion of surveyed wreck sites with derelict nets present (n=1).

The mean estimated density of ALDFG from gillnet and trammel net fisheries, in units of length of nets per area of surveyed fishing grounds, was 4.4 km net/km^2 fishing grounds (± 3.8 SEM, range 0.027–15.7, n=4) (Table 2b). An 86 percent CV, with all 4 estimates falling outside ± one SD from the mean, indicates extremely high variability. Similar variability was found when using results presented in units of length of derelict gillnets per unit length of survey transects, with a mean density of 0.07 km gillnet/km survey transect (± 0.03 SEM, range 0.01–0.1, n=4), 39 percent CV, with all 4 estimates falling outside ± one SD from the mean. One of the reviewed studies, which reported the observed density of fishing nets without estimating the proportion that was gillnet/trammel net gear (Kang, 2003), was excluded from the records used in producing these summary statistics.

Studies have employed a mix of towing "creeper" grappling devices and various *in situ* survey methods to estimate the density of ALDFG from gillnet and trammel net fisheries. In Puget Sound, Washington, the United States of America, two studies used a combination of interviews, surveys and direct observations from ALDFG removal operations. Few studies towing creepers accounted for the estimated proportion of ALDFG that the creeper did not recover. Main units for reporting ALDG density have been the length of derelict nets per unit area of survey fishing grounds, or length per unit length of survey transects. Consistent with Macfadyen, Huntington and Cappel (2009), the sparse number of relevant studies are primarily from Europe, are largely dated and spatially and temporally patchy, with large dispersion in estimates of the density of ALDFG.

3.2.3 Methods and estimates of ghost fishing mortality rates and duration of fishing efficiency

Various methods have been employed to estimate ghost fishing mortality rates and the duration of ghost fishing efficiency in ALDFG from gillnet and trammel net fisheries, or in experimental nets deployed to simulate derelict gear (Table 2c). In some experimental studies, nets were deployed at conventional fishing grounds. In others, study areas were selected away from conventional fishing grounds in order to avoid disturbance by commercial fishing vessels using the same gear as well conflicts with mobile gear, and to facilitate monitoring (shallow depth to aid observations by divers, close to seaport to facilitate access). Most studies employing simulated derelict gear employed commercial gear designs and fishing methods (Table 2c). Study designs that deviate from typical commercial operations might not characterize ghost fishing in the commercial fishery (e.g. Kaiser *et al.*, 1996).

In some studies, one end of simulated derelict demersal nets was loose, either by not anchoring it or cutting the float line, and in some cases the net was dragged for a certain period (e.g. 2 minutes) or distance (e.g. 150 m) to simulate a net that was lost from interacting with towed gear, such as a trawl net dragging the gillnet or trammel net along the bottom until eventually cutting the net, dragging away one portion and leaving the remainder with one end still anchored (Kaiser *et al.*, 1996; Erzini *et al.*, 1997; MacMullen *et al.*, 2003; Revill and Dunlin, 2003; Santos *et al.*, 2003b; Santos, Gaspar and Monteiro, 2009). To simulate the loss of end markers or movement of a fleet due to currents, which are common causes of gear becoming lost at deep-water fishing grounds, studies simulating derelict gear at deep-water sites anchored both ends of a fleet (Humborstad *et al.*, 2003).

Duration of fishing efficiency has been estimated via periodic monitoring of derelict or simulated derelict gear until the gear is observed to no longer retain any catching capacity, no longer catches main market species, or retains a small proportion (e.g. 1–5 percent) of species-specific or total catch capacity relative to its initial fishing efficiency or relative to in-use gear deployed in the same area and time (Kaiser *et al.*, 1996; Erzini *et al.*, 1997; Revill and Dunlin, 2003; Sancho *et al.*, 2003; Tschernij and Larsson, 2003; Ayaz *et al.*, 2006; Baeta, Costa and Cabral, 2009). The percentage of retained fishing efficiency of ALDFG has been estimated by comparing the short-period catch rate when first set to that after a period of soaking, or to that of similar commercial in-use nets used in the same area and time.

Short-period (hours to weeks) ghost fishing mortality rates, in units of number or biomass of catch per time period per unit of fishing effort by species or group, have been estimated by counting the number of organisms that became newly captured since a previous observation. To make this estimate, tags have been affixed to organisms caught in derelict gear to enable the identification of new organisms caught in the net since a previous monitoring event (Kaiser *et al.*, 1996; Akiyama, Saito and Watanabe, 2007; Gilardi *et al.*, 2010). Other studies assumed that catch in good condition observed present in a net at the time of monitoring were caught within an estimated time period prior to the monitoring event, based on previous observations made in that region. For example, Santos *et al.* (2003b) and Santos, Gaspar and Monteiro (2009) and a study in MacMullen *et al.* (2003) assumed "good condition" catch had been caught in the previous 24 hours. Another study in MacMullen *et al.* (2003) assumed that fish degraded within 3 days and shellfish within 15 days. Sancho *et al.* (2003) assumed that monkfish in "fresh" condition had been caught in the previous four days. Similarly, Tschernij and Larsson (2003), upon retrieving simulated derelict demersal gillnets at multiple-month intervals, categorized catch as marketable, decomposing and skeletons. To estimate short-term catch rates in a simulated derelict deep-water demersal gillnet, Humborstad *et al.* (2003) assumed that live fish and fish that were dead but with no or minor damage had been recently captured, and excluded more degraded dead fish.

Use of catch condition to estimate the short-term catch rate is necessary for studies of derelict gear at deep-water sites where *in situ* monitoring to tag organisms is not possible (Humborstad *et al.*, 2003). Monitoring has been conducted *in situ* by divers and using ROVs, in some cases aided with the use of still photography and video, attaching still and video cameras in one case to a balloon, and via repeated retrieval of the nets (Kaiser *et al*., 1996; Erzini *et al.*, 1997; Pawson, 2003; Sancho *et al.*, 2003; Baeta, Costa and Cabral, 2009; Gilardi *et al.*, 2010).

Exponential regression decay models (or their inverse logarithmic function) have been fitted to time series of records of short-period (24-hour to biweekly) catch rate data in order to estimate a total ghost fishing mortality level over a study period that ended before derelict gear ceased to ghost fish, or for the estimated duration of fishing efficiency of an individual derelict net or group of nets, and to estimate duration of fishing efficiency (e.g. Santos *et al.*, 2003b; Santos, Gaspar and Monteiro, 2009). Catch rate data can be soak time vs the number or length or weight of organisms caught since the previous observation, or otherwise estimated to have been caught within a certain time period prior to the current monitoring event per unit of effort. A decay model could be fitted to catch rate data for a single species group (e.g. demersal fish, crustaceans) and for a specific type of ALDFG (e.g. gillnet ALDFG on wreck, trammel net ALDFG on flat sandy bottom). For example, fitting daily ghost fishing catch rate data, in numbers of caught organisms, to Equation 2, an exponential regression function:

Equation 2: $N_t = N_0 e^{-rt}$

The terms of Equation 2 are defined as follows:
- N_t: The total number of organisms that an individual derelict net will catch from time 0, the point in time when the net is deployed, to time t, the time period that the derelict net continues to have catch efficiency.
- N_0: The y-intercept.
- r: The rate of decrease in the daily catch rate.

To clarify, t is the duration of ghost fishing efficiency (the time between setting the net and when the derelict net no longer catches organisms). Thus, Equation 2 provides an estimate of total ghost fishing mortality level, in weight or number of organisms, for an individual derelict net (Kaiser *et al.*, 1996; Erzini *et al.*, 1997; MacMullen *et al.*, 2003; Ayaz *et al.*, 2006; Akiyama, Saito and Watanabe, 2007; Santos *et al.*, 2003b; Santos, Gaspar and Monteiro, 2009). Alternatively, Sancho *et al.* (2003) developed a model to estimate the total level of target species ghost fishing catch in a derelict gillnet during the period that the derelict net maintains fishing efficiency that assumed that there was no trend in the ghost fishing mortality rate over an initial soak period, followed by a period with a linearly decreasing trend in the catch rate until reaching t, cessation of fishing efficiency.

Affixing tags to organisms caught in derelict gear, and to captive organisms placed in the gear, enables monitoring of the change in condition of catch between monitoring events and over a full study period. This enables the complete removal of ghost caught organisms from a derelict net due to decomposition and scavenging to be accounted for in models that estimate total ghost fishing mortality levels (Kaiser *et al.*, 1996; Erzini *et al.*, 1997; Gilardi *et al.*, 2010).

Given temporal variability in factors that affect the duration of fishing efficiency at a fixed study site where an anchored net is deployed or over the area that a driftnet covers during a study period, the season (or seasons) during which a study is conducted can have a large effect on findings. For example, a study conducted during a season with higher probability of storms might find lower ghost fishing mortality rates and levels than one conducted in a season with mild weather (Carr, Blott and Caruso, 1992; Erzini *et al.*, 1997; MacMullen *et al.*, 2003; Sancho *et al.*, 2003; Santos *et al.*, 2003b). Temporal (seasonal, annual) variability in the abundance of species caught by gillnets and trammel nets, and in seasonal variability in degree of biofouling, also means that the timing and duration of a study will affect observed ghost fishing mortality rates and levels (e.g. Sancho *et al.*, 2003; MacMullen *et al.*, 2003). To obtain robust estimates of the duration of fishing efficiency of ALDFG, relatively long study periods of years can be required at fishing grounds with conditions that result in a long duration of ghost fishing efficiency (Section 1.4) (e.g. Kaiser *et al.*, 1996; Nakashima and Matsuoka, 2004).

Ghost fishing mortality rates based on data from periodic monitoring of derelict nets can result in large underestimates when organisms are caught in between two monitoring events and are completely removed from the net before the net is subsequently monitored (Kaiser *et al.*, 1996; Erzini *et al.*, 1997). This source of uncertainty applies to very short intervals in between monitoring periods of less than a day. For example, an organism can become captured in ALDFG, escape, and later die as a direct or indirect result of the interaction, and predators can rapidly remove recently caught live organisms (Carr, Blott and Caruso, 1992; Kaiser *et al.*, 1996; Erzini *et al.*, 1997; Gilardi *et al.*, 2010; Gilman *et al.*, 2013). It also applies to intervals of days to months. For example, scavengers have been observed to completely remove catch over a period of days, and catch can completely decompose over periods of days to weeks, depending on the location of the site and species of catch (Kaiser *et al.*, 1996; Erzini *et al.*, 1997; Gilardi *et al.*, 2010).

There is also uncertainty in estimating the fate of an observed new captured organism that is not present upon a subsequent monitoring event. The organism may have: escaped alive and survived; escaped injured and subsequently died from the interaction; been completely removed by predators; died in the gear and fallen out from mechanical action or been completely removed by scavengers; or died and completely decomposed (Kawamura, 1993; Kaiser *et al.*, 1996; Erzini *et al.*, 1997; Akiyama, Saito and Watanabe, 2007; Gilardi *et al.*, 2010; Gilman *et al.*, 2013).

Estimating the number of caught organisms in nets through periodic retrieval of a subset of derelict nets may provide a large underestimate of ghost fishing mortality rates as there is evidence that a large proportion of the caught organisms can drop out of the nets during retrieval. For example, Gilardi *et al.* (2010) observed that 13 percent of invertebrates, 32 percent of fish and 21 percent of seabirds caught in derelict nets fell out of the gear during the process of retrieving the net.

Matsuoka, Nakashima and Nagasawa (2005) developed a model of ghost fishing removals per unit of time by extrapolating from experimentally derived estimates of ghost fishing. Model inputs included estimates of: average species-specific mortality rates per derelict gear per unit of time; the area of the fishing grounds; the amount of derelict gear in the fishing ground; and the proportion of total derelict gear in the area that continues to maintain some catching efficiency (Matsuoka, Nakashima and Nagasawa, 2005).

Equation 3 identifies factors needed to estimate the total level of ghost fishing mortality in a spatially explicit area over a selected time period:

Equation 3: $G_p = (D_{FE\text{-}ALDFG} * A) * (N_t * p * t^{-1})$

The terms of Equation 3 are defined as follows:

- G_p: Total ghost fishing mortality level, of specified species or all catch, in a selected study area over a specified time period p.
- $D_{FE\text{-}ALDFG}$: Estimate of the density of derelict gear retaining some ghost fishing efficiency (i.e. it has been soaking for $< t$).

- A: Area of the selected study area, such that the factor $D_{FE\text{-}ALDFG}$*A produces the total quantity of the unit of fishing effort of ALDFG with fishing efficiency in the study area at a point in time.
- N_t: As in Equation 2, the total ghost fishing mortality level of a single derelict net over the full period that the derelict gear continues to have fishing efficiency.
- p^*t^{-1}: Referring to the definition of t provided in Equation 2, the proportion or factor of duration of fishing efficiency that the selected study period p covers.

The model assumes that the mean age of ALDFG retaining fishing efficiency in the site is half of t; i.e. that the rate of input of ALDFG is constant over p. The term p needs to be sufficiently long to account for temporal variability in the various terms included in the equation. For example, there might be cyclical intra-annual (seasonal) uneven distribution of fishing effort, which causes temporal variability in the mean age of derelict gear in the study area over a small time series. Moreover, there can be seasonal variability in the loss of gear owing to seasonal variability in the frequency of conflicts with towed gear sectors, or in inclement weather, which causes temporal variability in the mean density of derelict gear in the study area over a short time series.

Fishing mortality by gear that was temporarily lost but soon retrieved by the vessel might not be considered ghost fishing mortality, as the fisher did not permanently lose control over the gear (Matsuoka, Nakashima and Nagasawa, 2005). While it can be helpful to have agreed terminology for the various components of fishing mortality, what is ultimately important is to ensure that all mortality sources are accurately estimated and accounted for (ICES, 2005).

Duration of fishing efficiency and total ghost fishing mortality removals from a derelict net has also been estimated for some taxa with time series data on the effective fishing area and visibility of gillnets and trammel nets (Kaiser *et al.*, 1996; Erzini *et al.*, 1997; Revill and Dunlin, 2003). For example, Kaiser *et al.* (1996) found a significant relationship between headline height (an indicator of effective fishing area) and number of fish caught in a simulated derelict gillnet, but not for crustaceans.

Given the paucity of data on ghost fishing mortality rates by gillnets and trammel nets derived from experiments and from monitoring ALDFG in some regions, data on catch rates from monitoring in-use gear is a more readily available source of information that could be used in models to predict ghost fishing mortality rates. For example, Carr and Cooper (1987) estimated that the average catch rates of observed derelict demersal gillnets found in the Gulf of Maine were about 15 percent of active commercial groundfish gillnets, based on observations of the average profile, degree of fouling and overall integrity of the derelict nets. While this method can be applied to ALDFG from demersal fisheries, it may not be as appropriate in driftnet fisheries where ghost fishing from derelict nets shifts to non-target species (often demersal) once deposited on the seafloor.

There have been inconsistent definitions of fishing effort in gillnet and trammel net fisheries (FAO, 2007; Gilman, 2009). It would be beneficial to standardize units for the reporting of catch per unit of effort (CPUE) in gillnet and trammel net fisheries in order to enable more meaningful comparisons between experiments and fisheries, and to support the pooling of data for broad spatial-scale studies, including meta-analyses. Alternative CPUE units for passive net fisheries identified in Gilman (2009) were the number of caught organisms per: (i) trip, (ii) set, (iii) unit length of net, (iv) unit area of net, (v) unit area per soak time, and (vi) the weight of the net. Many of these methods do not provide effective ways to compare catch rates between fisheries, vessels within a fishery, or even of catch rates by an individual vessel. For example, reporting catch per horizontal length of a net can be a misleading measure of CPUE for comparisons of different net designs if the net heights are dissimilar, and if organisms are not caught in the same vertical portion of the net (Gilman *et al.*, 2010). Fishing effort is not effectively characterized by identifying the number of vessels in a fleet or number of fishers participating in a fishery, as this is not a reliable indicator to compare fishing efficiency between fisheries. Moreover, comparisons of effort by gear with different designs can be problematic because of inherent differences in the catching process of the different gear (Chapter 2). There is also a need for gillnet and trammel net ghost fishing catch rate units to be standardized to account for the duration that the gear has been derelict, as there can be significant reductions in catching efficiency of derelict gear over time (Kaiser *et al.*, 1996; Erzini *et al.*, 1997; Pawson, 2003; Matsuoka, Nakashima and Nagasawa, 2005). The lack of use of standardized ghost fishing catch rate units, this in addition to variable methods employed in studies that estimated ghost fishing mortality rates (Table 2c), has made it problematic to compare findings among these studies (Chopin *et al.*, 1996).

Of the 23 studies reviewed in Table 2c, 56 percent were from Europe (10 Northeast Atlantic Ocean, 2 Mediterranean Sea, 1 Baltic Sea), 22 percent from the United States of America (3 Atlantic, 2 Pacific), 13 percent from Japan, and 9 percent on the Pacific high seas. Seventeen of the studies observed coastal demersal gillnets and/or trammel nets, one was of a demersal wreck gillnet, one was of a coastal demersal gillnet entangled on a FAD, one was of deep water demersal gillnets, two of high seas driftnets, and two were of coastal driftnets deposited on the seafloor (Table 2c).

Three of the 23 studies were based on observations of ALDFG from gillnet and trammel net fisheries, the other 20 having deployed simulated derelict gear (Table 2c). Of the 20 using simulated derelict gear, most (14, 70 percent) employed commercial gear designs and fishing methods, and selected sites within commercial fishing grounds. Fifteen of the 23 studies (65 percent) monitored the catch and condition of the gear via *in situ* methods, 7 (30 percent) via periodic retrieval of subset of gear, and 1 study hauled the gear after a period of soaking without conducting periodic monitoring during the soak (Table 2c). Fourteen of the 23 studies estimated short-term (hours to weeks) ghost fishing mortalities. Eight of these 14 (57 percent) counted the number of organisms that became newly captured since a previous observation, marking catch to enable the identification of new catch in a subsequent monitoring event. The remainder (6 of 14, 43 percent) counted the number of recently captured organisms in "good condition" observed present at the time of monitoring. The fishing efficiency of derelict gear / simulated derelict gear at the end of the study period was compared with its initial fishing efficiency in 3 studies, and was compared to in-use gear during the same period and area as the study gear in 5 studies. In ten studies, derelict gear was monitored until it ceased to retain any fishing efficiency or a small proportion of initial efficiency, by either monitoring temporal changes in ghost fishing catch rates or in net condition factors that are an indicator of catch capacity. Nine studies fitted an ALDFG catch efficiency decay model to short-term ghost fishing catch rate data to: (i) estimate a total ghost fishing mortality level over a study period that ended before derelict gear ceased to ghost fish, or for the estimated duration of fishing efficiency; and/or (ii) estimate the duration of fishing efficiency (Table 2c).

The two studies of simulated derelict driftnets monitored net condition over time. Mio *et al.* (1990) observed five 2 km long driftnets had formed a single large tangled mass after 3 months of soaking. Gerrodette, Choy and Hiruki (1987, 1990) observed four driftnets 50 m, 100 m, 350 m and 1 km long had been reduced to < 5 percent of their original lengths after between 0.5 and 10 days of soaking.

Numerous units were used to report ghost fishing mortality rates: (i) number (n=4) or weight (n=2) of organisms caught per unit area of net for the full duration of fishing efficiency of fish; (ii) number of fishes per unit area of net for the full duration of fishing efficiency (n=4) or to reach 5 percent of initial efficiency (n=1); (iii) number of crustaceans per unit area of net for the full duration of fishing efficiency (n=1); (iv) number of fishes per unit length of net for the full duration of fishing efficiency (n=2); (v) number of market species per unit area of net (n=1), weight of target species per unit area of net (n=2), number of market species per unit length of net (n=1), and weight of target species per unit length of net (n=1) for the full duration of fishing efficiency; (vi) number and weight of non-market species per unit area of net for the full duration of fishing efficiency (n=1); (vii) number of organisms, market species or fish per unit area of net (n=4, 2 and 1, respectively) or unit length of net (n=4) per unit time based on the observed level of catch during the study period; (viii) percentage of fish catch efficiency of derelict nets surveyed in an area relative to that of in-use gear (n=1); and (ix) weight of target species per unit area of net per day once catch efficiency declined to 20–30 percent of the initial fishing efficiency (Table 2c).

