Food and Agriculture Organization of the United Nations

FAO FISHERIES AND AQUACULTURE PROCEEDINGS
44
ISSN 2070-6103

Proceedings of the Expert Workshop on Estimating Food Loss and Wasted Resources from Gillnet and Trammel Net Fishing Operations

8–10 April 2015
Cochin, India

Cover photograph:
Gillnet fishers in Cochin, India. Courtesy of Petri Suuronen, FAO

FAO
FISHERIES AND
AQUACULTURE
PROCEEDINGS
44

Proceedings of the Expert Workshop on Estimating Food Loss and Wasted Resources from Gillnet and Trammel Net Fishing Operations

8–10 April 2015
Cochin, India

Edited by

Petri Suuronen
Fishery Industry Officer
Fishing Operations and Technology Branch
FAO, Rome, Italy

Susana V. Siar
Fishery Industry Officer
Fishing Operations and Technology Branch
FAO, Rome, Italy

Leela Edwin
Principal Scientist and Head
Fishing Technology Division
Central Institute of Fisheries Technology
Cochin, India

Saly N. Thomas
Principal Scientist
Fishing Technology Division
Central Institute of Fisheries Technology
Cochin, India

P. Pravin
Principal Scientist
Fishing Technology Division
Central Institute of Fisheries Technology
Cochin, India

and

Eric Gilman
Consultant
Honolulu, Hawaii

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 2017

ISBN 978-92-5-109581-2

Preparation of this document

This document provides a summary of the presentations and discussions of the Expert Workshop on Estimating Food Loss and Wasted Resources from Gillnet and Trammel Net Fishing Operations, held in Cochin, India, on 8–10 April 2015. The Indian Council for Agricultural Research – Central Institute of Fisheries Technology (ICAR-CIFT) co-organized and hosted the workshop under a letter of agreement with FAO. Eric Gilman, consultant, drafted the workshop report, with contributions from ICAR-CIFT and the workshop participants. Susana V. Siar and Petri Suuronen, FAO Fishery Industry Officers, finalized the workshop report.

The appendixes and contributed papers are reproduced as submitted.

Abstract

Food is lost during all stages along supply chains of capture fishery products, during capture operations, post-harvest handling and processing, storage, distribution and consumption. Reducing food loss increases the sustainable production of fishery resources, supporting the long-term capacity to provide food, and increases economic opportunities for the capture fisheries sector. Gillnets and trammel nets are main fishing gears used in tropical fisheries associated with significant loss of fishery resources and food during fishing operations.

The Indian Council for Agricultural Research – Central Institute of Fisheries Technology (ICAR-CIFT) and Food and Agriculture Organization of the United Nations (FAO) convened the Expert Workshop on Estimating Food Loss and Wasted Resources from Gillnet and Trammel Net Fishing Operations in Cochin, India, from 8 to 10 April 2015. Sixteen experts from 9 countries participated.

FAO's Fishing Operations and Technology Branch prepared a background paper and distributed it to workshop participants in advance of the meeting, providing a starting point for discussion during the workshop. This paper included as an appendix a draft data collection form for an assessment of food loss during gillnet and trammel net fishing operations. ICAR-CIFT conducted a trial of this draft methodology and produced a report providing recommendations for modifying the draft form. Working groups discussed this draft methodology for assessing food loss and wasted resources and the trial findings, and the outputs were presented during the plenary.

The participating experts each provided 15-minute presentations on gillnet and trammel net fishing in their country, addressing: the main characteristics and extent of such fisheries in their country; catch quantities and composition; estimated quantities of resources lost, wasted or discarded in these fisheries; and causes of losses/waste and discarding.

The case studies from different countries pointed out the occurrence of food loss from gillnet and trammel net fisheries. However, there is a lack of information (qualitative and quantitative) on food loss and resources waste. Hence, it was decided to assess the level of food loss and resource wastage from such fisheries in selected countries on a pilot project basis, to analyse the findings, and to refine the methodology for assessment of the food loss and wasted resources from selected fisheries.

FAO. 2017. *Proceedings of the Expert Workshop on Estimating Food Loss and Wasted Resources from Gillnet and Trammel Net Fishing Operations, 8–10 April 2015, Cochin, India,* by Petri Suuronen, Susana V. Siar, Leela Edwin, Saly N. Thomas, P. Pravin and Eric Gilman, eds. FAO Fisheries and Aquaculture Proceedings No. 44. Rome, Italy.