Similarly, various units were likewise used for the duration of fishing efficiency: (i) time for fishing efficiency to cease for all species (n=7), fishes (n=7), target species (n=1), crustaceans (n=1), (ii) time for fishing efficiency to decline to < 1 percent of in-use gear (n=2); (iii) time for fishing efficiency to decline to < 5 percent of initial efficiency (n=1); (iv) time for fishing efficiency to decline to < 7 percent of initial efficiency (n=1); and (v) time for fishing efficiency to decline to < 30 percent of initial efficiency.

The mean of ghost fishing mortality rate estimates, in units of the number of fishes per unit area of gillnets and trammel nets for the full duration of fishing efficiency (n=4), and to reach 5 percent of initial catch efficiency (n=1), was 92.8 fish per 100 m^2 of net (± 47.2 SEM, range 22.4–275, n=5) (Table 2c). There was very high variability, with 51 percent CV, with 4 of 5 of the records falling outside of ± one SD from the mean. There was similar high variability when using results using units of the number of organisms per unit area of net for the full duration of finfish fishing efficiency, with a mean of 83.1 organisms per 100 m^2 of net (± 25.5 SEM, range 18.7–131.0, n=4), 31 percent CV, and 3 of the 4 records falling outside ± one SD from the mean.

The mean of duration of ghost fishing efficiency estimates in units of the number of weeks for ALDFG to cease catch efficiency of all organisms (n=7), decline to < 1 percent of the catch rate of in-use gear (n=2), decline to < 5 percent of initial ghost fishing efficiency (n=1) and decline to < 7 percent of initial ghost fishing efficiency (n=1) was 35.0 weeks (± 6.4 SEM, range 8.3–80.1, n=11). An 18.2 percent CV, with 7 of the 11 records falling outside ± one SD from the mean, indicates moderate dispersion in estimates. Relatively higher variability was found when using results presented in units of the number of weeks to cease fishing efficiency of fishes, with a mean of 37.5 weeks (± 20.4 SEM, range 3.1–156.0, n=7), 54 percent CV, and 5 of the 7 records falling outside ± one SD from the mean.

The large dispersion in estimates of ghost fishing mortality rates and duration of ghost fishing efficiency is probably a result of extremely small sample sizes as well as from the pooling of data from studies employing variable methods, studying ALDFG with variable gear designs and materials, and at sites with variable environmental and physiographic conditions (Section 1.4).

More than half of the sparse number of relevant studies were conducted in Europe. Most are dated, so that results might not characterize current fisheries. Studies were spatially and temporally patchy, and there was large dispersion in estimates. A wide variety of units were used to report ghost fishing catch rates and duration of fishing efficiency, precluding the pooling of records and comparing findings. Most studies designed to estimate ghost fishing mortality rates and the duration of fishing efficiency by ALDFG have used simulated derelict gear. Most studied demersal nets set at coastal sites within commercial fishing grounds at relatively shallow depths. Most studies monitored the catch and condition of the gear via *in situ* methods, others periodically retrieved a subset of gear. Many of the reviewed studies fit a ghost fishing efficiency decay model to short-term ghost fishing catch rate data to estimate the duration of fishing efficiency and the total ghost fishing mortality level for the estimated duration of fishing efficiency.

3.2.4 Research priorities for robust regional and global estimates of gillnet and trammel net ghost fishing mortality levels

Findings highlight fundamental gaps in information to support robust estimates of regional and global rates and levels of ghost fishing mortality by individual species and higher taxonomic groups. Each of the terms of Equation 3 represent basic information needed to estimate the total level of ghost fishing mortality in a spatially explicit area over a selected time period. There are large information deficits for each of the terms. The following is a summary of the key information gaps:

- There are small sample sizes for rates of producing derelict gear, density of derelict gear, ghost fishing mortality rates and levels, by region and gear type. This reduces the certainty in the estimation of means.
- A portion of the small number of studies employed methods that reduced the certainty of findings, such as introducing sampling bias in selecting study sites and not accounting for organisms that are caught in a ghost net but are completely removed in between two monitoring events. This increases the margin of error of estimated means.
- There was under-representation by region and gear type for estimates of rates of producing derelict gear, of the density of derelict gear, and of ghost fishing mortality rates and levels. This lack of balance in sample sizes by region and types of gillnets and trammel nets would reduce the accuracy of estimates if data across regions and fishing methods were pooled and then raised to produce a global estimate.
- Variable units have been used to report estimated rates of abandonment, loss and discarding gear, density of ALDFG, and ghost fishing mortality rates and levels. This prevents the pooling of some records, reducing sample sizes available to estimate means.
- There was wide dispersion in estimates of rates of producing derelict gear, density of ALDFG, and of ghost fishing mortality rates. Raised estimates will similarly have large estimates of error.
- Many estimates are dated. They may not characterize ALDFG and ghost fishing in contemporary fisheries.
- There are no available databases providing estimates of levels of global gillnet and trammel net fishing effort (Luca Garibaldi, FAO, personal communication, 2015; e.g. the Global Capture Production database does not contain information on fishing effort or catch levels by gear type, FAO, 2015). This information could, in theory, be used to raise estimates of rates of producing ALDFG, the density of ALDFG, and ghost fishing mortality levels.

In summary, these information gaps would result in very high uncertainty in an estimate of a globally averaged ghost fishing mortality level, especially for taxa that are rare-event captures, such as marine megafauna. Four priorities to fill these identified information gaps are to:

- Harmonize data collection protocols on ALDFG from gillnet and trammel net fisheries in logbook and observer programmes where they are in place, and fill gaps in ALDFG data collection protocols where they are not currently in place. Producing larger logbook and observer programme datasets of records of rates and amounts of abandoned, lost and discarded fishing gear, and rates of fishing vessel encounters with ALDFG produced by other vessels, using standardized data collection protocols, provides a priority resource for research on ALDFG and ghost fishing (discussed further in Chapter 4).
- Conduct additional research, using best practice methods identified in this study to reduce sources of uncertainty, to estimate ghost fishing mortality rates and levels, balanced spatially, temporally and by type of gillnet and trammel net

fishing gear and method. Employ standardized units to report estimated rates of abandonment, loss and discarding of gear, density of ALDFG, and ghost fishing mortality rates and levels.
- Conduct meta-analyses of data from relevant compiled studies to produce more precise and accurate estimates of rates of producing ALDFG, density of ALDFG, and ghost fishing mortality rates. Owing to the larger sample size plus the number of studies, correctly designed meta-analyses can provide estimates with increased precision and accuracy over estimates from individual studies, with increased statistical power (e.g. Borenstein *et al.*, 2009; Musyl *et al.*, 2011).
- Develop robust estimates of regional and global gillnet and trammel net fishing effort. This activity is prioritized both to identify regions where managing ALDFG by these gear types is most important, and to support estimates of ghost fishing mortality levels.

4. Monitoring and management by regional fishery bodies and arrangements

4.1 INTRODUCTION, STUDY SCOPE AND METHODS

An assessment was conducted to benchmark international monitoring and management of ALDFG and ghost fishing from marine gillnet and trammel net fisheries. Regional fishery bodies (RFBs) and arrangements (RFAs), including regional fisheries management organizations (RFMOs), were selected for inclusion in the study sample if they: (i) have the competence to establish binding measures for marine capture fisheries; (ii) have competence over fishery resources that are captured in an active gillnet or trammel net fishery; and (iii) the agreement that formed the RFB or RFA is in force (Table 3) (FAO, 2011b; Gilman, Passfield and Nakamura, 2012). A regional or global "body" is an organization that has established a secretariat that operates under a governing body of member States, while a regional or global "agreement" does not have such a secretariat (FAO, 2013). Hereafter, the bilateral (two parties) and multilateral (three or more parties) bodies and arrangements included in the study sample are collectively referred to as RFB/As.

The RFMOs are a type of RFB/A with the competence to establish binding conservation and management measures. They provide a formal mechanism for fishing States and States in whose jurisdiction fishery resources occur to meet their international obligation to cooperate to sustainably govern shared living marine resources throughout their distributions (UNCLOS Articles 63, 66(5), 118; Code Articles 7.1.5, 6.12 [FAO. 1995]; PSMA Article 4(1)(b) [FAO, 2009]). Since the first was established in 1923, RFMOs have played a critical role in multilateral fisheries governance of stocks that straddle or occur beyond national jurisdiction and of highly migratory stocks. While spatial, fishery and taxonomic gaps remain, a large proportion of global marine fisheries are now managed by one or multiple RFMOs, and most areas of the high seas are now covered by at least one RFMO (Lodge *et al*., 2007; FAO, 2011b; Gilman, Passfield and Nakamura, 2012).

The assessment identified the gear types employed in active fisheries that catch covered species/stocks (fishery resources over which the RFB/A is mandated to manage) in order to determine whether an RFB/A manages active gillnet or trammel net fisheries. Convention and agreement texts typically identify covered species or stocks over which the RFB/A has a mandate, and do not identify fisheries or gear types that the convention or agreement covers. Therefore, this study determined which RFB/As to include by identifying whether an RFB/A's covered fishery resources are caught in an active gillnet or trammel net fishery. This was determined by reviewing: (i) relevant databases identifying catch by gear type; (ii) conservation and management measures to identify what gear types they apply to; (iii) authorized vessel lists to identify gear types of vessels authorized to fish in the convention area for covered resources; (iv) member and cooperating non-member reports to the RFB/A that identify the gear types used by their flag vessel to catch covered fishery resources; (v) IUU fishing vessel lists to identify what gear types were employed by vessels presumed to have carried out IUU fishing for resources covered by the RFB/A; and (vi) input from secretariat staff on gear types of active fisheries over which the RFB/A has competence.

The convention texts or agreements that established the RFB/As were reviewed to determine whether they include an explicit mandate to monitor and/or control ALDFG and ghost fishing. Binding CMMs and logbook and observer data collection protocols designed to monitor and mitigate (prevent and remediate) ALDFG and ghost fishing adopted by the RFB/As included in the study were summarized. The CMMs were included if they had a direct connection to monitoring or mitigating ALDFG and ghost fishing, reviewed in Table 1. Measures designed to deter IUU fishing can contribute to reducing intentional abandonment and discarding of fishing gear (Table 1). Only measures designed to curtail IUU fishing directly related to deterring non-compliance with requirements to monitor and control ALDFG and ghost fishing were included in the assessment. Those CMMs related to deterring IUU fishing with broader, more general aims indirectly related to ALDFG and ghost fishing were not included in the assessment. The assessment included only binding measures, as the adoption of binding measures, as opposed to voluntary measures, potentially demonstrates a stronger political will by parties of an RFB/A to address issues resulting from ALDFG. Moreover, binding measures may be more likely to be implemented in the domestic legal and regulatory systems of member States (e.g. Barth and Dette, 2001).

TABLE 3
RFB/As with the competence to establish binding measures for marine capture fisheries, and the subset with competence over fishery resources captured in an active gillnet or trammel net fishery, where the agreement that formed the RFB/A is in force

Body/Arrangement	Acronym	Active gillnet or trammel net fishery catch covered resources
Global, transocean and mandate broader than managing fishing		
International Whaling Commission	IWC	
Commission for the Conservation of Antarctic Marine Living Resources	CCAMLR	
North Atlantic Salmon Conservation Organization	NASCO	X
North Pacific Anadromous Fish Commission	NPAFC	X
Tuna RFMOs		
Commission for the Conservation of Southern Bluefin Tuna	CCSBT	
Indian Ocean Tuna Commission	IOTC	X
Inter-American Tropical Tuna Commission	IATTC	
International Commission for the Conservation of Atlantic Tunas	ICCAT	X
Western and Central Pacific Fisheries Commission	WCPFC	X
Other RFB/As		
General Fisheries Commission for the Mediterranean	GFCM	X
International Pacific Halibut Commission	IPHC	
Joint Norwegian-Russian Fisheries Commission	JNRFC	X
Northwest Atlantic Fisheries Organization	NAFO	
North East Atlantic Fisheries Commission	NEAFC	
Pacific Salmon Commission	PSC	X
Regional Commission for Fisheries	RECOFI	X
South East Atlantic Fisheries Organisation	SEAFO	
Southern Indian Ocean Fisheries Agreement	SIOFA	X
South Pacific Regional Fisheries Management Organisation	SPRFMO	

This assessment adapted methods employed in two previous studies. Gilman, Passfield and Nakamura (2012) assessed ecosystem-based governance of bycatch by RFMOs having three or more parties, and included a criterion that considered whether binding conservation and management measures to mitigate ghost fishing from ALDFG had been adopted. Gilman (2015) assessed RFB/As' data collection protocols and management measures to mitigate ALDFG and ghost fishing in marine capture fisheries. Consistent with Gilman, Passfield and Nakamura (2012) and Gilman (2015), this study excluded the Convention on the Conservation and Management of the Pollock Resources in the Central Bering Sea (CCBSP) and the International Baltic Sea Fishery Commission (IBSFC). There are no active CCBSP-managed fisheries because, since its convention came into effect in 1995, owing to low pollock biomass, the annual harvest level has been set at zero and no individual national quotas have been established (CCBSP, no date, 2012). The IBSFC was dissolved and ceased activities on 31 December 2005 (Aps et al., 2007; FAO, 2011c). Three bilateral bodies and arrangements that, as RFMOs, are multilateral and thus have at least three parties (e.g. Keohane, 1990), also make binding decisions (IPHC, JNRFC, PSC) were considered for inclusion in this study. However, they were excluded by Gilman, Passfield and Nakamura (2012) because their convention areas were exclusively or predominately under national jurisdiction, and as a result, were presumed to probably have governance structures that differ from RFMOs with at least three parties, whose convention areas are predominantly on the high seas (Lugten, 2010). Moreover, two RFMOs whose agreements entered into force since Gilman, Passfield and Nakamura (2012) were considered for inclusion in the study sample (Southern Indian Ocean Fisheries Agreement, and Convention on the Conservation and Management of High Seas Fishery Resources in the South Pacific Ocean).

Four of the RFB/As considered for inclusion in this assessment are global or transoceanic, and three of these have mandates that are broader than managing marine fisheries (CCAMLR, NASCO, NPAFC). These are regional bodies with the competence to establish binding fisheries CMMs, including measures related to ALDFG, and thus their inclusion was deemed relevant.

Gilman, Passfield and Nakamura (2012) excluded the International Whaling Commission (IWC) from their sample because it does not manage fisheries for marine fish or shellfish species (IWC, 1946). The present study did consider the IWC for inclusion in the study sample, consistent with Gilman (2015), because there are active fisheries for whales for scientific research permissible under Article VIII of the convention, active indigenous subsistence whaling permitted under current IWC regulations, and, while a moratorium has been in effect since the 1985/86 season, Norway and Iceland conduct commercial whaling under objection or reservation to the moratorium (IWC, 1946, 2013b).

Of the 19 assessed RFB/As (Table 3), the following were excluded from the study sample based on the determination that covered resources are not caught in an active gillnet or trammel net fishery: CCAMLR, CCSBT, IATTC, IPHC, IWC, NAFO, NEAFC, SEAFO and SPRFMO (NEAFC, 2008; Lopez-Abellan *et al.*, 2010; CCAMLR, 2012, 2013a, 2013b; IWC, 2011, 2013b; CCSBT, 2013; Bob Kennedy, CCSBT Secretariat, personal communication, 2014; IATTC, 2013, 2014a, 2014b; IPHC, 2013, 2014; NAFO, 2013; Ricardo Federizon, NAFO, personal communication, 2014; SEAFO, 2010, 2014; SPRFMO, 2013, 2014).

4.2 RESULTS: RFB/A MONITORING AND MANAGEMENT OF ALDFG AND GHOST FISHING

For each of the ten RFB/As included in the study, the following sections provide information on evidence for active gillnet and/or trammel net fisheries that take fishery resources covered by the RFB/A, and whether the RFB/A's mandate explicitly calls for monitoring and controlling ALDFG and ghost fishing. Summaries are also provided of data collection protocols related to ALDFG, and CMMs related to preventing or remediating ALDFG and ghost fishing (Table 4). For information on the area of competence of these RFB/As, see FAO (2011b).

TABLE 4

RFB/As with the competence to establish binding CMMs for marine capture fisheries that have competence over fishery resources captured in an active gillnet or trammel net fishery, whether the mandate explicitly calls for monitoring and controlling ALDFG and ghost fishing, and CMMs and observer and logbook data collection protocols related to monitoring, preventing or remediating ALDFG and ghost fishing

Regional fishery body/ arrangement[1]	Types of gillnets and/or trammel nets employed in active fisheries that catch covered species/stocks	Convention specifically mandates monitoring and/or controlling ALDFG and/or ghost fishing?	CMMs and data collection protocols on monitoring and controlling ALDFG and/or ghost fishing by gillnets or trammel nets
Mandate broader than managing fisheries			
NASCO	Surface gillnet (NASCO, 2011).	N	Closed areas to targeted salmon fishing, including on the high seas and in areas beyond 12 nautical miles from the baseline of coastal States, excluding an area around West Greenland and within the area of fisheries jurisdiction of Faroe Islands (NASCO, 1983).
NPAFC	Driftnet (NPAFC, 2010; NFMS, 2012; Vladimir Radchenko, NPAFC Secretariat, personal communication, 2014).	N	Prohibition on directed high-seas fishing for North Pacific anadromous fish (NPAFC, 1992).
Tuna RFMOs			
IOTC	Driftnet, set gillnet (IOTC, no date [Table 11], 2009, 2010, 2014a, 2014b).	N	High seas large-scale driftnets are banned in the IOTC area of competence (IOTC, 2012). Gear marking of flag or radar reflector buoys by day and light buoys by night is required for the ends of nets, lines and gear in the sea sufficient to indicate their position and extent (IOTC, 2001, 2013a). Marker buoys and similar objects intended to indicate the location of fixed fishing gear (IOTC, 2001, 2013a). Onboard observers are to collect information on the amount of ALDFG (IOTC, 2013c).
ICCAT	Anchored gillnet (ICCAT, 2014).	N	Requirement to mark fishing gear to identify ownership (ICCAT, 2003a). Driftnets for fisheries of large pelagics are banned in the Mediterranean (ICCAT, 2003c).
WCPFC	Gillnet (WCPFC, 2013a).	Y	High seas large-scale driftnets are banned on the high seas in the WCPFC Convention Area (WCPFC, 2008). Observers of the WCPFC Regional Observer Programme (currently placed in purse seine, longline and pole-and-line fisheries) are to record whether the vessel found ALDFG from another vessel (WCPFC, no date; SPC, 2009a, 2009b).
Other RFMOs			
GFCM	Encircling gillnet, driftnet, staked gillnet, anchored gillnet, combination gillnet – trammel net, trammel net (GFCM, 2014).	N	Driftnets for fisheries of large pelagics are banned in the Mediterranean (GFCM, 2005). Driftnets > 2.5 km are banned, nets >1 km are required to remain attached to the vessel unless the vessel is within the 12 mile coastal band, in which case a vessel may detach itself from the net provided it keeps the net under constant observation (GFCM, 1997b). The use of gillnets with monofilament with a twine diameter > 0.5 mm is banned (GFCM, 2012).
JNRFC[2]	Gillnet (JNRFC, no date a; FCI, 2010; Lockwood *et al.*, 2010).	N	A Norwegian regulation requires vessel operators to record in catch reports whether or not gear was lost during each fishing operation (Directorate of Fisheries, 2012).

TABLE 4 (CONTINUED)

Regional fishery body/ arrangement[1]	Types of gillnets and/or trammel nets employed in active fisheries that catch covered species/stocks	Convention specifically mandates monitoring and/or controlling ALDFG and/or ghost fishing?	CMMs and data collection protocols on monitoring and controlling ALDFG and/or ghost fishing by gillnets or trammel nets
PSC[2]	Driftnet, gillnet, net, reefnet (PSC, 2013a, 2013b).	N	None[3]
RECOFI	Anchored gillnet, driftnet (RECOFI, 2008 [Appendix G], 2013a, 2013b).	N	None
SIOFA	Deep sea gillnet, driftnet (SIOFA, 2013).	N	None

[1] Acronyms defined in Table 3, and listed under "Abbreviations and acronyms" at front of publication.
[2] Bilateral bodies and agreements.
[3] PSC does not adopt fisheries regulations. Instead, PSC recommends fishery management measures that are adopted and implemented by the two PSC parties (PSC, 2013a [Article IV]).

4.2.1 General Fisheries Commission for the Mediterranean (GFCM)

Active gillnet or trammel net fisheries under GFCM's area of competence
Established by the Agreement for the Establishment of the General Fisheries Commission for the Mediterranean, an agreement under Article XIV of the FAO Constitution, the agreement does not identify specific fisheries or gear types that are to be managed by the GFCM (GFCM, 1997a). The agreement mandates GFCM to, "promote the development, conservation, rational management and best utilization," of all living marine resources in the area covered by GFCM (Article III(1), GFCM, 1997a).

The GFCM Record of Vessels over 15 Metres Authorized to Operate in the GFCM Area identified the following gillnet or trammel net gear types: encircling gillnet, driftnet, staked gillnet, anchored gillnet, combination gillnet – trammel net, and trammel net (GFCM, 2014). The GFCM manages fisheries for small pelagics, bottom fisheries for mixed demersal fish and invertebrates, as well as fisheries for large pelagics (GFCM, 2011a). Assessments and advice for fisheries for large pelagic species, however, are provided by ICCAT (Pilar Hernandez, GFCM Secretariat, personal communication, 2014).

Mandate Includes monitoring and/or controlling ALDFG and ghost fishing?
The Agreement does not explicitly mandate the GFCM to monitor, prevent or remediate ALDFG or ghost fishing (GFCM, 1997a).

Relevant conservation and management measures
A GFCM recommendation bans driftnets > 2.5 km, requires nets > 1 km to remain attached to the vessel unless the vessel is within the 12 mile coastal band, in which case a vessel may detach itself from the net provided it keeps the net under constant observation (GFCM, 1997b). To reduce fishing mortality of juvenile swordfish, a GFCM recommendation bans driftnets for fisheries of large pelagics in the Mediterranean (GFCM, 2005). To mitigate cetacean bycatch, a GFCM recommendation bans the use of gillnet fisheries using monofilament with a twine diameter greater than 0.5 mm starting 1 January 2015 (GFCM, 2012).

Relevant observer and logbook data collection protocols
The GFCM does not implement a regional observer programme (GFCM, 2011a). The GFCM logbook data collection protocols, required for use by vessel > 15 m in

length overall, do not call for vessel operators to report whether they abandoned, lost or discarded any fishing gear or encountered any ALDFG during fishing operation (GFCM, 2011b [Annex 1]).

4.2.2 Indian Ocean Tuna Commission (IOTC)

Active gillnet or trammel net fisheries under IOTC's area of competence

The IOTC agreement identifies 16 species of tuna and tuna-like species and billfishes that are covered by the agreement but does not identify covered fisheries or gear types (IOTC, 1993). The IOTC fisheries data reporting requirements apply to any contracting party and cooperating non-contracting party vessel under its flag that catches covered species in the IOTC area, regardless of what gear type is employed by the vessel (IOTC, no date). Gillnet and trammel net fishing gear types for which statistics on the capture of IOTC covered species have been reported to date include: driftnet and set gillnet (IOTC, no date [Table 11], 2009, 2010, 2014a). The IOTC record of currently authorized vessels includes vessels that use gillnets (IOTC, 2014b).

Mandate includes monitoring and/or controlling ALDFG and ghost fishing?

The IOTC agreement does not specifically mandate the IOTC to monitor or manage ALDFG or ghost fishing (IOTC, 1993).

Relevant conservation and management measures

The IOTC (2012) bans large-scale (> 2.5 km in length) high seas driftnets within the IOTC area of competence.

The IOTC (2001, 2013a) requires that gear be "marked appropriately, e.g. the ends of nets, lines and gear in the sea, shall be fitted with flag or radar reflector buoys by day and light buoys by night sufficient to indicate their position and extent", which could contribute to avoiding accidental gear loss when damaged by passing vessels or active gear (Table 1). In addition, these measures require "Marker buoys and similar objects floating and on the surface, and intended to indicate the location of fixed fishing gear, shall be clearly marked at all time with the letter(s) and/or number(s) of the vessel to which they belong," which might prevent ALDFG (Table 1).

Relevant observer and logbook data collection protocols

The IOTC (2011) requires a minimum of 5 percent observer coverage "for each gear type by the fleet of each [contracting party and cooperating non-contracting party] while fishing in the IOTC area of competence of 24 metres overall length and over, and under 24 metres if they fish outside their Exclusive Economic Zone (EEZ)." A template observer trip report adopted by the IOTC Scientific Committee and endorsed by the IOTC, calls for the collection of information on, "lost fishing gear, such as length of line lost, amount of net, and other gear such as floats," (IOTC, 2013c).

The IOTC (2013a) requires vessels > 24 m in length overall and authorized to fish in the IOTC convention area to maintain a logbook. The IOTC (2013b [Annex II and III]), which identifies information to be recorded in logbooks by operators of longline, purse seine, gillnet, pole-and-line, handline and trolling vessels, does not require the recording of information on the vessel's abandonment, loss or discarding of fishing gear, or encounters with ALDFG from other vessels.

4.2.3 International Commission for the Conservation of Atlantic Tunas (ICCAT)

Active gillnet or trammel net fisheries under ICCAT's area of competence

The International Convention for the Conservation of Atlantic Tunas (ICCAT) does not identify specific fisheries or gear types covered by its convention but does state that the convention applies to "populations of tuna and tuna-like fishes (the Scombriformes with the exception of the families Trichiuridae and Gempylidae and the genus *Scomber*) and such other species of fishes exploited in tuna fishing in the Convention area as are not under investigation by another international fishery organization" (Article IV, ICCAT, 1992). The ICCAT record of vessels (includes fishing vessels authorized to fish in the ICCAT convention area that are longer than 20 m, fish actively for bluefin tuna, catch swordfish in the Mediterranean Sea, and fish for bigeye and yellowfin tuna) includes anchored gillnet (ICCAT, 2014).

Mandate includes monitoring and/or controlling ALDFG and ghost fishing?

Its convention does not explicitly mandate ICCAT to monitor, prevent or remediate ALDFG or ghost fishing (ICCAT, 1992).

Relevant conservation and management measures

An ICCAT recommendation requires parties to mark fishing gear "in such a way that they can be readily identified in accordance with generally accepted standards such as the FAO standard specification for the marking and the identification of fishing vessels" (ICCAT, 2003a). Gear marking to identify ownership might prevent ALDFG (Table 1).

An ICCAT recommendation bans driftnets for fisheries of large pelagics in the Mediterranean (ICCAT, 2003c).

Relevant observer and logbook data collection protocols

Data collection protocols for parties observer programmes, for the ICCAT Regional Observer Programme for Eastern Atlantic and Mediterranean Bluefin Tuna, and for logbook data collection requirements for vessels catching bluefin tuna in the eastern Atlantic and Mediterranean do not call for collecting information on a vessel's abandonment, loss or discarding of fishing gear or encounters with ALDFG from other vessels (ICCAT, 2012a [Paragraphs 90 and 91, and Annex 2 and 7]; 2012b).

Data collection protocols under the ICCAT Regional Observer Programme for Bigeye and Yellowfin Tuna and for logbook data collection requirements for vessels catching bigeye and yellowfin tunas do not call for the recording of information on a vessel's abandonment, loss or discarding of fishing gear or encounters with ALDFG from other vessels (ICCAT, 2003b, 2011 [Annex 1 and 3]; 2012b).

4.2.4 Joint Norwegian-Russian Fisheries Commission (JNRFC)

Active gillnet or trammel net fisheries under JNRFC's area of competence

The 1975 Framework Agreement (Agreement between the Government of the Kingdom of Norway and the Government of the Union of Soviet Socialist Republics on Co-operation in the Fishing Industry), which established the JNRFC, and is complemented by the Mutual Access Agreement of 1976 and the 2010 Grey Zone Agreement (the latter was not renewed and is no longer in force), mandates the JNRFC to negotiate total allowable catches, allocation of these fishery resources between Norway, the Russian Federation and third States, and to establish reciprocal access to fisheries in national zones and quota exchanges for joint and national stocks (JNRFC, 1975, 2010). Decisions of the JNRFC are based on advice provided by the International Council for the Exploration of the Sea (ICES) in response to requests by Norway and the Russian Federation (JNRFC, no date a). The framework agreement does not identify specific fisheries or gear types that fall under the JNRFC's competence area (JNRFC, 1975; Molenaar, Iferink and Rothwell, 2013). Measures adopted by the JNRFC have been for shrimp demersal trawl fisheries and fisheries that target joint stocks of demersal species of northeast Arctic cod, haddock, capelin and Greenland halibut (JNRFC, no date a, no date b). Gillnet is one of the fishing gear types identified as being used by fisheries to target these demersal stocks managed by the JNRFC (JNRFC, no date a; FCI, 2010; Lockwood *et al.*, 2010).

Mandate includes monitoring and/or controlling ALDFG and ghost fishing?
The framework agreement does not mandate the JNRFC to monitor, prevent or remediate ALDFG or ghost fishing (JNRFC, 1975).

Relevant conservation and management measures
No JNRFC measures relate to monitoring, preventing or remediating ALDFG or ghost fishing (JNRFC, no date a).

Relevant observer and logbook data collection protocols
A Norwegian regulation requires vessel operators to record in catch reports whether gear was lost during each fishing operation (Directorate of Fisheries, 2012). No JNRFC requirements for observer or logbook data collection on Norwegian or Russian flagged vessel loss, abandonment or discarding of fishing gear, or encounters with ALFG from other vessels, have been adopted (JNRFC, no date a).

4.2.5 North Atlantic Salmon Conservation Organization (NASCO)

Active gillnet or trammel net fisheries under NASCO's area of competence
The Convention for the Conservation of Salmon in the North Atlantic Ocean mandates NASCO to propose regulatory measures for salmon fisheries in the area of fisheries jurisdiction of one party that takes salmon originating in the rivers of another party (Article 7[1], NASCO, 1983). Regulatory measures or decisions have been adopted by NASCO for the salmon fisheries at Faroe Islands and West Greenland in most years since NASCO's establishment in 1984. Currently, a relatively small West Greenland nearshore surface gillnet internal-use fishery is the one active NASCO-managed fishery. The reported catch in 2012 was 33 tonnes (9 900 salmon) (NASCO, 2013). While there is one salmon river in Greenland, stocks fished in Greenland fisheries are from North America and Southern European rivers (NASCO, 2008). Under NASCO decisions there has been no commercial salmon fishery at Faroe Islands since the early 1990s, and no non-commercial salmon fishing since 2000 (NASCO, 2010, 2011). NASCO-member States of origin retain their management of salmon fisheries in national homewaters (NASCO, 1983; Crozier *et al.*, 2004).

Mandate includes monitoring and/or controlling ALDFG and ghost fishing?
Its convention does not explicitly mandate NASCO to monitor, prevent or remediate ALDFG or ghost fishing (NASCO, 1983). The convention obligates NASCO members of the North American Commission "with respect to its vessels and the area under its fisheries jurisdiction, take the measures necessary to minimize by-catches of salmon originating in the rivers of the other member" (Article 7[2], NASCO, 1983), which might be interpreted to include salmon ghost fishing mortality in ALDFG. The ICES has advised that the current salmon fisheries probably have nominal influence on the marine ecosystem, but may affect species composition in riverine ecosystems (NASCO, 2013a). Throughout the NASCO convention area, an increasing proportion of salmon catch is taken in rivers or estuaries rather than coastal fisheries (NASCO, 2013a). NASCO management of distant-water salmon-targeted fisheries represents but one small component of NASCO's broad comprehensive North Atlantic salmon conservation activities (NASCO, 2012).

Relevant conservation and management measures

The convention created a large area closed to targeted fisheries for Atlantic salmon, including the high seas, and in areas beyond 12 nautical miles from the baseline of coastal States, excluding an area around West Greenland (up to 40 nautical miles from the baseline) and within the area of fisheries jurisdiction of Faroe Islands (NASCO, 1983).

Relevant Observer and Logbook Data Collection Protocols

NASCO's Minimum Standard for Catch Statistics does not call for reporting information on ALDFG (NASCO, 1993). Data collection protocols of a voluntary logbook system employed in the Greenland fishery do not include reporting information on vessels abandonment, loss or discarding of gear or encounters with ALDFG from other fisheries (NASCO, 2013a). There is no NASCO regional or domestic observer programme for the Greenland fishery (NASCO, 2013b [paragraph 7.3]).

4.2.6 North Pacific Anadromous Fish Commission (NPAFC)

Active gillnet or trammel net fisheries under NPAFC's area of competence

The Convention of Anadromous Stocks in the North Pacific Ocean has a broad aim of promoting the conservation of anadromous stocks in the convention area. The convention mandates NPAFC to manage specific anadromous fish stocks in the convention area, and does not identify fisheries or gear types managed by the Commission (NPAFC, 1992, 2012a). The convention prohibits directed fisheries for anadromous fish on the high seas, calls for minimized incidental catch of anadromous fish, and prohibits the retention of anadromous fish taken incidentally during fishing directed at non-anadromous fish (NPAFC, 1992). Incidental capture of anadromous species in fisheries that occur in the convention area occurs in driftnet and other fisheries (NPAFC, 2010; NMFS, 2012; Vladimir Radchenko, NPAFC Secretariat, personal communication, 2014).

Mandate includes monitoring and/or controlling ALDFG and ghost fishing?

Its convention does not explicitly mandate NPAFC to monitor, prevent or remediate ALDFG or ghost fishing (NPAFC, 1992). The convention obligates NPAFC members to minimize the "incidental taking" of anadromous fish, defined by the Convention as the "catching, taking or harvesting a species or stock of fish while conducting directed fishing for another species or stock of fish", and as such does not include ghost fishing mortality in ALDFG (Article II(5) and Article III(1)(b), NPAFC, 1992).

Relevant conservation and management measures

The convention prohibits directed high-seas fishing for anadromous fish in the convention area (NPAFC, 1992). Soon after the convention was adopted, NPAFC successfully ended directed high seas salmon fishing in the North Pacific by the parties, which had been mainly conducted using large-scale drift gillnets, and there has been a large decrease in illegal high seas driftnet fishing in the convention area (NPAFC, 2010, 2012a).

Relevant observer and logbook data collection protocols

The NPAFC does not require vessels operating in the convention area to use logbooks and does not manage a regional fisheries observer programme. Instead, activities focus on enforcing the ban on high-seas driftnetting for anadromous fish in the NPAFC convention area (NPAFC, 2012b).

4.2.7 Pacific Salmon Commission (PSC)

Active gillnet or trammel net fisheries under PSC's area of competence
The Treaty between the Government of Canada and the Government of the United States of America Concerning Pacific Salmon, which established the Pacific Salmon Commission, covers fisheries that harvest or seek to harvest salmon. Fishery resources subject to the treaty are Pacific salmon stocks that originate in the waters of one party (either Canada or the United States of America) and: (i) are subject to interception by the other party; (ii) affect the management of stocks of the other party; or (iii) affect biologically the stocks of the other party (PSC, 2013a [Article 1]). The treaty, and PSC regulatory advice, identify several specific fisheries that are covered by the treaty, including those using driftnet, gillnet, and unspecified net gears (PSC, 2013a, 2013b).

Mandate includes monitoring and/or controlling ALDFG and ghost fishing?
The treaty does not specifically mandate the PSC to monitor, prevent or remediate ALDFG or ghost fishing (PSC, 2013a).

Relevant conservation and management measures
Regulatory advice from the PSC for the most current (2013) salmon season did not address monitoring, preventing or remediating ALDFG (PSC, 2013b).

Relevant observer and logbook data collection protocols
The PSC does not manage a logbook or regional fisheries observer programme (PSC, 2013a). It does not adopt regulations for salmon fisheries but instead recommends fishery regimes that are transmitted to the two member States, which then adopt the fishery regimes, and establish and enforce regulations to implement the adopted fishery regimes (PSC, 2013a [Article IV]).

4.2.8 Regional Commission for Fisheries (RECOFI)

Active gillnet or trammel net fisheries under RECOFI's area of competence
The Agreement for the Establishment of the Regional Commission for Fisheries established the Regional Commission for Fisheries (RECOFI) as an international agreement under Article XIV of the FAO Constitution (FAO, 1999; RECOFI, 2009). RECOFI is mandated to conserve and manage living marine resources in the RECOFI agreement area (FAO, 1999 [Article III (1)(b)(i)]). RECOFI (2008 [Appendix G], 2013a, 2013b) has identified anchored and drift gillnet for finfish as included as some of the RECOFI-managed marine capture fisheries that are conducted by member States.

Mandate includes monitoring and/or controlling ALDFG and ghost fishing?
The agreement does not explicitly mandate RECOFI to monitor, prevent or remediate ALDFG (FAO, 1999).

Relevant conservation and management measures
There are no RECOFI binding measures related to monitoring, preventing or remediating ALDFG (RECOFI has adopted one binding measure, on minimum data reporting [RECOFI, 2011]).

Relevant observer and logbook data collection protocols
There is no regional observer coverage of RECOFI-managed fisheries (RECOFI, 2009, 2013b). Logbooks are not explicitly identified as being employed by RECOFI members to meet RECOFI reporting requirements for national catch and effort data (RECOFI, 2013a). Data reporting requirements of RECOFI members do not include

reporting information on vessel abandonment, loss or discarding of fishing gear, or encounters with ALDFG of other vessels (RECOFI, 2011).

4.2.9 Southern Indian Ocean Fisheries Agreement (SIOFA)

Active gillnet or trammel net fisheries under SIOFA's area of competence
SIOFA, a regional fishery arrangement established by the Southern Indian Ocean Fisheries Agreement, does not identify specific fisheries or gear types covered by the agreement, but identifies covered fishery resources. SIOFA-covered fishery resources are fish, molluscs, crustaceans and other sedentary species within the agreement area, excluding sedentary species under the jurisdiction of coastal States, and excluding highly migratory species listed in Annex I of the United Nations Convention on the Law of the Sea of 10 December 1982 (UNCLOS) (SIOFA, 2006 [Article 1(f)]). The need for conservation and management measures for deep-sea gillnet and large-scale driftnet fisheries was discussed at the first SIOFA meeting (SIOFA, 2013), indicating that these gear types are employed in active fisheries for SIOFA-covered resources.

Mandate includes monitoring and/or controlling ALDFG and ghost fishing?
The agreement does not explicitly identify a mandate to monitor, prevent or remediate ALDFG or ghost fishing (SIOFA, 2006).

Relevant conservation and management measures
No relevant measures have been adopted by SIOFA (European Commission, 2014).

SIOFA entered into force in 2012. It held its first meeting in October 2013, where decisions focused on establishing rules of procedure, with a second meeting scheduled for March 2015 (SIOFA, 2013; European Commission, 2014). As a regional fishery agreement, unlike RFBs, SIOFA does not automatically establish a commission. Instead, issues are to be discussed at an annual SIOFA meeting of parties.

Relevant observer and logbook data collection protocols
A SIOFA resolution that identifies recommended information to be collected from high seas non-tuna fisheries does not call for the collection of information on vessel abandonment, loss or discarding of fishing gear or on encounters with ALDFG of other vessels (SIOFA, 2004).

4.2.10 Western and Central Pacific Fisheries Commission (WCPFC)

Active gillnet or trammel net fisheries under WCPFC's area of competence
The convention of the WCPFC applies to all stocks of highly migratory fish (defined as all fish stocks of the species listed in Annex I of UNCLOS occurring in the convention area and such other species of fish as the commission may determine) within the convention area, except sauries (United Nations, 1982; WCPFC, 2000). However, the Convention does not identify specific fisheries or gear types covered by the convention (WCPFC, 2000).