Contents

Abbreviations and acronyms

ALDFG	abandoned, lost or otherwise discarded fishing gear
E/IFLAM	exploratory/informal fish loss assessment method
FIAO	Fishing Operations and Technology Branch (FAO)
FIAM	Products, Trade and Marketing Branch (FAO)
FMA	fisheries management area
GDP	gross domestic product
ICAR-CIFT	Indian Council for Agricultural Research – Central Institute of Fisheries Technology
QLAM	questionnaire loss assessment method
SSI	semi-structured interview
UWVCC	underwater visual census camera

1. Introduction

Attention toward reduction of food loss and food waste is growing at the international, regional and national levels. Food loss and waste are widely acknowledged as threats to sustainability, as well as food security. However, the pattern and scale of food waste throughout the supply chain remains poorly understood.

To improve food security and to reduce the adverse ecological effects of fisheries production, it is necessary to reduce loss and waste of food along the entire fisheries supply chain. Food is lost during all stages of capture fishery production: capture; handling and processing; storage; packaging; distribution; and consumption. Loss of fishery products reduces sustainable production, threatening long-term capacity to provide food, and reduces economic opportunities for the capture fisheries sector.

In tropical and subtropical fisheries, gillnets and trammel nets are the principal fishing gear types associated with significant loss of fishery resources and food. These two gear types are primarily used in artisanal, small-scale, household-based fisheries but large-scale gillnet fishing also exists. The extent and magnitude of these losses and of methods to assess loss during fishing operations for these gear types have not been well quantified or studied. Three harvesting stages identified for loss of fishery products from gillnet and trammel net fisheries were the setting, soaking and retrieval of fishing gear. Five broad categories of sources of loss during fishing operations can be described:

- Pre-catch (pre-harvest) mortalities, when organisms are caught, or collide with the gear, and die but are not brought onboard when the gear is retrieved. For example, organisms may be caught and die in the gear and be removed by predators or scavengers before gear retrieval, or organisms may escape from the gear but die later due to stress or injury resulting from the interaction (i.e. avoidance mortality).
- Discarding or downgrading upon haulback of the gear, and in subsequent stages, due to poor quality or economic or regulatory reasons (i.e. discard mortality).
- Post-release fishing mortality, when catch is landed on board and then released alive but stressed or injured to a degree that causes the organism to die later (i.e. delayed mortality).
- Fishing mortality in abandoned, lost or otherwise discarded fishing gear (ALDFG or ghost gear).
- Collateral sources of fishing mortality, caused by various ecological effects of fishing. For example, cumulative sublethal stressors from fishing or habitat degradation mortality may result in collateral mortalities.

The above-mentioned categories broadly constitute the pathways for losses associated from fishing operations in gillnets and trammel nets until the catch is brought to shore or transferred at sea. More information and greater understanding are needed on the types of fisheries resources that are lost to each cause, and during which stage of fishing operations each cause of loss occurs. Depending on the quality status and subsequent handling practices, high losses may incur between arrival on deck and when the catch is eventually landed or transferred.

The Fishing Operations and Technology Branch (FIAO) and the Products, Trade and Marketing Branch (FIAM) of FAO are currently engaged in food loss and waste reduction in the whole fish supply chain, beginning with harvesting and carrying on to distribution. FIAO is focusing on the harvesting stage of the fish supply chain and the goal of its programme is three-fold: (i) develop and agree on a methodology to estimate the loss and wasted resources in fishing operations; (ii) use the methodology to undertake case studies with selected fishing gears in selected countries, refining the methodology based on the findings, and identify technological and management options to reduce wasted resources from fishing operations; and (iii) test the management and technological options in selected fisheries.

For the biennium 2014-2015, FIAO's work focused on gillnetting, one of the major fishing methods in tropical and subtropical fisheries associated with significant waste of fisheries resources and food.

The Indian Council for Agricultural Research – Central Institute of Fisheries Technology (ICAR-CIFT) and FAO convened the Expert Workshop on Estimating Food Loss and Wasted Resources from Gillnet and Trammel Net Fishing Operations in Cochin, India, from 8 to 10 April 2015. Sixteen experts from 9 countries participated. Each participating expert was asked to provide a 15-minute presentation on gillnet and trammel net fishing in their country, addressing among others the following points:

- the main characteristics and extent of the gillnet and trammel net fisheries in their country or region (e.g. types of gear, numbers of vessels, types of vessel, main fishing areas and depths, number of people employed, participation of women in the supply chain);
- catch quantities, catch composition;
- estimated quantities of fish/catch lost, wasted or discarded in these fisheries;
- causes of losses/waste and discarding;
- other related problems and issues to be solved.