Fishing gear types reported used by member and cooperating non-member fisheries operating in the WCPFC convention area in calendar year 2012 to catch WCPFC-covered stocks included gillnet (WCPFC, 2013a). Of the 30 countries, territories and entities that reported having one or more fishery active in the WCPFC convention area in 2012, only one reported catch with gillnet (Viet Nam) (WCPFC, 2013a).

The main industrial fishing methods employed in the WCPFC convention area to catch covered stocks are purse seine, longline, pole-and-line and troll (Miyake *et al.*, 2010; SPC, 2013; Anthony Beeching, WCPFC Secretariat, personal communication, 2014). However, a number of other gear types, including gillnets, which are used primarily in domestic waters, also contribute to fishing mortality of WCPFC-covered stocks (e.g. 20 percent of reported landings of yellowfin tuna in the WCPFC statistical area in 2012 was by gear types other than these four main industrial methods) (Miyake *et al.*, 2010; SPC, 2013). While some WCPFC CMMs are explicit in not being binding in archipelagic waters and territorial seas (e.g. WCPFC, 2013b [Paragraph I(12)]), there is a lack of consensus among members and cooperating non-members regarding whether the convention area includes "domestic" archipelagic waters, territorial seas and EEZs. Moreover, it is unclear whether, under the convention, members and cooperating non-members are obligated to minimize adverse effects of ALDFG in their "domestic" waters and fisheries (WCPFC, 2000).

Mandate includes monitoring and/or controlling ALDFG and ghost fishing?
The convention explicitly mandates the Commission to "adopt measures to minimize … catch by lost or abandoned gear [and] pollution originating from fishing vessels" (WCPFC, 2000 [Article 5(e)]).

Relevant conservation and management measures
Use of large scale drift gillnets (> 2.5 km in length) is prohibited on the high seas in the WCPFC convention area, in part, to avoid ghost fishing (WCPFC, 2008).

Relevant observer and logbook data collection protocols
Observers of the WCPFC regional observer programme are to record whether the vessel abandoned, lost or discarded any fishing gear, whether the vessel found ALDFG from another vessel, and whether the vessel failed to report any lost or abandoned gear if required by the country in whose waters the vessel was fishing (WCPFC, no date; SPC, 2009a, 2009b). The WCPFC regional observer programme currently provides coverage of purse seine, longline and pole-and-line fisheries (SPC, 2009c; Gilman, Passfield and Nakamura, 2012). Therefore, of the observer data collection protocols, the observer data collection protocol of recording vessel encounters with ALDFG produced by other vessels, including ALDFG from gillnet and trammel net fisheries, is of relevance to this assessment. Logbook forms for longline, purse seine, pole-and-line, handline, troll and artisanal vessels do not have vessel operators report whether they abandoned, lost or discarded any fishing gear or encountered any ALDFG from other vessels (SPC, 2007a, 2007b, 2007c, 2009d, 2009e, 2010, 2011).

4.3 Discussion and conclusions

4.3.1 RFB/A mandate to monitor and control ALDFG

Of the ten RFB/As included in the assessment, one, WCPFC, has a convention that explicitly mandates mitigating ALDFG and ghost fishing (Table 4). Members might consider whether modifying mandates is necessary to enable RFB/As to adopt needed measures to effectively monitor and manage ALDFG and ghost fishing by gillnet and trammel net fisheries.

4.3.2 RFB/A logbook and observer data collection protocols on ALDFG

Of the ten assessed RFB/As, three have logbook and/or observer data collection protocols that call for reporting abandonment, loss and discarding of fishing gear from gillnet or trammel net fisheries (IOTC, JNRFC and WCPFC; Tables 4 and 5). Relevant observer data collection protocols require observers to collect information on the amount of ALDFG (IOTC, no date), and whether the vessel found ALDFG generated by another vessel (including gillnets and trammel nets) (WCPFC, no date; SPC, 2009a, 2009b). One relevant logbook data collection protocol requires vessel operators to record whether gear was lost during each fishing operation (Directorate of Fisheries, 2012). There is a need to harmonize ALDFG data fields, data collection protocols, and database formats where they are in place, and to fill gaps for those lacking procedures to collect and report this information. Standardizing data fields, data collection protocols and database formats facilitates comparisons between regions, enables pooling of data necessary to support large spatial scale analyses within and across regions, and enables standardization of training materials and courses within and across regions (Gilman and Hall, 2015).

Collecting and reporting accurate information on the abandonment, loss and discarding of gillnets and trammel nets can contribute to more accurate estimates of the ecological and socio-economic effects of ALDFG, including from ghost fishing mortality. However, reporting systems on ALDFG only contribute to mitigating ALDFG and ghost fishing if they are implemented in combination with a derelict gear retrieval programme, where retrieval responses ideally are conducted as close to the time of loss as possible to maximize the likelihood of finding and then removing the lost gear.

TABLE 5
RFB/As with the competence to establish binding measures

Body or agreement[1]	Bilateral or multilateral	Observer or logbook data collection on ALDFG from gillnet or trammel net fisheries	≥ 1 binding measure related to monitoring or controlling ALDFG or ghost fishing in gillnet or trammel net fisheries
Mandate broader than managing fisheries			
NASCO	Multilateral		X
NPAFC	Multilateral		X
Tuna RFMOs			
IOTC	Multilateral	X	X
ICCAT	Multilateral		X
WCPFC	Multilateral	X	X
Other RFB/As			
GFCM	Multilateral		X
JNRFC	Bilateral	X	
PSC	Bilateral		
RECOFI	Multilateral		
SIOFA	Multilateral		

[1] Acronyms defined in Table 3, and listed under Abbreviations and acronyms.

4.3.3 RFB/A controls of ALDFG and ghost fishing

Of the ten assessed RFB/As, six had one or more binding measure that contribute to controlling ALDFG or ghost fishing from gillnet or trammel net fisheries (Table 5). Table 6 identifies which of the 18 categories of measures for preventing and remediating ALDFG and ghost fishing described in Table 1 that each RFB/A employs. The six RFB/As with relevant measures are making use of a small proportion of available approaches to prevent and remediate ALDFG and ghost fishing. Of 18 identified categories of measures to avoid and prevent ALDFG and ghost fishing, 13 are not used by any of the 10 assessed RFB/As. As explained in Chapter 1, while many of these 18 categories of methods have broad fisheries management purposes that do not have a primary purpose of managing ALDFG and ghost fishing, their implementation contributes to mitigating ALDFG and ghost fishing. Of the 18 categories of methods, the 5 with a primary purpose of avoiding and remediating ALDFG and ghost fishing are: (i) raised awareness and compliance with the international ban on intentional discarding and abandonment of fishing gear at sea under MARPOL Annex V; (ii) economic incentives and disincentives; (iii) port reception facilities for both unwanted fishing gear and ALDFG; (iv) removal of ALDFG detected inadvertently or via programmes that search for derelict gear; and (v) programmes to disable the ghost fishing efficiency of ALDFG (Table 1). None of the ten RFB/As had binding measures in place to implement any of these five methods (Table 6).

Spatial and temporal planning and management measures were used by six of the RFB/As to control ALDFG and ghost fishing (Tables 4 and 6). Most of these measures prohibit the use of gillnet and trammel net gear in part or all of the RFB/A's area of competence, which contributes to reducing ALDFG and ghost fishing (Table 4). However, none of the measures separates passive and mobile gear sectors to avoid gear conflicts and concomitant gear loss, or prohibits fishing in areas where there is a high probability of gear loss and abandonment owing to contact with submerged features, which are both common causes of ALDFG (MacMullen *et al.*, 2003; Macfadyen, Huntington and Cappel, 2009; FAO, 2010a; Antonelis, 2012, 2013).

Gear marking to identify ownership and to increase passive surface gear visibility were used by 2 and 1 of the RFB/As, respectively (Tables 4 and 6). Gear marking to identify ownership can create a disincentive for the deliberate abandonment and discarding of unwanted gear, an incentive to retrieve lost gear, and facilitate enforcement actions of violations of rules on monitoring and controlling ALDFG (Table 1). Gear marking to increase the visibility of passive gear can contribute to avoiding gear loss through interactions with passing vessels or active gear (FAO, 1993; Table 1).

A GFCM measure, which established a maximum gillnet twine diameter (GFCM, 2012), was the one measure requiring the use of a gear technology method with the

TABLE 6
Methods for preventing and remediating ALDFG and ghost fishing in marine gillnet and trammel net fisheries, and which are required by the RFB/As assessed in this study

Method	Body/agreement with ≥ 1 relevant binding measure in effect[1]
Preventive	
Gear marking to identify owner	ICCAT, IOTC
Gear marking to increase visibility of passive gear	IOTC
Technology to avoid unwanted gear contact with sea bed	
Technology to track gear position	
Gear technology to reduce the incidence of gear loss	
Input controls, including limit on soak time	
Periodic or constant observation of passive gear	GFCM
Spatial and temporal planning (including measures banning gillnets and trammel nets gears in part of or in the entire area of competence of an RFB/A)	GFCM, ICCAT, IOTC, NASCO, NPAFC, WCPFC
Deter IUU fishing	
Prohibition of intentional abandonment and discarding of fishing gear at sea	
Economic incentives and disincentives	
Port reception facilities for unwanted gear	
Training for new entrants	
Remedial	
ALDFG port reception and recycling facilities	
Detect and remove ALDFG	
Disable ghost fishing efficiency of ALDFG	
Gear technology that increases ghost fishing selectivity in passive gear ALDFG	
Less durable and degradable gear to reduce ghost fishing duration	GFCM

[1] Acronyms defined in Table 3,and listed under Abbreviations and acronyms.

potential to reduce ghost fishing mortality of cetaceans and other taxa that are strong enough to escape from the less durable gear. The GFCM was also the only RFB/A to have a measure in place requiring fishing practices (requires large nets to be attached to the vessel or be under constant observation [GFCM, 1997b]) that could reduce the incidence of ALDFG. The RFB/As could consider additional measures prescribing the use of gear technology methods and fishing practices that prevent and remediate ALDFG and ghost fishing by gillnets and trammel nets (Table 1). None of the ten RFB/As required gillnet and trammel net fishing vessels to attempt to detect and attempt to remove ALDFG and to report ALDFG that they could not retrieve, an additional approach to remediate ALDFG (Table 1).

4.3.4 Monitoring and controlling ALDFG and ghost fishing by bilateral and multilateral arrangements and bodies

Two of the ten arrangements and bodies in the study sample are bilateral arrangements (Table 5). In general, bilateral arrangements and bodies have convention areas that are exclusively or predominately under national jurisdiction, while multilateral arrangements and bodies (≥ 3 parties) have convention areas that fall predominantly in the high seas (Lugten, 2010; Gilman, Passfield and Nakamura, 2012). The observation that two of the three identified bilateral arrangements/bodies have competence over fishery resources captured in an active gillnet or trammel net fishery (Table 3) is consistent with the understanding that gillnet and trammel net fisheries largely occur in coastal areas (Bjordal, 2002; MacMullen *et al.*, 2003). The observation that neither the JNRFC nor the PSC, the two bilateral arrangements included in the study sample, had binding measures in place to avoid or mitigate ALDFG or ghost fishing from gillnet and trammel net fisheries, while 6 of the 8 multilateral arrangements and bodies did have relevant measures in place, was unexpected given that these gear types are predominant in nearshore areas.

5. Summary and recommendations

Abandoned, lost or otherwise discarded fishing gear causes substantial ecological and socio-economic problems. Ghost fishing is one problem resulting from ALDFG that has received increasing international attention over the past decade. Ghost fishing mortality is infrequently accounted for in fisheries management, potentially compromising the accuracy of population and stock assessment models and efficacy of harvest strategies. Ghost fishing by ALDFG removes both target and non-target species. Species with relatively low fecundity and other life-history characteristics that make them particularly sensitive to anthropogenic mortality sources are also subject to ghost fishing mortality. These include species of seabirds, sea turtles, marine mammals and elasmobranchs, some of which are endangered, threatened and protected. Mortalities from ghost fishing by ALDFG are also a source of wastage and reduce the sustainable production of fishery resources and economic opportunities for the marine capture sector. Social welfare issues are also raised over ghost fishing mortality of flagship megafauna, as well as the extensive duration for some organisms caught in ALDFG to succumb relative to captures in in-use gear.

Marine gillnets and trammel nets have relatively high ghost fishing potential. These gear types are used worldwide primarily in coastal, artisanal fisheries, and supply about a fifth of global marine fisheries landings. Recognizing this, FAO and UNEP commissioned this study to identify best practice methods for estimating ghost fishing rates and levels, priority research needs, and the status of international monitoring and management of ALDFG and ghost fishing by marine gillnet and trammel net fisheries.

A sample of studies were compiled and synthesized in order to document methods and estimates of: rates of abandonment, loss and discarding of gillnets and trammel nets; the density of ALDFG; the duration of fishing efficiency of ALDFG; and ghost fishing mortality rates of ALDFG. This provided a basis for understanding the degree of dispersion in methods and findings, and augmented the state of understanding of the severity of ALDFG and ghost fishing by gillnet and trammel net fisheries. In addition, general best practice estimation methods to reduce uncertainty and priority information gaps were identified to provide robust estimates of regional and global ghost fishing mortality rates and levels by ALDFG.

Relative to some other gear types, and relative to other sources of collateral fishing mortality, there has been good progress in the development of methods to estimate ghost fishing mortality rates and the duration of fishing efficiency in gillnets and trammel nets. However, a wide variety of units have been employed for rates of abandonment, loss and discarding, density, ghost fishing catch rates, and duration of fishing efficiency of ALDFG from gillnet and trammel net fisheries. This precludes meaningful comparisons of findings between most studies, and prevents pooling data. The few relevant studies are primarily from Europe, are largely dated and spatially and temporally patchy, with large dispersion in estimates. Potentially significant explanatory factors were highly variable amongst the compiled studies. This heterogeneity of the sampled studies, small sample size, and high dispersion in rates of production and density of ALDFG and ghost fishing mortality rates and duration of fishing efficiency in gillnet and trammel net fisheries means that the observed means are not generalizable regionally or globally.

A mean of 0.9 percent (± 0.3 SEM, 38 percent CV, n=10) of gear was lost from gillnet and trammel net fisheries and was not subsequently retrieved. Similar high dispersion in results were found for studies that reported findings as the number of lost net panels per vessel per year (26 percent CV, n=8) and length of lost nets per vessel per year (33 percent CV, n=6). Few studies estimated rates of gear abandonment and discarding. Studies have primarily estimated gear loss rates through fishers surveys; estimates have not been based on data from experiments, observer programmes or logbook programmes, which could validate the first-order estimates from the fishers surveys.

There was extremely high variability in estimates of the density of ALDFG from gillnet and trammel net fisheries reported in units of length of nets per area of surveyed fishing grounds (mean of 4.4 km of net/km^2 fishing grounds ± 3.8 SEM, 86 percent CV, n=4). There was also low consistency in findings using a unit of length of derelict gillnets per unit length of survey transects (39 percent CV, n=4). Studies have employed a mix of fisher interviews, towing "creeper" grappling devices and various *in situ* survey methods to estimate the density of ALDFG from gillnet and trammel net fisheries. Few studies towing creepers accounted for the estimated proportion of ALDFG that the creeper did not recover. Main units for reporting ALDG density have been the length of derelict nets per unit area of survey fishing grounds, or length per unit length of survey transects.

There was similarly high dispersion in estimates of ghost fishing mortality rates and duration of ghost fishing efficiency. The mean number of ghost caught fishes per unit area of gillnets and trammel nets for the full duration of fishing efficiency or to reach 5 percent of initial catch efficiency was 92.8 fish per 100 m^2 of net (± 47.2 SEM, 51 percent CV, n=5). Similar variability was found with results presented in units of the number of organisms per unit area of net for the full duration of finfish fishing efficiency (mean of 83.1 organisms per 100 m^2 of net, ± 25.5 SEM, 31 percent CV, n=4). There was moderate variability in estimates of the duration of ghost fishing efficiency in units of the unit of time to cease catch efficiency of all organisms, or to decline to a small percentage of in-use gear or of initial ghost fishing efficiency (mean of 35.0 weeks, ± 6.4 SEM, 18.2 percent CV, n=11). There was higher variability when using results presented in units of the unit of time to cease fishing efficiency of fishes (mean of 37.5 weeks, ± 20.4 SEM, 54 percent CV, n=7). Estimates of the duration of driftnet fishing efficiency have ranged from less than a day for small, 50–100 m length nets, to three months for 2 km length nets. Most studies designed to estimate ghost fishing mortality rates and the duration of fishing efficiency by ALDFG have used simulated derelict gear. Most studied demersal nets set at coastal sites within commercial fishing grounds at relatively shallow depths. Most studies monitored the catch and condition of the gear via *in situ* methods, others periodically retrieved a subset of gear. Many of the reviewed studies fit a ghost fishing efficiency exponential regression decay model to short-term ghost fishing catch rate data to estimate the duration of fishing efficiency and the total ghost fishing mortality level for the estimated duration of fishing efficiency. The large dispersion in estimates of ghost fishing mortality rates and duration of ghost fishing efficiency is probably a result of extremely small sample sizes as well as from pooling data from studies employing variable methods, studying ALDFG with variable gear designs and materials, and at sites with variable environmental and physiographic conditions (e.g. flat substrate in shallow water with strong currents and abundant biofouling organisms, debris and particulate matter vs entangled on three-dimensional objects in deep water with weak current and limited biofoulers, debris and particulate matter; site with active towed fishing gear vs site lacking active gear fishing effort).

There were small sample sizes in available estimates of rates of producing derelict gear, density of derelict gear, ghost fishing mortality rates and levels, with under-representation by region and gear type. Many estimates are dated, and may not characterize ALDFG and ghost fishing in contemporary fisheries. Large sources of uncertainty were introduced in some of these studies, such as owing to sampling bias in selecting study sites. The use of variable units to report estimates prevents the pooling of some records, reducing sample sizes available to estimate means. There are no available databases estimating regional and global levels of gillnet and trammel net fishing effort. As a result of these deficiencies, there would be very high uncertainty in estimates of regionally and globally averaged ghost fishing mortality rates and levels, especially for taxa that are rare-event captures, such as marine megafauna. Four priorities were identified to fill these key information deficits. Recommendations to obtain robust estimates of regional and global rates and levels of ghost fishing from ALDFG from marine gillnet and trammel net fisheries are, *inter alia*:

- Domestic and regional authorities should harmonize logbook and observer programme data fields, data collection protocols and database formats on ALDFG from gillnet and trammel net fisheries where they are in place, and fill gaps in ALDFG monitoring. Standardizing data fields, data collection protocols and database formats facilitates comparisons between regions, enables the pooling of data necessary to support large spatial scale analyses within and across regions, and enables standardization of training materials and courses within and across regions. This would also produce larger logbook and observer programme datasets of records of rates of generating ALDFG from gillnet and trammel net fisheries, and rates of fishing vessel encounters with ALDFG, with broader spatial coverage.
- More research should be conducted, using best practice methods identified through this study to minimize sources of uncertainty, to estimate ghost fishing mortality rates and levels. These studies should be balanced spatially, temporally and by type of gillnet and trammel net fishing gear and method.
- Studies designed to estimate ghost fishing mortality rates and levels should employ standardized units to report estimates in order to facilitate pooling.
- Meta-analyses of data from relevant compiled studies should be conducted to produce estimates of generating ALDFG, density of ALDFG, and ghost fishing mortality rates with increased precision, accuracy and statistical power over estimates from individual studies.
- Robust estimates of regional and global gillnet and trammel net fishing effort should be developed.

Despite increasing international recognition of the need for multilateral efforts to address effectively the transboundary problems resulting from ALDFG, including ghost fishing, there has been limited progress in international monitoring and management of ALDFG by gillnet and trammel net fisheries. To benchmark regional measures for monitoring and mitigating ALDFG and ghost fishing, an assessment was made of the data collection protocols and management measures to prevent and remediate ALDFG and ghost fishing of then regional bodies and arrangements with the competence to establish binding controls for marine capture fisheries, and that have competence over fishery resources captured in an active gillnet or trammel net fishery.

Of the ten RFB/As, three collect data via logbook or observer programmes related to ALDFG from gillnet or trammel net fisheries. Harmonizing ALDFG data collection protocols where they are in place, and filling gaps for those RFB/As lacking procedures to collect this information, would contribute to improved monitoring of ALDFG in regional marine capture fisheries. Only one of the assessed RFB/As is explicitly mandated by its convention or agreement text to monitor and control ALDFG and ghost fishing. Modifying mandates might improve regional monitoring and management of ALDFG and ghost fishing by gillnet and trammel net fisheries.

More than half of assessed RFB/As have adopted binding measures to manage ALDFG from gillnet or trammel net fisheries. However, the six organizations that have controls in place, make use of a small subset of available tools. Only 5 of 18 categories of methods to prevent and remediate ALDFG and ghost fishing are in use by the 10 RFB/As. None of the 10 RFB/As had binding measures in place for 5 methods that are implemented specifically to mitigate ALDFG and ghost fishing.

Prohibiting the use of gillnet and trammel net gear in part or all of an RFB/A's area of competence, which contributes to reduced ALDFG and ghost fishing, was the most commonly employed measure. Gear marking to identify ownership and to increase passive surface gear visibility was the second-most commonly employed method. Both forms of gear marking contribute to reducing ALDFG. Recommendations to improve regional monitoring and management of ALDFG and ghost fishing by marine gillnet and trammel net fisheries are, *inter alia*:

- Bilateral and multilateral fishery bodies and arrangements can harmonize ALDFG logbook and observer data collection and reporting protocols where they are in place, and fill gaps in bodies and arrangements lacking procedures to collect and report this information.
- For bodies and arrangements lacking binding measures to manage ALDFG and ghost fishing, members can raise awareness of the impacts of ALDFG and ghost fishing, and learn from the experiences of bodies and arrangements that have made progress in adopting relevant measures, with an aim to harmonize management systems to achieve consistency and compatibility.
- Through consideration of the full suite of complementary methods, members of fishery bodies and arrangements should consider adopting management measures that directly and indirectly prevent and remediate ALDFG and associated ghost fishing. These methods include:
  - Preventive methods:
    - Gear marking systems to identify ownership and to increase surface gear visibility, where adoption of a global standard for gear marking would facilitate consistent implementation regionally and nationally.
    - Technology to avoid unwanted gear contact with the sea bed.
    - Technology to track gear position and gear used to mark passive gear location that is designed to minimize the risk of loss owing to contact by passing vessels.
    - Gear designs and materials that reduce the risk of gear loss.
    - Input controls, including limits on gear soak time.
    - Periodic or constant attendance by fishers while the gear is soaking.
    - Marine spatial and temporal planning, including to separate passive and mobile gears to avoid gear conflicts and concomitant gear loss, and to phase out gillnet and trammel net fishing at sites with high risk of gear snagging on submerged features.
    - Deterrents of illegal, unreported and unregulated (IUU) fishing.
    - Raised member awareness and incentives for compliance with the prohibition on intentional abandonment and discarding of fishing gear at sea under the International Convention for the Prevention of Pollution from Ships.
    - Economic incentives for proper disposal of unwanted gear and disincentives for fishers to generate ALDFG.
    - Raised member awareness that adequate (affordable and accessible) port reception and recycling facilities for unwanted "retired" fishing gear contributes to preventing ALDFG.
    - Programmes to train new fishery entrants to minimize the likelihood of gear loss and augment capacity to recover lost and abandoned gear.
  - Remedial methods:
    - Raised member awareness that adequate port reception and recycling facilities incentives the reporting, retrieval and delivery to these facilities of ALDFG encountered at sea.
    - Programmes for ALDFG detection, reporting and safe retrieval.
    - Programmes to disable the ghost fishing efficiency of ALDFG.

- Gear designs and fishing practices that reduce ghost fishing catch and mortality rates of species of conservation concern.
- Less-durable and degradable gear to reduce ghost fishing duration, if determined to outweigh costs of increased introduction of synthetic compounds into marine ecosystems and increased rates of gear loss and retirement.

6. References

Akiyama, S., Saito, E. & Watanabe, T. 2007. Relationship between soak time and number of enmeshed animals in experimentally lost gill nets. *Fisheries Science*, 73: 881–888.

Antonelis, K. 2012. *Qualitative estimates of current gillnet loss in the Puget Sound commercial salmon fisheries through semi-structured interviews*. Bellingham, USA, Northwest Straits Marine Conservation Foundation.

Antonelis, K. 2013. *Derelict gillnets in the Salish Sea: causes of gillnet loss, extent of accumulation and development of a predictive transboundary model* [available online]. University of Washington. (Master's thesis). [Cited 20 January 2015]. https://digital.lib.washington.edu/researchworks/handle/1773/23504

Antonelis, K., Huppert, D., Velasquez, D. & June, J. 2011. Dungeness crab mortality due to lost traps and a cost-benefit analysis of trap removal in Washington state waters of the Salish Sea. *North American Journal of Fisheries Management*, 31: 880–893.

Aps, R., Kell, L., Lassen, H. & Liiv, I. 2007. Short communication. Negotiation framework for Baltic fisheries management: Striking the balance of interest. *ICES Journal of Marine Science*, 64: 858–861.

Arthur, C., Baker, J. & Bamford, H., eds. 2009. Proceedings of the International Research Workshop on the Occurrence, Effects and Fate of Microplastic Marine Debris. Sept 9–11, 2008. NOAA Technical Memorandum NOS-OR&R-30. Silvery Spring, USA, National Oceanic and Atmospheric Administration. (also available at http://marinedebris.info/sites/default/files/literature/Proceedings%20of%20the%20International%20Research%20Workshop%20on%20the%20Occurrence%2C%20Effects%20and%20Fate%20of%20Microplastic%20Marine%20Debris.pdf).

Atapattu, A. 1991. The experience of fish aggregating devices for fisheries resource enhancement and management in Sri Lanka. *RAPA Report*, 11: 16–40.

Ayaz, A., Unal, V., Acarli, D. & Altinagac, U. 2010. Fishing gear losses in the Gokova Special Environmental Protection Area (SEPA), eastern Mediterranean, Turkey. *Journal of Applied Ichthyology*, 26: 416–419.

Ayaz, A., Acarli, D., Altinagac, U., Ozekinci, U., Kara, A. & Ozen, O. 2006. Ghost fishing by monofilament and multifilament gillnets in Izmir Bay, Turkey. *Fisheries Research*, 79: 267–271.

Baeta, F., Costa, M. & Cabral, H. 2009. Trammel nets' ghost fishing off the Portuguese central coast. *Fisheries Research*, 98: 33–39.

Barlow, J. & Cameron, G. 2003. Field experiments show that acoustic pingers reduce marine mammal bycatch in the California drift gill net fishery. *Marine Mammal Science*, 19: 265–283.

Barth, R. & Dette, B. 2001. The integration of voluntary agreements into existing legal systems. *In* C. Higley & F. Leveque, eds. *Environmental voluntary approaches: research insights for policy-makers*, pp. 14–33. Paris, CERNA. (also available at www.cerna.mines-paristech.fr/Documents/FLCJH-CAVAPolicyBrief.pdf#page=14).

Bjordal, A. 2002. The use of technical measures in responsible fisheries: regulation of fishing gear. *In* K. Cochrane, ed. *A fishery manager's guidebook: management measures and their application*, pp. 21–48. FAO Fisheries Technical Paper No. 424. Rome, FAO. 231 pp. (also available at www.fao.org/docrep/005/y3427e/y3427e00.HTM).

Borenstein, M., Hedges, L., Higgins, J. and Rothstein, H. (2009). *Introduction to Meta-analysis*. Wiley Press, West Sussex, U.K. 421 p.

Breen, P. 1990. A review of ghost fishing by traps and gillnets. *In* R. Shomura & M. Godfrey, M., eds. *Proceedings of the 2nd International Conference on Marine Debris, 2–7 April 1989, Honolulu, Hawaii, USA*, pp. 571–599. NOAA Technical Memorandum 154. La Jolla, USA, Southwest Fisheries Science Center, National Marine Fisheries Service. (also available at http://swfsc.noaa.gov/publications/tm/swfsc/noaa-tm-nmfs-swfsc-154_p571.pdf).

Brown, J. & Macfadyen, G. 2007. Ghost fishing in European waters: impacts and management responses. *Marine Policy*, 31: 488–504.

Caddy, J. 1996. *A checklist for fisheries resource management issues seen from the perspective of the FAO Code of Conduct for Responsible Fisheries*. FAO Fisheries Circular No. 917. Rome, FAO. 22 pp. (also available at www.fao.org/docrep/w3140e/w3140e00.htm).

Carr, H. & Cooper, R. 1987. Manned submersible and ROV assessment of ghost gillnets in the Gulf of Maine. DOI 10.1109/OCEANS.1987.1160764. IEEE Conf. Proc. 1987. *Oceans,* 1987: 622–625.

Carr, H., Blott, A. & Caruso, P. 1992. A study of ghost gillnets in the inshore waters of southern New England. *In*: *Proceedings of the MTS '92: Global Ocean Partnership*, pp. 361–367. Washington, DC, Marine Technology Society.

Carr, H., Amaral, E., Hulbert, A. & Cooper, R. 1985. Underwater survey of simulated lost demersal and lost commercial gillnets off New England. *In* R. Shomura & H. Yoshida, eds. *Proceedings of the Workshop on the Fate and Impact of Marine Debris. 26–29 November 1984. Honolulu, Hawaii, USA*, pp. 438–447. NOAA Technical Memorandum NOAA-TM-NMFS-SWFC-54. La Jolla, USA, National Marine Fisheries Service, Southwest Fisheries Center.

Casey, J. & Myers, R. 1998. Near extinction of a large, widely distributed fish. *Science*, 281: 690–691.

Chanrachkij, I., Siriraksophon, S. & Loog-on A. 2008. *Modifying the Drifting Fish Aggregating Devices to Mitigate Sea Turtle Mortality: A SEAFDEC Initiative*. Southeast Asian Fisheries Development Center, Bangkok.

Chaves, P. & Silveira, B. 2014. Working to reduce loss of gears in Brazilian fisheries. *In*: Abstracts. Fishery Dependent Information 2014. Rome and Copenhagen, FAO and ICES.

Cho, D. 2009. The incentive program for fishermen to collect marine debris in Korea. *Marine Pollution Bulletin*, 58: 415–416.

Chopin, F. & Arimoto, T. 1995. The condition of fish escaping from fishing gears - a review. *Fisheries Research*, 21: 315–327.

Chopin, F., Inoue, Y. & Arimoto, A. 1996. Development of a catch mortality model. *Fisheries Research*, 25: 377–382.

Chopin, F., Alverson, D., Inoue, Y., Arimoto, T., Suuronen, P. & Sangster, G. 1996. Sources of unaccounted mortality in fish capture technologies. *In*: D.A. Hancock, D.C. Smith, A. Grant & J.P. Beumer, eds. *Developing and Sustaining World Fisheries Resources: The State of Science and Management*. *Proceedings of the 2nd World Fisheries Congress, Brisbane, 28 July–2 August, 1997*, pp. 149–156. Collingwood, Australia, CSIRO Publishing.

Coggins, L., Catalano, M., Allen, M., Pine, W. & Walters, C. 2007. Effects of cryptic mortality on fishery sustainability and performance. *Fish and Fisheries*, 8: 1–15.

Commission for the Conservation of Southern Bluefin Tuna (CCSBT). 2013. *Global southern bluefin tuna catch by gear* [online]. Deakin West, Australia. [Cited 1 April 2014]. www.ccsbt.org/userfiles/file/data/CatchByOYF.xls

Commission on the Conservation of Antarctic Marine Living Resources (CCAMLR). 2012. *Fisheries monitoring. Fisheries in Areas 48, 58 and 88* [online]. North Hobart, Australia. [Cited 22 February 2012]. www.ccamlr.org/pu/e/sc/fish-monit/areas.htm

Commission on the Conservation of Antarctic Marine Living Resources (CCAMLR). 2013a. *Licensed vessels. Season 01 Dec 2013 – 30 Nov 2014* [online]. North Hobart, Australia. [Cited 22 March 2014]. www.ccamlr.org/en/compliance/licensed-vessels

Commission on the Conservation of Antarctic Marine Living Resources (CCAMLR). 2013b. *Schedule of conservation measures in force 2013/14 Season. As amended by the Commission at the thirty-second meeting, 23 October to 1 November 2013*. Hobart, Australia.

Convention on Conduct of Fishing Operations in the North Atlantic. 1967. *Convention on Conduct of Fishing Operations in the North Atlantic* [online]. Treaty Series No. 40. [Cited 31 March 2014]. http://faolex.fao.org/docs/pdf/mul20797.pdf

Convention on the Conservation and Management of Pollock Resources in the Central Bering Sea (CCBSP). (no date). *Description. The Convention on the Conservation and Management of Pollock Resources in the Central Bering Sea* [online]. Seattle, USA, Alaska Fisheries Science Center, National Marine Fisheries Service. [Cited 23 February 2014]. www.afsc.noaa.gov/REFM/CBS/convention_description.htm

Convention on the Conservation and Management of Pollock Resources in the Central Bering Sea (CCBSP). 2012. *Report of the 17th Annual Conference of the Parties to the Convention on the Conservation and Management of Pollock Resources in the Central Bering Sea, 12 November – 21 December 2012* [online]. Seattle, USA, Alaska Fisheries Science Center, National Marine Fisheries Service. [Cited 23 February 2014]. www.afsc.noaa.gov/REFM/CBS/Docs/17th%20Annual%20Conference/Final%20Conference%20Report%202012.pdf

Crozier, W., Schon, P., Chaput, G., Potter, E., Naoileidigh, N. & MacLean, J. 2004. Managing Atlantic salmon (*Salmo salar* L.) in the mixed stock environment: challenges and considerations. *ICES Journal of Marine Science*, 61: 1344–1358.

Dagorn, L., Holland, K., Restrepo, V. & Moreno, G. 2013. Is it good or bad to fish with FADs? What are the real impacts of the use of drifting FADs on pelagic marine ecosystems?. *Fish and Fisheries*, 14: 391–415.

Derraik, J. 2002. The pollution of the marine environment by plastic debris: a review. *Marine Pollution Bulletin*, 44: 842–852.

Directorate of Fisheries. 2012. Regulations amending the regulations relating to reporting (position, catch and activity data) and control, etc., during fishing and hunting operations in the Fisheries Protection Zone around Svalbard. In: *Directorate of Fisheries* [online]. (Cited 30 March 2014]. www.fiskeridir.no/english/content/download/26509/241119/version/5/file/20120119-Reporting-and-control-territorial-waters.pdf

Donohue, M., Boland, R., Sramek, C. & Antonelis, G. 2001. Derelict fishing gear in the Northwestern Hawaiian Islands: diving surveys and debris removal confirm threat to coral reef ecosystems. *Marine Pollution Bulletin*, 42: 1301–1312.

Dulvy, N., Ellis, J., Goodwin, N., Grant, A., Reynolds, J. & Jennings, S. 2004. Methods of assessing extinction risk in marine fishes. *Fish and Fisheries*, 5(3): 255–276.

Ebbesmeyer, C., Ingraham, W., Jones, J. & Donohue, M. 2012. Marine debris from the Oregon Dungeness crab fishery recovered in the Northwestern Hawaiian Islands: Identification and oceanic drift paths. *Marine Pollution Bulletin*, 65: 69–75.

Eckert, S.A., Gearhart, J., Bergmann, C. & Eckert, K. 2008. Reducing leatherback sea turtle bycatch in the surface drift-gillnet fishery in Trinidad. *Bycatch Communication Newsletter*, 8: 2–6.

Erzini, K., Monteiro, C., Ribeiro, J., Santos, M., Gaspar, M., Monteiro, P. & Borges, T. 1997. An experimental study of gill net and trammel net 'ghost fishing' off the Algarve (southern Portugal). *Marine Ecology Progress Series*, 158: 257–265.

European Commission. 2014. First Meeting of the Southern Indian Ocean Fisheries Agreement (SIOFA). In: *European Commission* [online]. Cited 30 March 2014]. http://ec.europa.eu/information_society/newsroom/cf/mare/itemdetail.cfm?item_id=12483

FAO. 1991. *Report of the Expert Consultation on the Gear Marking, Victoria, British Columbia, 14–19 July 1991.* FAO Fisheries Report No. 485 (FIIT/R485). Rome. 42 pp. (also available at www.fao.org/docrep/010/t0759t/t0759t00.htm).

FAO. 1993. *Recommendations for the Marking of Fishing Gear. Supplement to the Expert Consultation on the Marking of Fishing Gear. Victoria, British Columbia, Canada, 14–19 July, 1991*. FAO Fisheries Report No. 485(Suppl.). Rome. 48 pp.

FAO. 1995. *FAO Code of Conduct for Responsible Fisheries*. Rome. 41 pp. (also available at www.fao.org/docrep/005/v9878e/v9878e00.htm).

FAO. 1999. *Agreement for the Establishment of the Regional Commission for Fisheries established the Regional Commission for Fisheries (RECOFI)*. Rome. 7 pp. (also available at ftp://ftp.fao.org/FI/DOCUMENT/RNE/recofi_agreement_text.pdf).

FAO. 2003. *Fisheries management. 2. The ecosystem approach to fisheries*. FAO Technical Guidelines for Responsible Fisheries No. 4 (Suppl. 2). Rome. 112 pp. (also available at ftp://ftp.fao.org/docrep/fao/005/y4470e/y4470e00.pdf).

FAO. 2005. *World inventory of fisheries. Retrieval of lost gear*. Issues Fact Sheets. Text by Andrew Smith. In: *FAO Fisheries and Aquaculture Department* [online]. Rome. [Cited 21 March 2014]. www.fao.org/fishery/topic/14833/en

FAO. 2007a*. Implementing the ecosystem approach to fisheries, including deep-sea fisheries, biodiversity conservation, marine debris and lost or abandoned fishing gear* [online]. Committee on Fisheries (COFI). Twenty-Seventh Session. Rome, 5–9 March 2007. COFI/2007/8. [Cited 9 November 2015]. ftp://ftp.fao.org/docrep/fao/meeting/011/j8993e.pdf

FAO. 2007b. *Report of the Workshop on Assessing the Relative Importance of Sea Turtle Mortality due to Fisheries in Southeast Asia. FAO/SEAFDEC, Bangkok 19–23 March 2007*. FAO Interactions between Sea Turtles and Fisheries within an Ecosystem Context Meeting Report 2. 140 pp.

FAO. 2009. *Agreement on Port State Measures to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing* [online]. Rome. [Cited 9 November 2015]. www.fao.org/fileadmin/user_upload/legal/docs/037t-e.pdf

FAO. 2010a. *The State of World Fisheries and Aquaculture 2010*. Rome. 197 pp. (also available at www.fao.org/docrep/013/i1820e/i1820e00.htm).

FAO. 2010b. *Guidelines to reduce sea turtle mortality in fishing operations.* Rome. 128 pp. (also available at www.fao.org/docrep/012/i0725e/i0725e.pdf).

FAO. 2011a. *International Guidelines on Bycatch Management and Reduction of Discards. Directives Internationales sur la Gestion des Prises Accessoires et la Réduction des Rejets en Mar. Directrices Internationales para la Ordenación de las Capturas Incidentales y la Reducción de los Descartes.* Rome. 73 pp. (also available at www.fao.org/docrep/015/ba0022t/ba0022t00.pdf).