FIAO prepared a background paper, Avoiding and Reducing Food Loss during Gillnet and Trammel Net Fishing Operations, distributed it to workshop participants in advance of the meeting, providing a starting point for discussion during the workshop. This paper included as an appendix a draft data collection form for an assessment of food loss during gillnet and trammel net fishing operations. ICAR-CIFT conducted a trial of this draft methodology and produced the report, Pre-Test Report: An Assessment of Food Loss from Gillnets and Trammel Nets during Fishing Operations, providing recommendations for modifying the draft form. Working groups discussed this draft methodology for assessing food loss and wasted resources and trial findings, and the outputs where presented during the plenary.

2. Workshop aim and objectives

FAO and ICAR-CIFT convened an expert workshop to agree on a methodology for estimating food loss and wasted resources from gillnet and trammel net fishing, including suggestions for potential sites to pilot the methodology. The overarching aim of the workshop was to define an agreed methodology to identify the causes and quantify the extent of food loss from gillnet and trammel net fishing operations. Workshop objectives were to:

- discuss and describe gillnet fishing gear characteristics and fishing practices as they relate to food loss and waste;
- discuss and validate a draft methodology (including equipment and materials) to use in identifying and quantifying the extent of food loss from gillnet and trammel net fishing operations;
- identify case study countries to pilot the methodology;
- identify the next steps needed in finding solutions to reduce the food loss.

Appendix 1 presents the workshop agenda and Appendix 2 the list of participants.

3. Presentations

3.1 WORKSHOP BACKGROUND AND OBJECTIVES

Susana V. Siar, FAO

The presentation provided an overview of FAO's strategic objectives, including enabling inclusive and efficient agricultural food systems, under which FAO aims to reduce food loss and waste. Ms Siar introduced the Voluntary Guidelines for Securing Sustainable Small-scale Fisheries in the Context of Food Security and Poverty Eradication (SSF Guidelines), and relevant sections of the SSF Guidelines related to food loss and waste. Ms Siar also provided an overview of the FAO Definitional Framework of Food Loss, and definitions of quantitative and qualitative components of food loss, and the definition of food waste as a part of food loss. The presentation explained the Cochin workshop focus on estimating food loss during the harvesting portion of seafood supply chains. Ms Siar outlined the workshop aim and objectives (see Section 2), and reviewed the workshop agenda (Appendix 1).

3.2 OVERVIEW OF BACKGROUND REPORT: AVOIDING AND REDUCING FOOD LOSS DURING GILLNET AND TRAMMEL NET FISHING OPERATIONS

Petri Suuronen, FAO

Gillnets and trammel nets are main fishing gear types used in tropical fisheries associated with significant loss of fishery resources and food. These two gear types are primarily used in artisanal, small-scale, household-based fisheries. There is a paucity of data on the extent and magnitude of these losses and of methods to assess loss during fishing operations for these gear types. The various sources and causes for fishery products to be lost during the harvesting stage of the supply chain by marine and inland gillnet and trammel net fisheries were identified. The harvesting stage refers to the setting, soaking and retrieval of fishing gear. The types of resources that are lost due to each cause, and during which stage of fishing operations each cause of loss occurs, were also identified.

Five broad categories of sources of loss during fishing operations were described:

- Loss of fishery products results from pre-catch mortalities, when organisms are caught, or collide with the vessel or gear, and die but are not brought onboard when the gear is retrieved. For example, organisms may be caught and die in the gear and be removed by predators or scavengers before gear retrieval, or organisms may escape from the gear but die later due to stress or injury resulting from the interaction.
- Ghost fishing mortality by ALDFG is an additional source of food loss, which is particularly problematic in gillnet, trammel net and other passive fishing gears. Various fishery-specific intentional and unintentional causes for fishing gear to be abandoned, lost or discarded were reviewed.
- Upon haulback of the gear, dead catch might be discarded due to various economic or regulatory reasons.
- Post-release fishing mortality occurs when catch is landed onboard and then released alive but stressed or injured to a degree that causes the organism to die later.
- Collateral sources of fishing mortality are those that are indirectly caused by various ecological effects of fishing.