FAO. 2011b. Search Fishery Governance Fact Sheets. In: *FAO Fisheries and Aquaculture Department* [online]. [Cited 23 February 2014]. www.fao.org/fishery/rfb/search/en

FAO. 2011c. Regional Fishery Bodies Summary Description. International Baltic Sea Fishery Commission (IBSFC). In: *FAO Fisheries and Aquaculture Department* [online]. [Cited 23 February 2012]. www.fao.org/fishery/rfb/ibsfc/en

FAO. 2013. What Are Regional Fishery Bodies (RFBs)? In: *FAO Fisheries and Aquaculture Department* [online]. [Cited 23 February 2014]. www.fao.org/fishery/topic/16800/en

FAO. 2014. CWP Handbook of Fishery Statistical Standards. Section H: Fishing Areas for Statistical Purposes. In: *FAO Fisheries and Aquaculture Department* [online]. [Cited 19 March 2014]. www.fao.org/fishery/cwp/handbook/h/en

FAO. 2015. Fishery Statistical Collections: Global Capture Production. In: *FAO Fisheries and Aquaculture Department* [online]. [Cited 19 February 2015]. www.fao.org/fishery/statistics/global-capture-production/en

Filmalter, J., Capello, M., Deneubourg, J., Cowley. P. & Dagorn, L. 2013. Looking behind the curtain: quantifying massive shark mortality in fish aggregating devices. *Frontiers in Ecology and the Environment*, 11: 291–296.

Food Certification International (FCI). 2010. *MSC sustainable fisheries certification. The Barents Sea cod and haddock fisheries. Public certification report* [online]. Inverness, UK. [Cited 30 March 2014]. www.msc.org/track-a-fishery/fisheries-in-the-program/certified/north-east-atlantic/barents-sea-cod-and-haddock/assessment-downloads-1/Public_Certification_Report_-_Final_-_BSCH.pdf

Galil, B. 2007. Loss or gain? Invasive aliens and biodiversity in the Mediterranean Sea. *Marine Pollution Bulletin*, 55: 314–322.

Gearhart, J. & Eckert, S. 2007. *Field tests to evaluate the target catch and bycatch reduction effectiveness of surface and mid-water drift gillnets in Trinidad*. WIDECAST Information Document No. 2007-01. Beaufort, North Carolina, USA, Wider Caribbean Sea Turtle Conservation Network. 21 pp.

General Fisheries Commission for the Mediterranean (GFCM). 1997a. *Agreement for the Establishment of the General Fisheries Commission for the Mediterranean As amended by the General Fisheries Council for the Mediterranean at its First Special Session (May 1963), at its Thirteenth Session (July 1976) and at its Twenty-second Session (October 1997) and approved by the FAO Conference at its Twelfth Session (December 1963) and by the FAO Council at its Seventieth Session (December 1976) and at its Hundred and Thirteenth Session (November 1997)* [online]. Rome. [Cited 27 March 2014]. ftp://ftp.fao.org/FI/DOCUMENT/gfcm/web/GFCM_Agreement.pdf

General Fisheries Commission for the Mediterranean (GFCM). 1997b. *Limitation of the use of driftnets in the Mediterranean*. REC.CM-GFCM/22/1997/1. Rome.

General Fisheries Commission for the Mediterranean (GFCM). 2005. *Recommendation GFCM/2005/3 Concerning Selected ICCAT Recommendations. GFCM/2005/3(A). Recommendation [03-04] by ICCAT Relating to Mediterranean Swordfish* [online]. Rome. [Cited 15 April 2014]. ftp://ftp.fao.org/FI/DOCUMENT/gfcm/web/GFCM_Recommendations2005.pdf

General Fisheries Commission for the Mediterranean (GFCM). 2011a. *Performance review of the General Fisheries Commission for the Mediterranean and Black Sea*. Rome.

General Fisheries Commission for the Mediterranean (GFCM). 2011b. *Recommendation GFCM/35/2011/1 Concerning the Establishment of a GFCM Logbook, amending Recommendation GFCM/34/2010/1*. Rome.

General Fisheries Commission for the Mediterranean (GFCM). 2012. *On Mitigation of Incidental Catches of Cetaceans in the GFCM Area*. REC.CM-GFCM/36/2012/2. Rome.

General Fisheries Commission for the Mediterranean (GFCM). 2014. *GFCM record of vessels over 15 metres authorized to operate in the GFCM Area* [online]. Rome. [Cited 29 March 2014]. www.gfcm.org/gfcm/topic/17103/en

Gerrodette, T., Choy, B. & Hiruki, L. 1987. *An experimental study of derelict gill nets in the Central Pacific Ocean* [online]. Southwest Fisheries Center Administrative Report H-87-18. Honolulu, USA, Southwest Fisheries Center Honolulu Laboratory, National Marine Fisheries Service. [Cited 25 May 2014]. www.pifsc.noaa.gov/library/pubs/admin/SWFC_Admin_Report_87-18.pdf

Gerrodette, T., Choy, B. & Hiruki, L. 1990. An experimental study of derelict gillnet fragments in the central Pacific Ocean. *In*: R. Shornura & M. Godfrey, eds. *Proceedings of the Second International Conference on Marine Debris. 2-7 April 1989, Honolulu, Hawaii*, pp. 600–614 [online]. NOAA-TM-NMFS-SWFSC-154. La Jolla, USA, US National Marine Fisheries Service, Southwest Fisheries Science Center. [Cited 13 May 2014]. http://swfsc.noaa.gov/publications/TM/SWFSC/NOAA-TM-NMFS-SWFSC-154.PDF

GhostNets Australia. 2012. *2012 annual report*. Karumba, Australia.

Gilardi, K., Carlson-Bremer, D., June, J., Antonelis, K., Broadhurst, G. & Cowan, T. 2010. Marine species mortality in derelict fishing nets in Puget Sound, WA and the cost/benefits of derelict net removal. *Marine Pollution Bulletin*, 60: 376–382.

Gilman, E. 2005. *Feasibility study. Establishing a port reception facility for derelict fishing collected by the Hawaii longline fleet*. Honolulu, USA, National Marine Fisheries Service, Pacific Islands Regional Office.

Gilman, E., ed. 2009. *Proceedings of the Technical Workshop on Mitigating Sea Turtle Bycatch in Coastal Net Fisheries. 20-22 January 2009, Honolulu, U.S.A*. [online]. Gland, Switzerland; Honolulu, Bangkok, and Pascagoula, USA, IUCN, Western Pacific Regional Fishery Management Council, Southeast Asian Fisheries Development Center, Indian Ocean – South-East Asian Marine Turtle MoU, U.S. National Marine Fisheries Service, Southeast Fisheries Science Center. www.ioseaturtles.org/eleclib/Proceedings_Net_Fisheries_turtle_Bycatch-FINAL-lower-res.pdf

Gilman, E. 2011. Bycatch governance and best practice mitigation technology in global tuna fisheries. *Marine Policy*, 35: 590–609.

Gilman, E. 2015. Status of international monitoring and management of abandoned, lost and discarded fishing gear and ghost fishing. *Marine Policy*, 60: 225–239.

Gilman, E. & Hall, M. 2015. *Potentially significant variables explaining bycatch and survival rates and alternative data collection protocols to harmonize tuna RFMOs' pelagic longline observer programmes*. Appendix 1 to WCPFC-SC11-2015/EB-IP-05. Kolonia, Pohnpei, Micronesia (Federated States of), Western and Central Pacific Fisheries Commission.

Gilman, E., Owens, T. & Kraft, T. 2013. Ecological risk assessment of the Marshall Islands longline tuna fishery. *Marine Policy*, 44: 239–255.

Gilman, E., Passfield, K. & Nakamura, K. 2012. *Performance assessment of bycatch and discards governance by regional fisheries management organizations* [online]. Gland, Switzerland and Suva, Fiji; International Union for the Conservation of Nature, Commission on Ecosystem Management and Oceania Regional Office. http://data.iucn.org/dbtw-wpd/edocs/2012-034.pdf

Gilman, E., Passfield, K. & Nakamura, K. 2013. Performance of regional fisheries management organizations: ecosystem-based governance of bycatch and discards. *Fish and Fisheries*, DOI: 10.1111/faf.12021.

Gilman, E., Suuronen, P., Hall, M. & Kennelly, S. 2013. Causes and methods to estimate cryptic sources of fishing mortality. *Journal of Fish Biology*, 83: 766–803.

Gilman, E., Dunn, D., Read, A., Warner, R. & Hyrenbach, K. 2011. Designing criteria suites to identify discrete and networked sites of high value across manifestations of biodiversity. *Biodiversity and Conservation*, 20(14): 3363–3383.

Gilman, E., Gearhart, J., Price, B., Eckert, S., Milliken, H., Wang, J., Swimmer, Y., Shiode, D., Abe, O., Peckham, S., Chaloupka, M., Hall, M., Mangel, J., Alfaro-Shigueto, J., Dalzell, P. & Ishizaki, A. 2009. *Mitigating sea turtle bycatch in coastal passive net fisheries*. Gland, Switzerland, International Union for the Conservation of Nature.

Gilman, E, Gearhart, J., Price, B., Eckert, S., Milliken, J., Wang, J., Swimmer, Y., Shiode, D., Abe, O., Peckham, S., Chaloupka, M., Hall, M., Mangel, J., Alfaro-Shigueto, J., Dalzell, P. & Ishizaki, A. 2010. Mitigating sea turtle bycatch in coastal passive net fisheries. *Fish and Fisheries*, 11(1): 57–88.

Goncalves, J., Bentes, L., Coelho, R., Monteiro, P., Ribeiro, J., Correia, C., Lino, P. & Erzini, K. 2008. Non-commercial invertebrate discards in an experimental trammel net fishery. *Fisheries Management and Ecology*, 15: 199–210.

Goñi, R. 1998. Ecosystem effects of marine fisheries: an overview. *Ocean and Coastal Management*, 40: 37–64

Good, T., June, J., Etnier, M. & Broadhurst, G. 2009. Ghosts of the Salish Sea: threats to marine birds in Puget Sound and the Northwest Straits from derelict fishing gear. *Marine Ornithology*, 37: 67–76.

Good, T., June, J., Etnier, M. & Broadhurst, G. 2010. Derelict fishing nets in Puget Sound and the Northwest Straits: Patterns and threats to marine fauna. *Marine Pollution Bulletin*, 60: 39–50.

Hall, M. 1996. On bycatches. *Reviews in Fish Biology and Fisheries*, 6: 319–352.

Hall M., Alverson, D. & Metuzal, K. 2000. By-catch: problems and solutions. *Marine Pollution Bulletin*, 41: 204–219.

Hall, M., Mituhasi, T., Chapilliquen, S., *et al.* 2009. Characteristics of fishing gear and methods relevant for understanding sea turtle interactions. form for gillnets and trammel nets. *In* E. Gilman, ed. *Proceedings of the Technical Workshop on Mitigating Sea Turtle Bycatch in Coastal Net Fisheries. 20-22 January 2009, Honolulu, U.S.A.*, pp. 68–70. Gland, Switzerland, Honolulu, Bangkok, and Pascagoula, USA, IUCN, Western Pacific Regional Fishery Management Council, Southeast Asian Fisheries Development Center, Indian Ocean – South-East Asian Marine Turtle MoU, U.S. National Marine Fisheries Service, Southeast Fisheries Science Center.

Hallier, J. & Gaertner, D. 2008. Drifting fish aggregation devices could act as an ecological trap for tropical tuna species. *Marine Ecology Progress Series*, 353: 255–264.

Hammer, J., Kraak, M. & Parsons, J. 2012. Plastics in the marine environment: the dark side of a modern gift. *Reviews of Environmental Contamination and Toxicology*, 220: 1–44.

Hareide, N., Garnes, G., Rihan, D., Mulligan, M., Tyndall, P. *et al.* 2005. *A preliminary investigation on shelf edge and deep-sea fixed net fisheries to the west and north of Great Britain, Ireland, around Rockall and Hatton Bank* [online]. Bord Iascaigh Mhara, Fiskeridirecktoratet, NEAFC, Sea Fish Industry Authority, Joint Nature Conservation Committee, Marine Institute Foras na Mara. [Cited 1 May 2014]. www.seafish.org/media/Publications/DEEPNETfinalreport.pdf

Hayase, S. & Yatsu, A. 1993. Preliminary report of a squid subsurface driftnet experiment in the North Pacific during 1991. *International North Pacific Fisheries Commission Bulletin*, 53: 557–576.

High, W. 1985. Some consequences of lost fishing, gear. *In* R. Shomura & H. Yoshida, eds. *Proceedings of the Workshop on the Fate and Impact of Marine Debris. 26–29 November 1984. Honolulu, Hawaii, USA*, pp. 430–437 . NOAA Technical Memorandum NOAA-TM-NMFS-SWFC-54. La Jolla, USA, National Marine Fisheries Service, Southwest Fisheries Center.

Hubert, W. 1983. Passive capture techniques. *In* L. Nielson & L. Johnson, eds. *Fisheries Techniques*, pp. 95–112. Bethesda, American Fisheries Society.

Humborstad, O., Løkkeborg, S., Hareide, N. & Furevik, D. 2003. Catches of Greenland halibut (Reinhardtius hippoglossoides) in deepwater ghost-fishing gillnets on the Norwegian continental slope. *Fisheries Research*, 64: 163–170.

Imamura, J. 2011. ENFO reports at the annual meeting on enforcement activities. *Newsletter of the North Pacific Anadromous Fish Commission*, 29: 3.

Indian Ocean Tuna Commission (IOTC). (no date). *Guidelines for the reporting of fisheries statistics to the IOTC* [online]. Mahé, Seychelles. [Cited 28 February 2014]. www.iotc.org/Common/dataforms/Guidelines%20Data%20Reporting%20IOTC%5bE%5d.pdf

Indian Ocean Tuna Commission (IOTC). 1993. *Agreement for the Establishment of the Indian Ocean Tuna Commission*. Mahé, Seychelles.

Indian Ocean Tuna Commission (IOTC). 2001. *Resolution 01/02 Relating to the Control of Fishing Activities*. Indian Ocean Tuna Commission, Mahé, Seychelles.

Indian Ocean Tuna Commission (IOTC). 2009a. *Report of the IOTC Performance Review Panel: January 2009*. Mahé, Seychelles.

Indian Ocean Tuna Commission (IOTC). 2009b. *About IOTC. Background Information. Tuna Fisheries in the Indian Ocean* [online]. Updated 17 March 2009. Mahé, Seychelles. [Cited 27 February 2014]. www.iotc.org/English/info/background.php

Indian Ocean Tuna Commission (IOTC). 2010. *Report of the Technical Meeting on the IOTC Regional Observer Scheme*. IOTC-2010-ROS-R. Mahé, Seychelles.

Indian Ocean Tuna Commission (IOTC). 2011. *Resolution 11/04 on a Regional Observer Scheme*. Mahé, Seychelles.

Indian Ocean Tuna Commission (IOTC). 2012. *Resolution 12/12 to Prohibit the Use of Large-scale Driftnets on the High Seas in the IOTC Area*. Mahé, Seychelles.

Indian Ocean Tuna Commission (IOTC). 2013a. *Resolution 13/02 Concerning the IOTC Record of Vessels Authorised to Operate in the IOTC Area of Competence*. Mahé, Seychelles.

Indian Ocean Tuna Commission (IOTC). 2013b. *Resolution 13/03 on the Recording of Catch and Effort Data by Fishing Vessels in the IOTC Area of Competence*. Mahé, Seychelles.

Indian Ocean Tuna Commission (IOTC). 2013c. *IOTC Regional Observer Scheme. Observer trip report* [online]. Mahé, Seychelles. [Cited 28 February 2014. www.iotc.org/files/proceedings/2010/wros/IOTC%20Observer%20Trip%20Report.zip

Indian Ocean Tuna Commission (IOTC). 2014a. *IOTC Record of Vessels Authorised to Operate in the IOTC Area* [online]. Mahé, Seychelles. [Cited 27 February 2014]. www.iotc.org/English/record/stats3.php.

Indian Ocean Tuna Commission (IOTC). 2014b. *Record of Currently Authorized Vessels* [online]. Mahé, Seychelles. [Cited 30 March 2014]. www.iotc.org/vessels/current

Inter-American Tropical Tuna Commission (IATTC). 2013. *IATTC Resolutions and Recommendations 1998-2013* [online]. La Jolla, USA. [Cited 23 February 2014]. www.iattc.org/ResolutionsENG.htm

Inter-American Tropical Tuna Commission (IATTC). 2014a. *IATTC Vessel Database* [online]. La Jolla, USA. [Cited 25 February 2014]. www.iattc.org/VesselListsENG.htm

Inter-American Tropical Tuna Commission (IATTC). 2014b. *IATTC Current IUU Vessel List* [online]. La Jolla, USA. [Cited 25 February 2014]. www.iattc.org//VesselRegister/IUU.aspx?Lang=ENG

International Commission for the Conservation of Atlantic Tunas (ICCAT). 1992. *International Convention for the Conservation of Atlantic Tunas*. Madrid.

International Commission for the Conservation of Atlantic Tunas (ICCAT). 2003a. *Recommendation by ICCAT Concerning the Duties of Contracting Parties and Cooperating Non-contracting Parties, Entities or Fishing Entities in Relation to Their Vessels Fishing in the ICCAT Convention Area*. Recommendation 03-12. Madrid.

International Commission for the Conservation of Atlantic Tunas (ICCAT). 2003b. *Recommendation by ICCAT Concerning the Recording of Catch by Fishing Vessels in the ICCAT Convention Area*. Recommendation 03-13. Madrid.

International Commission for the Conservation of Atlantic Tunas (ICCAT). 2003c. *Recommendation by ICCAT Relating to Mediterranean Swordfish*. Recommendation 03-04. Madrid.

International Commission for the Conservation of Atlantic Tunas (ICCAT). 2011. *Recommendation by ICCAT on a Multi-Annual Conservation and Management Program for Bigeye and Yellowfin Tunas*. Recommendation 11-01. Madrid.

International Commission for the Conservation of Atlantic Tunas (ICCAT). 2012a. *Recommendation by ICCAT Amending the Recommendation by ICCAT to Establish a Multi-Annual Recovery Plan for Bluefin Tuna in the Eastern Atlantic and Mediterranean*. [online]. Recommendation 12-03. Madrid. [Cited 31 March 2014]. www.iccat.es/Documents/Recs/compendiopdf-e/2012-03-e.pdf.

International Commission for the Conservation of Atlantic Tunas (ICCAT). 2012b. *ICCAT Regional Observer Programme Manual* [online]. Madrid. [Cited 31 March 2014]. www.iccat.es/Documents/ROP/ICCAT_Observer_Manual.pdf

International Commission for the Conservation of Atlantic Tunas (ICCAT). 2014. *ICCAT Record of Vessels* [online]. Madrid. [Cited 25 March 2014]. www.iccat.es/en/vesselsrecord.asp

International Council for the Exploration of the Sea (ICES). 1995. *Report from the Study Group on Unaccounted Mortality in Fisheries. Aberdeen, Scotland, UK, April 1995*. ICES CM 1995/B:1. Copenhagen.

International Council for the Exploration of the Sea (ICES). 2005. *Joint Report of the Study Group on Unaccounted Fishing Mortality (SGUFM) and the Workshop on Unaccounted Fishing Mortality (WKUFM), 25-27 September 2005, Aberdeen, UK* [online]. ICES CM 2005/B:08. Copenhagen. [Cited 5 April 2013]. http://brage.bibsys.no/imr/bitstream/URN:NBN:no-bibsys_brage_3568/1/B08.pdf.

International Maritime Organization (IMO). 1978. *International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto (MARPOL). Annex V. Prevention of Pollution by Garbage from Ships*. London.