A method was presented that provides a first-order estimate of the level and causes of losses during gillnet and trammel net fishing operations. The assessment method employs a combination of an inventory of fishing gear and fisher interviews. A draft form to be used for the inventory and fisher interviews was presented. Inventories and expert surveys can provide a critically important first-order, qualitative understanding of basic characteristics of fishing gear and methods and causes of food loss where previously little or no information was available. Findings from a first-order food loss assessment could then be validated and augmented through more rigorous assessment methods. Information from the gear inventory can also enable a comparison of current gear designs and fishing methods to gear technology best practices to determine whether modifications could be introduced to mitigate problematic sources of loss, including bycatch of endangered, threatened and protected species.

3.3 GILLNET AND TRAMMEL NET FISHERIES OF THE EAST COAST OF INDIA

E. Vivekanandan, Central Marine Fisheries Research Institute

The India east coast has a 2 657 km long coastline, 118 000 km^2 continental shelf area, with 26 fishing harbours and 1 026 landing centres. Total gillnet landings in 2014 were 0.4 million tonnes, while total landings were 1.5 million tonnes. There are 12 100 mechanized drift gillnet vessels, which catch about 231 000 tonnes of fish per year, mainly hilsa, tunas and rays. Nets used by mechanized vessels are 1–6 km in length, and vessels fish within 25 km from shore. There are 39 600 motorized drift gillnet vessels, which catch about 130 000 tonnes per year, mainly Bombay duck, hilsa, clupeids and prawns. Nets used by motorized vessels are 0.4–0.8 km in length, and vessels fish within 5 km from shore. In addition, there are about 36 000 non-motorized drift gillnet vessels, which catch about 42 000 tonnes annually, comprised mainly of sardines and crabs. Nets used by non-motorized vessels are 0.3–0.6 km in length, and vessels fish within 3 km from shore. Demersal trammel nets of 400–800 m length are used by motorized vessels. Trammel net vessels fish 2–5 km from shore, in waters of about 20 m depth, and catch primarily shrimps, silverbellies and crabs.

Twenty fishers in the Chennai fisheries harbour were interviewed in March 2015 to obtain information on sources of food loss. The three main sources of food loss during harvesting operations were: (i) loss of drift gillnet gear (0.25 percent of gear was estimated to be lost); (ii) predation of gilled fish during long-duration hauls by mechanized vessels using drift gillnets (0.5 percent of catch, about 10–15 kg loss in 2.5 tonnes of catch); and (iii) predation on gilled shrimps and fish in trammel nets and demersal gillnets by pufferfish and crabs (about 1 percent of catch was estimated to be depredated). The total annual estimated level of food loss from these three sources at Chennai fisheries harbour was about 80 tonnes, or 0.57 percent of the total catch. Gear may also be lost when driftnets are long and have a long haul duration due to contact by passing vessels in navigation routes, and loss of demersal trammel nets and demersal gillnets which contact bottom boulders and shells. Value loss may occur when there is insufficient storage space and ice on board the vessel, estimated to cause a 10 percent loss in value in long-distance driftnet operations. There is nominal discarding of catch, as almost all the catch is retained and all the catch has some market value; however, some species that are required not to be retained by government regulations are then released alive or discarded dead. There may also be collateral food loss, such as large-mesh driftnets selectively removing pelagic predators, which reduces the mean trophic level by about 0.04–0.08 per decade, removing large spawners, and the incidental capture of endangered, threatened and protected species. Overall, food loss is low in the fisheries that are based out of the Chennai fisheries harbour relative to other gear types such as trawling. The catch enters the supply chain even if it has diminished value. However, reliable estimates of food loss are not available.