International Maritime Organization (IMO). 2011. *Annex 13. Resolution MEPC.201(62). Adopted on 15 July 2011. Amendments to the Annex of the Protocol of 1978 Relating to the International Convention for the Prevention of Pollution from Ships, 1973. (Revised MARPOL Annex V)* [online]. MEPC 62/24. Marine Environment Protection Committee, International Maritime Organization, London. [Cited 15 February 2014]. www.imo.org/OurWork/Environment/PollutionPrevention/Garbage/Documents/201(62).pdf

International Maritime Organization (IMO). 2012. *Annex 24. Resolution MEPC.219(63). Adopted on 2 March 2012. 2012 Guidelines for the Implementation of MARPOL Annex V* [online]. MEPC 63/23/Add.1. Marine Environment Protection Committee, International Maritime Organization, London. [Cited 15 February 2014]. www.imo.org/OurWork/Environment/PollutionPrevention/Garbage/Documents/219(63).pdf

International Pacific Halibut Commission (IPHC). 2013. *International Pacific Halibut Commission Annual Report 2012* [online]. Seattle, USA. [Cited 29 March 2014]. www.iphc.int/publications/annual/ar2012.pdf

International Pacific Halibut Commission (IPHC). 2014. *Pacific Halibut Fishery Regulations 2014* [online]. Seattle, USA. [Cited 29 March 2014]. www.iphc.int/publications/regs/2014iphcregs.pdf

International Whaling Commission (IWC). 1946. *International Convention for the Regulation of Whaling, Washington, D.C., 2 December 1946*. London.

International Whaling Commission (IWC). 2011. *Report of the Working Group on Whale Killing Methods and Associated Welfare Issues*. IWC/63/Rep 6. London.

International Whaling Commission (IWC). 2013a. *Report of the 2013 IWC Scientific Committee Workshop on Marine Debris*. SC/65a/Rep06. London.

International Whaling Commission (IWC). 2013b. *International Convention for the Regulation of Whaling, 1946. Schedule. As Amended by the Commission at the 64th Annual Meeting, Panama City, Panama, July 2012*. London.

Joint Norwegian–Russian Fisheries Commission (JNRFC). (no date) a. *Regulations* [online]. Norway Directorate of Fisheries, Bergen, Norway, and Russia Federal Agency for Fishery, Moscow. [Cited 30 March 2014]. www.jointfish.com/eng/REGULATIONS

Joint Norwegian–Russian Fisheries Commission (JNRFC). (no date) b. *Quotas* [online]. Norway Directorate of Fisheries, Bergen, Norway, and Russia Federal Agency for Fishery, Moscow. [Cited 30 March 2014]. www.jointfish.com/eng/STATISTICS/QUOTAS

Joint Norwegian–Russian Fisheries Commission (JNRFC). 1975. *Agreement between the Government of the Kingdom of Norway and the Government of the Union of Soviet Socialist Republics on Co-operation in the Fishing Industry.* 11 April 1975. Bergen, Norway, Norway Directorate of Fisheries, and Moscow, Russia Federal Agency for Fishery.

Joint Norwegian–Russian Fisheries Commission (JNRFC). 1976. *Agreement between the Government of the Kingdom of Norway and the Government of the Union of Soviet Socialist Republics Concerning Mutual Relations in the Field of Fisheries.* 15 October 1976. Bergen, Norway, Norway Directorate of Fisheries, and Moscow, Russia Federal Agency for Fishery.

Joint Norwegian–Russian Fisheries Commission (JNRFC). 2010. *Treaty between the Kingdom of Norway and the Russian Federation concerning Maritime Delimitation and Cooperation in the Barents Sea and the Arctic Ocean* [online]. Norway Directorate of Fisheries, Bergen, Norway, and Russia Federal Agency for Fishery, Moscow. [Cited 30 March 2014]. www.regjeringen.no/upload/ud/vedlegg/folkerett/avtale_engelsk.pdf

Jones, M. 1995. Fishing debris in the Australian marine environment. *Marine Pollution Bulletin*, 30: 25–33.

Jung, R., Hung, H., Chun, T. & Keel, S. 2010. Practical engineering approaches and infrastructure to address the problem of marine debris in Korea. *Marine Pollution Bulletin*, 60: 1523–1532.

Kaiser, M., Bullimore, B., Newman, P., Lock, K. & Gilbert, S. 1996. Catches in 'ghost fishing' set nets. *Marine Ecology Progress Series*, 145: 11–16.

Kang, C. 2003. *Marine litter in the Republic of Korea* [online]. United Nations Environment Programme, Nairobi. [Cited 5 May 2014]. http://marine-litter.gpa.unep.org/documents/marine-litter-Korea-Kang.pdf

Kawamura, G.1993. Escape behavior of Japanese spiny lobster from gillnet. *Suisan-no-kenkyu*, 64: 40–44.

Keohane, R. 1990. Multilateralism: An agenda for research. *International Journal*, 45: 731.

Kim, S., Lee, W. & Moon, Y. 2014. The estimation of derelict fishing gear in the coastal waters of South Korea: Trap and gill-net fisheries. *Marine Policy*, 46: 119–122.

Koschinski, S., Culik, B., Trippel, E. & Ginzkey, L. 2006. Behavioral reactions of free – ranging harbour porpoises *Phocoena phocoena* encountering standard nylon and $BaSO_4$ mesh gillnets and warning sound. *Marine Ecology Progress Series*, 313: 285–294.

Kuemlangan, B., Chopin, F. & d'Offay, B. 2011. Strengthening the global governance and regulatory framework to combat abandoned, lost or otherwise discarded fishing gear (ALDFG). *In* B. Carswell, K. McElwee & S. Morison, eds. 2011. *Technical Proceedings of the Fifth International Marine Debris Conference. March 20-25, 2011*, pp. 517–521. Technical Memorandum NOS-OR&R-38. Silver Spring, USA, National Oceanic and Atmospheric Administration.

Laist, D. 1995. Marine debris entanglement and ghost fishing: a cryptic and significant type of bycatch? *In*: *Solving Bycatch: Considerations for Today and Tomorrow. Proceedings of the Solving Bycatch Workshop, September 25-27 1995, Seattle, Washington*, pp. 33–39 . Alaska Sea Grant College Program Report AK-SG-96-03. Fairbanks, USA, Alaska Sea Grant College Program, University of Alaska.

Laist, D. 1997. Impacts of marine debris: Entanglement of marine life in marine debris including a comprehensive list of species with entanglement and ingestion records. *In* J. Coe & D. Rogers, eds. *Marine debris: sources, impacts, and solutions*, pp. 99–139. New York, USA, Springer.

Large, P., Graham, N., Hareide, N., Misund, R., Rihan, D., Mulligan, M., Randall, P., Peach, D., McMullen, P. & Harlay, X. 2009. Lost and abandoned nets in deep-water gillnet fisheries in the Northeast Atlantic: Retrieval exercises and outcomes. *ICES Journal of Marine Science*, 66: 323–333.

Larsen, F., Eigaard, O. & Tougaard, J. 2007. Reduction of harbour porpoise (*Phocoena phocoena*) bycatch by iron-oxide gillnets. *Fisheries Research*, 85: 270–278.

Levin, L., Ekau, W., Gooday, A. & Jorissen, F. 2009. Effects of natural and human-induced hypoxia on coastal benthos. *Biogeoscience Discussions*, 6: 3563–3654.

Lewison, R., Crowder, L., Read, A. & Freeman, S. 2004. Understanding impacts of fisheries bycatch on marine megafauna. *Trends in Ecology and Evolution*, 19: 598–604.

Lockwood, S., Pilling, G., Hoel, A., Hough, A. & Davies, S. 2010. *Final report for North East Arctic offshore haddock fishery* [online]. Final Report V. 4. Moody Marine Ltd., Derby, UK. [Cited 30 March 2014]. www.msc.org/track-a-fishery/fisheries-in-the-program/certified/north-east-atlantic/Norway-north-east-arctic-offshore-haddock/assessment-downloads-1/31.03.2010-norway-ne-arctic-offshore-haddock-final-report.pdf

Lodge, M., Anderson, D., Lobach, T., Munro, G., Sainsbury, K. & Willock, A. 2007. *Recommended best practices for regional fisheries management organizations. Report of an independent panel to develop a model for improved governance by regional fisheries management organizations*. London, Chatham House.

Longpierre, S., Robert, A., Levi, F. & Francour, P. 2005. How an invasive alga species (Caulerpa taxifolia) induces changes in foraging strategies of the benthivorous fish Mullus surmuletus in coastal Mediterranean ecosystems. *Biodiversity & Conservation*, 14: 365–376.

Lopez-Abellan, L., Serralde, R., Barreiro, S., Munoz, P., Gonzalez, C., Iglesias, S. & Paz, X. 2010. *Mapping the Spanish bottom fishing footprint (1996-2006) in the SEAFO area: a possible example to proceed*. Windhoek, South East Atlantic Fisheries Organisation.

Lugten, G. 2010. *The role of international fishery organizations and other bodies in the conservation and management of living aquatic resources*. FAO Fisheries and Aquaculture Circular No. 1054. Rome, FAO. 123 pp. (also available at www.fao.org/docrep/012/i1493e/i1493e00.htm)

Macfadyen, G., Huntington, T. & Cappel, R. 2009. *Abandoned, lost or otherwise discarded fishing gear*. UNEP Regional Seas Reports and Studies No. 185. FAO Fisheries and Aquaculture Technical Paper No. 523. Rome, UNEP/FAO. 115 pp. (also available at www.fao.org/docrep/011/i0620e/i0620e00.htm).

Mack, R., Simberloff, D., Lonsdale, W.M., Evans, H., Clout, M. & Bazzaz, F. 2000. Biotic invasions: causes, epidemiology, global consequences, and control. *Ecological Applications*, 10: 689–710.

MacMullen, P., Hareide, N., Furevik, D., Larsson, P., Tschernij, V., *et al.* 2003. *A study to identify, quantify and ameliorate the impacts of static gear lost at sea* [online]. FANTARED 2. Sea Fish Industry Authority, Hull, UK. [Cited 18 April 2014]. www.seafish.org/media/Publications/FANTARED_2_COMPLETE.pdf

Manuel, M. & Koyanagi, K. 2011. Diving for debris: methods and approaches for human-powered in-water marine debris removal. *In* B. Carswell, K. McElwee & S. Morison, eds. 2011. *Technical Proceedings of the Fifth International Marine Debris Conference. March 20-25, 2011*, pp. 41–42. Technical Memorandum NOS-OR&R-38. Silver Spring, USA, National Oceanic and Atmospheric Administration.

Marsac, F., Fonteneau, A. & Ménard, F. 2000. Drifting FADs used in tuna fisheries: an ecological trap? *In* J. Le Gall, P. Cayré & M. Taquet, M., eds. *Pêche thonière et dispositifs de concentration de poissons*, pp. 537–552. Montpellier, France, IRD, Laboratoire HEA.

Matsuoka, T., Nakashima, T. & Nagasawa, N. 2005. A review of ghost fishing: scientific approaches to evaluation and solutions. *Fisheries Science*, 71: 691–702.

Matsushita, Y., Machida, S., Kanehiro, H., Nakamura, F. & Honda, N. 2008. Analysis of mesh breaking loads in cotton gill nets: possible solution to ghost fishing. *Fisheries Science*, 74: 230–235.

McElwee, K. & Morishige, C., eds. 2010. *Proceedings of the Workshop on At-sea Detection and Removal of Derelict Fishing Gear. Honolulu, HI, December 9-10, 2008*. Technical Memorandum NOS-OR&R-34. Silver Spring, USA, National Oceanic and Atmospheric Administration.

Melvin, E., Parrish, J. & Conquest, L. 2001. Novel tools to reduce seabird bycatch in coastal gillnet fisheries. *In* E. Melvin & J. Parrish, eds. *Seabird bycatch: trends, roadblocks, and solutions*, pp. 161–184. AK-SG-01-01i. University of Alaska Sea Grant.

Mio, S., Domon, T., Yoshida, K. & Matsumura, S. 1990. Preliminary study on change in shape of drifting nets placed in the sea. *In* R. Shornura & M. Godfrey, eds. *Proceedings of the Second International Conference on Marine Debris. 2-7 April 1989, Honolulu, Hawaii*, pp. 615–620 [online]. NOAA Tech Memo NMFS, NOAA-TM-NMFS-SWFSC-154. U.S. National Marine Fisheries Service, Southwest Fisheries Science Center, La Jolla, California, USA. [Cited 13 May 2014]. http://swfsc.noaa.gov/publications/TM/SWFSC/NOAA-TM-NMFS-SWFSC-154.PDF

Misund, R., Kolle, J., Haugen, S. & Hareide, R. 2006. *The Norwegian retrieval survey for lost gillnets 2005* [online]. Norwegian Directorate for Fisheries, Bergen, Norway. [Cited 12 June 2014]. www.fiskeridir.no/content/download/7860/64040/version/1/file/engelsk_mars06.pdf

Miyake, M., Guillotreau, P., Sun, C. & Ishimura, G. 2010. *Recent developments in the tuna industry. Stocks, fisheries, management, processing, trade and markets*. FAO Fisheries and Aquaculture Technical Paper No. 543. Rome, FAO. 125 pp. (also available at www.fao.org/3/a-i1705e/index.html).

Molenaar, E., Iferink, A. & Rothwell, D., eds. 2013. *The Law of the Sea and the polar regions: interactions between global and regional regimes*. Leiden, the Netherlands, Martinus Nijhoff Publishers.

Moore, C. 2008. Synthetic polymers in the marine environment: a rapidly increasing, long-term threat. *Environmental Research*, 108: 131–139.

Murphy, P. 2011. In-water technology to detect derelict fishing gear in marine/estuarine ecosystems. *In* B. Carswell, K. McElwee & S. Morison, eds. 2011. *Technical Proceedings of the Fifth International Marine Debris Conference. March 20-25, 2011*, pp. 25–26. Technical Memorandum NOS-OR&R-38. Silver Spring, USA, National Oceanic and Atmospheric Administration.

Murphy, B. & Willis, D. 1996. *Fisheries techniques*. Bethesda, USA, American Fisheries Society.

Musick, J., ed. 1999a. *Life in the slow lane: ecology and conservation of long-lived marine animals*. Symposium 23. Bethesda, USA, American Fisheries Society.

Musick, J. 1999b. Criteria to define extinction risk in marine fishes. *Fisheries*, 24: 6–14.

Musyl, M., Brill, R., Curran, D., Fragoso, N., McNaughton, L., Nielsen, A., Kikkawa, B. and Moyes, C. (2011). Postrelease survival, vertical and horizontal movements, and thermal habitats of five species of pelagic sharks in the central Pacific Ocean. *Fishery Bulletin* 109, 341-361.

Nakashima, T. & Matsuoka, T. 2004. Ghost-fishing ability decreasing over time for lost bottom-gillnet and estimation of total number of mortality. *Nippon Suisan Gakkaishi* (Japanese Edition), 70: 728–737.

Nakashima, T. & Matsuoka, T. 2005. Ghost fishing mortality and fish aggregation by lost bottom-gillnet tangled around fish aggregation device. *Nippon Suisan Gakkaishi* 71: 178– 187.

National Fish and Wildlife Foundation (NFWF). 2013. *National fishing for energy locations* [online]. Washington, DC. [Cited 19 March 2014]. www.nfwf.org/fishingforenergy/Documents/FFE.Collection.Locations.pdf

National Marine Fisheries Service (NMFS). 2012. *Chinook salmon bycatch management* [online]. Alaska Regional Office, Juneau, USA. [Cited 15 February 2012]. www.fakr.noaa.gov/sustainablefisheries/bycatch/default.htm

Natural Resources Consultants. 2013. *Deepwater derelict fishing gear removal protocols* [online]. Prepared for the National Oceanic and Atmospheric Administration and Northwest Straits Marine Conservation Foundation. Natural Resources Consultants, Seattle. [Cited 21 March 2014]. www.derelictgear.org/uploads/pdf/Derelict%20Gear/DG-Deepwater_DFGR_Protocols.063013.pdf

Nedelec, C. & Prado, J. 1990. *Definition and classification of fishing gear categories*. FAO Fisheries Technical Paper No. 222, Revision 1. Rome, FAO. 92 pp. (also available at ftp://ftp.fao.org/docrep/fao/008/t0367t/t0367t00.pdf).

North Atlantic Salmon Conservation Organization (NASCO). 1983. *The Convention for the Conservation of Salmon in the North Atlantic Ocean*. Edinburgh, UK.

North Atlantic Salmon Conservation Organization (NASCO). 1993. *Minimum Standard for Catch Statistics Adopted by the Council at its Tenth Annual Meeting 7-11 June 1993, Edinburgh, UK* [online]. CNL(93)51. Edinburgh, UK. [Cited 2 April 2014]. www.nasco.int/pdf/agreements/minimum_standard.pdf

North Atlantic Salmon Conservation Organization (NASCO). 2008. *Fisheries Management Focus Area Report. Denmark (Faroe Islands and Greenland) – Greenland*. IP(08)07rev. Prepared by the Greenland Department of Fisheries, Hunting and Agriculture. Edinburgh, UK.

North Atlantic Salmon Conservation Organization (NASCO). 2010. *Decision Regarding the Salmon Fishery in the Faroese Waters 2011*. NEA(10)8. Edinburgh, UK.

North Atlantic Salmon Conservation Organization (NASCO). 2011. *Report of the ICES Advisory Committee*. CNL(11)8. Edinburgh, UK.

North Atlantic Salmon Conservation Organization (NASCO). 2012. *Background* [online]. Edinburgh, UK. [Cited 10 January 2012]. www.nasco.int/background.html

North Atlantic Salmon Conservation Organization (NASCO). 2013a. *Report of the ICES Advisory Committee*. NASCO Council CNL(13)8. North Atlantic Salmon Conservation Organization, Edinburgh, UK.

North Atlantic Salmon Conservation Organization (NASCO). 2013b. *Report of the Thirtieth Annual Meeting of the West Greenland Commission of the North Atlantic Salmon Conservation Organization. Westcourt Hotel, Drogheda, Ireland 4 - 7 June 2013* [online]. WGC(13)11. Edinburgh, UK. [Cited 2 April 2014]. www.nasco.int/pdf/reports_annual/2013%20Commissions%20Report.pdf

Northwest Atlantic Fisheries Organization (NAFO). 2013. *Scientific council reports 2013*. Dartmouth, Canada.

Northwest Straits Foundation. 2007. *Derelict fishing gear priority ranking project*. Bellingham, USA, Northwest Straits Foundation.

North East Atlantic Fisheries Commission (NEAFC). 2008. *Performance Review Panel Report of the North East Atlantic Fisheries Commission, NEAFC*. London.

North Pacific Anadromous Fish Commission (NPAFC). 1992. *Convention for the Conservation of Anadromous Stocks in the North Pacific Ocean*. Vancouver, Canada.

North Pacific Anadromous Fish Commission (NPAFC). 2010. *Performance Review Panel Report*. Vancouver, Canada.

North Pacific Anadromous Fish Commission (NPAFC). 2012a. *About NPAFC* [online]. Vancouver, Canada. [Cited 22 January 2012]. www.npafc.org/new/about_convention.html

North Pacific Anadromous Fish Commission (NPAFC). 2012b. *North Pacific Anadromous Fish Commission Annual Report 2012* [online]. Vancouver, Canada. [Cited 4 April 2014]. www.npafc.org/new/publications/Annual%20Report/2012/Annual%20Report%202012/index.html#/2/

O'Hare, G. 2001. Hurricane 07B in the Godavari Delta, Andhra Pradesh, India: vulnerability, mitigation and the spatial impact. *The Geographical Journal*, 167: 23–38.,

Pacific Salmon Commission (PSC). 2013a. *Treaty Between the Government of Canada and the Government of the United States of America Concerning Pacific Salmon* [online]. Vancouver, Canada. [Cited 5 April 2014]. www.psc.org/pubs/Treaty/Treaty.pdf

Pacific Salmon Commission (PSC). 2013b. *FRP news releases and regulatory announcements 2013* [online]. Vancouver, Canada. [Cited 7 April 2014]. www.psc.org/news_frpnews.htm

Parker, P. 1990. Cleaning the oceans of the plastics threat. *Sea Frontiers*, 36: 18–27.

Pawson, M. 2003. The catching capacity of lost static fishing gears: introduction. *Fisheries Research*, 64: 101–105.

Pham, C., Ramirez-Llodra, E., Alt, C., ***et al.*** 2014. Marine litter distribution and density in European Seas, from the shelves to deep basins. *PLoS ONE*, 9(4): e95839 [online]. doi: 10.1371/journal.pone.0095839.

Pramod, G., Pitcher, T., Pearch, J. & Agnew, D. 2008. *Sources of information supporting estimates of unreported fishery catches (IUU) for 59 countries and the high seas* [online]. Fisheries Centre Research Reports 16(4). Fisheries Centre, University of British Columbia, Vancouver, Canada. [Cited 15 May 2014]. https://circle.ubc.ca/bitstream/handle/2429/40935/FCRR_2008_16-4.pdf?

Price, B. & Van Salisbury, C. 2007. *Low-profile gillnet testing in the deep water region of Pamlico Sound, NC*. Morehead City, USA, North Carolina Department of Environment and Natural Resources, Division of Marine Fisheries.

Punt, A., Smith, D., Tuck, G. & Methot, R. 2006. Including discard data in fisheries stock assessments: two case studies from south-eastern Australia. *Fisheries Research*, 79: 239–250.

Recht, F. 2010. *Fishing gear recycling and disposal options and guidelines* [online]. Prepared for West Coast Governor's Agreement on Ocean Health Derelict Fishing Gear Workshop, March 2010. Pacific States Marine Fisheries Commission, Portland, USA. [Cited 19 March 2014]. www.psmfc.org/habitat/Fishing_Gear_Recycling.pdf

Regional Commission for Fisheries (RECOFI). 2008. *Report of the Second Session of the RECOFI Working Group on Fisheries Management, Cairo, Egypt, 27-30 October 2008*. FAO Fisheries and Aquaculture Report No. 889. Cairo, FAO. 61 pp. (also available at www.fao.org/docrep/011/i0664e/i0664e00.htm).

Regional Commission for Fisheries (RECOFI). 2009. *Outline of the Commission Structure and Modus Operandi*. Regional Commission for Fisheries (RECOFI) Fifth Session, Dubai, United Arab Emirates, 12-14 May 2009. Cairo.

Regional Commission for Fisheries (RECOFI). 2011. *Recommendation RECOFI/6/2011/1 on Minimum Data Reporting in the RECOFI Area*. Cairo.

Regional Commission for Fisheries (RECOFI). 2013a. *Implementation of RECOFI Recommendation RECOFI/6/2011/1 on Minimum Data Reporting in the RECOFI Area* [online]. RECOFI/VII/2013/9. Cairo. [Cited 12 April 2014]. ftp://ftp.fao.org/FI/DOCUMENT/RNE/RECOFI_2013_7th/9e.pdf

Regional Commission for Fisheries (RECOFI). 2013b. *Report of the Sixth Meeting of the RECOFI Working Group on Fisheries Management, Doha, The State of Qatar, 5-8 November 2012*. Cairo.

Revill, A. & Dunlin, G. 2003. The fishing capacity of gillnets lost on wrecks and on open ground in UK coastal waters. *Fisheries Research*, 64: 107–113.

Rose, C., Carr, A., Ferro, D., Fonteyne, R. & MacMullen, P. 2000. Using gear technology to understand and reduce unintended effects of fishing on the seabed and associated communities: background and potential directions. *In* ICES. *Working Group on Fishing Technology and Fish Behavior, 10–14 April 2000, Ijmuiden, The Netherlands* [online]. Fisheries Technology Committee ICES CM 2000/B:03. International Council for the Exploration of the Seas, Copenhagen. [Cited 13 June 2014]. www.imr.no/ftfb/Rose%20et%20al%20(File%203).pdf

Sancho, G., Puente, E., Bilbao, A., Gomez, E. & Arregi, L. 2003. Catch rates of monkfish (*Lophius spp*.) by lost tangle nets in the Cantabrian Sea (northern Spain). *Fisheries Research*, 64: 129–139.

Santos, M., Gaspar, M. & Monteiro, C. 2009. Ghost fishing on by-catch species from a gill net hake fishery. *Fisheries Management and Ecology*, 16: 72–74.

Santos, M., Saldanha, H., Gaspar, M. & Monteiro, C. 2003a. Causes and rates of net loss off the Algarve (southern Portugal). *Fisheries Research*, 64: 115 – 118.

Santos, M., Saldanha, H., Gaspar, M. & Monteiro, C. 2003b. Hake (*Merluccius merluccius*, L. 1758) ghost fishing by gill nets off the Algarve (southern Portugal). *Fisheries Research*, 64: 119 128.

Sea Around Us Project (SAUP). 2011. *Landings by gear type in the global ocean, 2006* [online]. University of British Columbia, Vancouver, Canada. [Cited 11 June 2014]. www.seaaroundus.org/global/1/5.aspx

Secretariat of the Pacific Community (SPC). 2007a. *SPC/FFA Regional Pole-and-Line Logsheet* [online]. Revised Nov. 2007. Noumea. [Cited 29 March 2014]. file:///C:/Users/ELG/Desktop/Web_Downloads/07%20PL.pdf

Secretariat of the Pacific Community (SPC). 2007b. *SPC/FFA Regional Handline Logsheet* [online]. Revised Nov. 2007. Noumea. [Cited 29 March 2014]. file:///C:/Users/ELG/Desktop/Web_Downloads/07%20Handline.pdf

Secretariat of the Pacific Community (SPC). 2007c. *SPC/FFA Regional Troll Logsheet* [online]. Revised Nov. 2007. Noumea. [Cited 29 March 2014]. file:///C:/Users/ELG/Desktop/Web_Downloads/07%20Troll.pdf

Secretariat of the Pacific Community (SPC). 2009a. *SPC/FFA Regional Observer Vessel Trip Report. Form GEN-3* [online]. Noumea. [Cited 16 March 2014]. file:///C:/Users/ELG/Desktop/Web_Downloads/09%20-%20Obs%20GEN-3%20(final).pdf

Secretariat of the Pacific Community (SPC). 2009b. *SPC/FFA Regional Observer Pollution Report*. Form GEN-6. Noumea.

Secretariat of the Pacific Community (SPC). 2009c. *Coverage 2009* [online]. Noumea. [Cited 16 March 2014]. www.spc.int/oceanfish/custom/coverage/Coverage2009.pdf.

Secretariat of the Pacific Community (SPC). 2009d. *SPC/FFA Regional Longline Logsheet – Expanded Format* [online]. Revised Nov. 2009. Noumea. [Cited 29 March 2014]. www.spc.int/oceanfish/en/publications/doc_download/986-ll-logsheet-expanded

Secretariat of the Pacific Community (SPC). 2009e. *SPC/FFA Regional Purse-Seine Logsheet* [online]. Revised Nov. 2009. Noumea. [Cited 29 March 2014]. file:///C:/Users/ELG/Desktop/Web_Downloads/09%20PS.pdf

Secretariat of the Pacific Community (SPC). 2010. *Regional Artisanal Tuna Fishing Logsheet* [online]. Interim SPC/FFA Feb. 2010. Noumea. [Cited 29 March 2014]. file:///C:/Users/ELG/Desktop/Web_Downloads/09%20Artisanal%20FAD%20 logsheet.pdf

Secretariat of the Pacific Community (SPC). 2011. *Report of the Eighth Meeting of the Tuna Fishery Data Collection Committee. 16-19 November 2009. Noumea, New Caledonia* [online]. Noumea. [Cited 29 March 2014]. file:///C:/Users/ELG/Desktop/Web_Downloads/DCC8%20final.pdf

Secretariat of the Pacific Community (SPC). 2013. *Western and Central Pacific Fisheries Commission Tuna Fishery Yearbook 2012*. Oceanic Fisheries Programme. Noumea.

Shester, G. & Micheli, F. 2011. Conservation challenges for small-scale fisheries: bycatch and habitat impacts of traps and gillnets. *Biological Conservation*, 144: 1673–1681.

South East Atlantic Fisheries Organisation (SEAFO). 2009. *Report of the SEAFO Scientific Committee. 2009*. Windhoek.

South East Atlantic Fisheries Organisation (SEAFO). 2010. *Report of the Performance Review Panel*. Windhoek.

South East Atlantic Fisheries Organisation (SEAFO). 2014. *SEAFO Authorised Vessel List 2014* [online]. Windhoek. [Cited 12 March 2014]. www.seafo.org/AuthorisedVessellist.pdf

South Pacific Regional Fisheries Management Organisation Secretariat (SPRFMO). 2013. *Conservation and Management Measure for Gillnets in the SPRFMO Convention Area*. CMM 1.02. Wellington.

South Pacific Regional Fisheries Management Organisation Secretariat (SPRFMO). 2014. *Conservation and Management Measure on Standards for the Collection, Reporting, Verification and Exchange of Data*. CMM 2.02. Wellington.

Southern Indian Ocean Fisheries Agreement (SIOFA). 2004. *Resolution on Data Collection Concerning the High Seas in the Southern Indian Ocean* [online]. [Cited 30 March 2014]. www.fao.org/fileadmin/user_upload/legal/docs/035t-e.pdf

Southern Indian Ocean Fisheries Agreement (SIOFA). 2006. *Southern Indian Ocean Fisheries Agreement* [online]. [Cited 30 March 2014]. www.fao.org/fileadmin/user_upload/legal/docs/035t-e.pdf

Southern Indian Ocean Fisheries Agreement (SIOFA). 2013. *Report of the First Meeting of the Parties to the Southern Indian Ocean Fisheries Agreement. Melbourne, Australia 18-19 October 2013*.

Suuronen, P. & Erickson, D. 2010. Mortality of animals that escape fishing gears or are discarded after capture: Approaches to reduce mortality. *In* P. He, ed. *Behavior of marine fishes. capture processes and conservation challenges*, Chapter 11, pp. 265–294. Oxford, UK, Blackwell Publishing.

Suuronen, P., Chopin, F., Glass, C., Lokkeborg, S., Matsushita, Y. Queirolo, D. & Rihan, D. 2012. Low impact and fuel efficient fishing—Looking beyond the horizon. *Fisheries Research*, 119–120: 135–146.

Swimmer, Y. & Gilman, E., eds. 2012. *Report of the Sea Turtle Longline Fishery Post-release Mortality Workshop, November 15-16, 2011* [online]. NOAA Technical Memorandum NMFS-PIFSC-34. National Marine Fisheries Service, Pacific Islands Fisheries Science Center, Honolulu, USA. www.pifsc.noaa.gov/library/pubs/tech/NOAA_Tech_Memo_PIFSC_34.pdf

Tabata, K. & Kanehiro, H. 2004. Application of biodegradable plastic to fishing implements. *Aquabiology*, 26: 136–141.

Thorpe, T. & Frierson, D. 2009. Bycatch mitigation assessment for sharks caught in coastal anchored gillnets. *Fisheries Research*, 98: 102–112.

Trippel, E., Holy, N., Palka, D., Shepherd, T., Melvin, G. & Terhune, J. 2003. Nylon barium sulphate gillnet reduces porpoise and seabird mortality. *Marine Mammal Science*, 19: 240–243.

Tschernij, V. & Larsson, P. 2003. Ghost fishing by lost cod gill nets in the Baltic Sea. *Fisheries Research*, 64: 151–162.

Uhlmann, S. & Broadhurst, M. 2013. Mitigating unaccounted fishing mortality from gillnets and traps. *Fish and Fisheries*, doi: 10.1111/faf.12049.

United Nations. 1982. *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*. New York, USA.

United Nations. 2007. *Sixth Round of Informal Consultations of States Parties to 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, New York, 23-24 April 2007. Annex II. Recommended Minimum Criteria for Reviewing the Performance of Regional Fisheries Management Organizations (RFMOs) Draft, 13 April 2007*. ICSP6/UNFSA/REP/INF.1. New York, USA.

United Nations Environment Programme (UNEP). 2005a. *Marine litter: an analytical overview* [online]. Nairobi. [Cited 25 April 2014]. www.unep.org/regionalseas/marinelitter/publications/docs/anl_oview.pdf

United Nations Environment Programme (UNEP). 2005b. *Regional seas partnerships for sustainable development* [online]. Regional Seas Programme, United Nations Environment Programme, Nairobi. [Cited 19 March 2014]. www.unep.org/regionalseas/publications/brochures/pdfs/regionalseas_brochure.pdf

United Nations Environment Programme (UNEP). 2012. *Manila Declaration on Furthering the Implementation of the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities* [online]. UNEP/GPA/IGR.3/CRP.1/Rev.1. United Nations Environment Programme, Nairobi. [Cited 16 April 2014]. www.iyds-2013.org/sites/www.iyds-2013.org/files/Manila%20Declaration.pdf

United Nations Environment Programme (UNEP). 2014. *The Regional Seas Programmes* [online]. Nairobi. [Cited 21 April 2014]. www.unep.org/regionalseas/programmes/default.asp

United Nations Environment Programme (UNEP) & National Oceanic and Atmospheric Administration (NOAA). 2012. *The Honolulu Strategy. A global framework for prevention and management of marine debris*. Nairobi and Washington, DC.

United Nations General Assembly (UNGA). 1991. *Large-scale Pelagic Drift-net Fishing and its Impact on the Living Marine Resources of the World's Oceans and Seas*. United Nations General Assembly Resolution A/RES/46/215. New York, USA.

United Nations General Assembly (UNGA). 2004. *Resolution adopted by the General Assembly [without reference to a Main Committee (A/59/L.23 and Add.1)]. 59/25. Sustainable fisheries, including through the 1995 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, and related instruments*. United Nations General Assembly Resolution A/RES/59/25. New York, USA.

United Nations General Assembly (UNGA). 2006a. *United Nations General Assembly Resolution 60/31. Sustainable fisheries, including through the 1995 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, and related instruments*. New York, USA.

United Nations General Assembly (UNGA). 2006b. *United Nations General Assembly Resolution 60/30. Oceans and the Law of the Sea*. New York, USA.

United Nations General Assembly (UNGA). 2007a. *United Nations General Assembly Resolution 61/222. Oceans and the Law of the Sea*. New York, USA.

United Nations General Assembly (UNGA). 2007b. *United Nations General Assembly Resolution 61/105. Sustainable fisheries, including through the 1995 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, and related instruments*. New York, USA.

United Nations General Assembly (UNGA). 2009a. *United Nations General Assembly Resolution 63/111. Oceans and the Law of the Sea*. New York, USA.

United Nations General Assembly (UNGA). 2009b. *United Nations General Assembly Resolution 63/112. Sustainable fisheries, including through the 1995 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, and related instruments*. New York, USA.

United Nations General Assembly (UNGA). 2010a. *United Nations General Assembly Resolution 64/72. Sustainable fisheries, including through the 1995 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, and related instruments*. New York, USA.

United Nations General Assembly (UNGA). 2010b. *United Nations General Assembly Resolution 64/71. Oceans and the Law of the Sea*. New York, USA.

United Nations General Assembly (UNGA). 2011. *United Nations General Assembly Resolution 65/38. Sustainable fisheries, including through the 1995 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, and related instruments*. New York, USA.

United Nations General Assembly (UNGA). 2012a. *United Nations General Assembly Resolution 66/68. Sustainable fisheries, including through the 1995 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, and related instruments*. New York, USA.

United Nations General Assembly (UNGA). 2012b. *United Nations General Assembly Resolution 66/231. Oceans and the Law of the Sea*. New York, USA.

United Nations General Assembly (UNGA). 2013a. *United Nations General Assembly Resolution* 67/78. *Oceans and the Law of the Sea*. New York, USA.

United Nations General Assembly (UNGA). 2013b. *United Nations General Assembly Resolution* 67/79. *Sustainable fisheries, including through the 1995 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, and related instruments*. New York, USA.

United Nations General Assembly (UNGA). 2014a. *United Nations General Assembly Resolution 68/70. Oceans and the Law of the Sea*. New York, USA.

United Nations General Assembly (UNGA). 2014b. *United Nations General Assembly Resolution 68/71 (available as A/68/L.19). Sustainable fisheries, including through the 1995 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, and related instruments* [online]. Section VIII, Fisheries By-catch and Discards. Paragraph 96. New York, USA. [Cited 16 April 2014]. www.un.org/en/ga/search/view_doc.asp?symbol=A/RES/68/71

Valdemarsen, J.W. & Suuronen, P. 2003. Modifying fishing gear to achieve ecosystem objectives. *In* M. Sinclair & G. Valdimarsson, eds. *Responsible fisheries in the marine ecosystem*, pp. 321–341. FAO and CABI International Publishing.

Vanderlaan, A., Smedbol, R. & Taggart, C. 2011. Fishing-gear threat to right whales (*Eubalaena glacialis*) in Canadian waters and the risk of lethal entanglement. *Canadian Journal of Fisheries and Aquatic Sciences*, 68: 2174–2193.

Wang, J., Fisler, S. & Swimmer, Y. 2010. Developing visual deterrents to reduce sea turtle bycatch in gill net fisheries. *Marine Ecology Progress Series*, 408: 241–250.

Way, E. 1977. *Lost Gillnet (Ghost Net) Retrieval Project, 1976*. St Johns, Environment Canada, Fisheries and Marine Service, Industrial Development Branch.

Weimerskirch, H. & Jouventin, P. 1987. Population dynamics of the wandering albatross *Diomedea exulans* of the Crozet Islands: Causes and consequences of the population decline. *Oikos*, 49: 315–322.

Werner, T., Kraus, S., Read, A. & Zollett, E. 2006. Fishing techniques to reduce the bycatch of threatened marine animals. *Marine Technology Society Journal*, 40: 50–68.

Western and Central Pacific Fisheries Commission (WCPFC). (no date). *WCPFC Regional Observer Program Minimum Standard Data Fields and Instructions* [online]. Palikir. [Cited 16 March 2014]. www.wcpfc.int/system/files/Table-ROP-data-fields-instructions.pdf

Western and Central Pacific Fisheries Commission (WCPFC). 2000. *Convention on the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific Ocean*. Palikir.

Western and Central Pacific Fisheries Commission (WCPFC). 2008. *Conservation and Management Measure to Prohibit the Use of Large Scale Driftnets on the High Seas in the Convention Area*. Conservation and Management Measure 2008-04. Palikir.

Western and Central Pacific Fisheries Commission (WCPFC). 2013a. *Provision of Annual Catch Estimates for 2012* [online]. Palikir. [Cited 3 April 2014]. www.wcpfc.int/system/files/cat_est_2012.pdf

Western and Central Pacific Fisheries Commission (WCPFC). 2013b. *Conservation and Management Measure for Bigeye, Yellowfin and Skipjack Tuna in the Western and Central Pacific Ocean*. Conservation and Management Measure 2013-01. Palikir.

Wilcox, C., Hardesty, B., Sharples, R., Griffin, D., Lawson, T. & Gunn, R. 2013. Ghostnet impacts on globally threatened turtles, a spatial risk analysis for northern Australia. *Conservation Letters*, 6: 247–254.

World Society for the Protection of Animals (WSPA). 2014. *Fishing's phantom menace. How ghost fishing gear is endangering our sea life*. London.

Yates, L. 2007. *Nets to energy: The Honolulu derelict net recycling program. In: Proceedings of Coastal Zone 07* [online]. NOAA Coastal Services Center, Charleston, USA. [Cited 7 February 2014]. https://www.csc.noaa.gov/cz/

Problems resulting from abandoned, lost and discarded fishing gear (ALDFG) from marine gillnet and trammel net fisheries is increasingly of concern. Marine gillnets and trammel nets, which have relatively high ghost fishing potential, are globally important gear types, supplying about a fifth of global marine fisheries landings. The study describes and evaluates approaches to estimate ghost fishing mortality rates and levels and reviews the status of international monitoring and management of ALDFG and ghost fishing by marine gillnet and trammel net fisheries. The report recommends methods to estimate ghost fishing rates and levels, identifies research priorities, and recommends future action to enhance data collection and management to prevent and remediate ALDFG and ghost fishing by marine gillnets and trammel nets.

ISBN 978-92-5-108917-0 ISSN 2070-7010

9 789251 089170

I5051E/1/04.16