3.4 GILLNET AND TRAMMEL NET FISHERIES OF THE WEST COAST OF INDIA

P. Pravin, ICAR-CIFT

On the west coast of India, there are five coastal states: Gujarat, Maharashtra, Goa, Karnataka and Kerala. There are a total of 13 435 non-motorized fishing boats, 22 273 motorized vessels, and 7 750 mechanized vessels that use gillnets and trammel nets from these five states. Non-motorized gillnet vessels fish up to 3 km offshore at depths of 5–20 m. Motorized gillnet vessels fish between 3 and 5 km from shore at depths of 15–100 m. Mechanized gillnet vessels fish from 5 to 50 km offshore, at depths of more than 1 000 m. The mechanized gillnet vessels use nets that are 1–15 km in length and fish at depths of 8–20 m to target tunas, seerfish, sharks, barracuda and billfish. Drift and set gillnets catch ribbonfish, tunas, carangids, seerfish, sciaenids, pomfrets, sharks, rays, crabs, lobsters, golden anchovy, barracudas, billfishes, polynemids, and whitefishes. Trammel nets catch crabs, lobsters, shrimps and various fishes. There are data gaps in estimated pre-catch fishing mortality levels and rates, and estimated post-harvest losses on board. Main reasons for discarding catch are predation, spoilage, non-target species, long duration of trips, lack of ice and proper storage, and the net being cut due to contact by ships, strong currents and wind, and from the net snagging on bottom features. In estimating food loss from these fisheries, the reliability of information provided by fishers needs to be considered.

3.5 BAY OF BENGAL OF BANGLADESH REGION

Bikram Jit Roy, Marine Fisheries Survey and Management Unit, Bangladesh

In Bangladesh, there are about 32 609 gillnet fishing vessels. Of these, an estimated 19 789 are mechanized vessels, and 12 820 are non-mechanized. There are also 131 trammel net fishing vessels. There are about 114 353 gillnets in use, 73 768 nets used by mechanized vessels, and 40 585 nets used by non-mechanized vessels. There are 422 trammel nets used by the 131 trammel net vessels. Gillnets and trammel nets contribute 60 percent and 2 percent of total marine fisheries production per year, respectively. The government has established a marine reserve in the Middle Ground and South Patches, with a total area of 698 km^2. There are numerous different drift and set gillnet designs in use in Bangladesh, with different designs and fishing depths depending on the main target species. For example, the Ilish Jal driftnet is between 2.2 and 2.5 km in length, fishes at 8–10 m depth, and targets hilsa species. The large mesh driftnet Lakka jal / Bol hal is 2–5 km in length, fishes at a depth of about 25 m, and targets Indian salmon, croaker, grunter and catfish. As a third example, the Rog / Rocket jal driftnet is about 25 m in length, is set at 8–10 m depth, and is used to catch mainly sardines and croakers. Gillnet fisheries using drift and set gillnets target a large number of species, including hilsa, bigeye ilish, sharks, pomfret, tunas, mackerel, sardines, crabs, lobsters, shrimps, etc. There is also a wide range of designs of trammel nets depending on the target species. For example, the Tin porolla jal trammel net is about 20 m long, fishes at about 8–20 m depth, and targets shrimps, lobsters, jewfish, and other species. Food loss may occur due to discarding unmarketable species and pre-harvest mortality of escapees. There are also post-harvest losses, where an estimated 20 percent of landed marine fish can have reduced quality.

3.6 GILLNET AND TRAMMEL NET FISHING IN INDONESIA

Wudianto, Research Center for Fisheries Management and Conservation, Ministry of Marine Affairs and Fisheries, Indonesia

For better management of fisheries, the government of Indonesia through Ministry Regulation no. 01/2009 established 11 fisheries management areas (FMAs). There are four categories of gillnet fisheries in Indonesia: driftnet, encircling gillnet, shrimp gillnet, and set nets. In addition, there are trammel net fisheries. Gillnet and trammel nets catch small and large species of pelagic fishes, demersal fishes, coral fishes, crustaceans and molluscs. As an example, the catch of the South of Java, Indian Ocean gillnet fishery in 2011 was a total of 3 557 tonnes, made up of 68.5 percent skipjack tuna, 8.2 percent sharks, 8 percent bigeye tuna, 6.4 percent billfishes, and the remainder a mix of other large pelagic fish species. The catch of the sardine gillnet fishery of the Bali Strait, for comparison, is made up of 97 percent of a single species, *Sardinella lemuru*. Related to food loss, the lobster gillnet fishery loses a lot of lobsters to ghost fishing. There is no information on catch lost and discard from gillnet fisheries.

3.7 ESTIMATING FOOD LOSS AND WASTED RESOURCES FROM GILLNET AND TRAMMEL NET FISHING IN THAILAND

Anukorn Boutson, Kasetsart University, Thailand

Gillnet and entangling net fisheries in Thailand include a driftnet fishery for king mackerel, encircling gillnet fishery for Indo-Pacific mackerel, crab gillnet fishery, shrimp trammel net fishery, squid trammel net fishery, gillnet fishery for Indo-Pacific mackerel, and mullet gillnet fishery. In 2010, gillnet and trammel net fisheries produced a total of 54 735 tonnes from the Gulf of Thailand, and 22 407 tonnes from the Indian Ocean for a total of 77 142 tonnes. The research team conducted a study to modify shrimp trammel nets to reduce discarding. In this fishery, prawns, shrimp, spotted sicklefin, cuttlefish and barracuda are the retained market species. Species with low or no market value are discarded, and include pony fish, tripodfish, theraponid, cardinal fish, flathead fish, murex, pipefish and sea urchins. In addition, small sizes of market species are also discarded. About 90 percent of the catch by number of organisms and 87 percent by weight is discarded in this fishery. Two methods shown to reduce the catch of species and sizes that are discarded in this trammel net fishery are: increasing the mesh size of the inner net of the trammel net; and decreasing the height of the net. The research team also conducted a study on bycatch and discards in Rayong Province from bottom gillnet fishery targeting blue swimming crabs. The study was conducted by interviewing fishers, GPS tracking, reviewing logbook data and conducting an onboard survey. The main retained species are flathead lobster, bream, diamond trevally and oyster. Species with low or no market value are discarded, and include several crab species and *Murex pectin*. Crabs and *Murex pectin* are discarded due to being of low or no market value, oysters because too few are caught, and bream and diamond trevally because the catch was undersized.

3.8 STATUS OF GILLNETS AND TRAMMEL NETS IN VIET NAM

Nguyen Viet Nghia, Research Institute for Marine Fisheries, Viet Nam

In Viet Nam, the fisheries sector contributes about 3.0 percent of gross domestic product (GDP) and provide 40 percent of animal protein consumption. The numbers of vessels has increased rapidly (2002: 79 996 units; 2011: 128 363 units; 2013: 117 016 units). There are four management areas: Tonkin Gulf, Central, Southeast and Southwest. The main gear types include: trawl; purse seine; gillnets/trammel nets; falling nets; longline/hand line. Of a total of 47 295 fishing boats, there are 20 073 monofilament drift gillnets, 5 829 multifilament drift gillnets, 16 009 bottom gillnets, and 5 384 trammel nets. Total annual catch by driftnets is 394 714 tonnes, and the total annual catch by bottom gillnets is 185 130 tonnes.

Trammel net fisheries target demersal species, squid, crab and shrimp. Small vessels fish in coastal areas, with depths less than 30 m, mainly in the Tonkin Gulf. Monofilament driftnet fisheries target small pelagic species, demersal species, squid, crab and shrimp. Mainly small vessels fish primarily in shallow coastal areas in the Tonkin Gulf and Central regions. Multifilament driftnets target tuna and tuna-like species, use large vessels, and fish in offshore areas of the Central and Southeast regions. Bottom gillnets target demersal species, squid, crab and shrimp. Small vessels fish in shallow coastal areas in the Tonkin Gulf and Southwest regions.

There is a lack of knowledge on food loss and wasted resources by gillnets and trammel net fisheries, which likely represents a big challenge to sustainable development.

3.9 GILLNET AND TRAMMEL NET DISCARDS IN THE GULF OF SUEZ AND MEDITERRANEAN, EGYPT

Azza El Ganainy, National Institute of Oceanography and Fisheries, Egypt (presented by P. Suuronen, FAO)

Gillnet and trammel net are two of the various gear types used in artisanal inland and marine fisheries of Egypt in the Mediterranean Sea and Red Sea. Of a total of 3.5 million fishers involved in Egyptian fisheries, 85 percent are engaged in trammel net and gillnet fisheries. There are three main landing sites along the Suez Gulf (Attaka, Salakhana and Tur). In 2013, there were 711 fishing boats using longline, hooks, trammel nets and gillnets along the whole fishing ground. The catch of the Gulf of Suez represented by 33.6 percent of the total landing of the Egyptian Red Sea fisheries. The high value groupers (*Serranidae*) and emperors (*Lethrinidae*) are the most important species for the artisanal fishery. Gillnet and trammel net fisheries operating in the Gulf of Suez catch rabbitfish (29 percent of the catch), striped piggy (21 percent), sea bream (19 percent), cuttlefishes (12 percent), crabs (8 percent), horse mackerel (4 percent), grey mullet (4 percent), sardine (2 percent), and Spanish mackerel (1 percent). In the Mediterranean Sea, fishing is concentrated in the coastal zone, from Alexandria to Port Said, about 300 km in length. Trammel net fisheries operating in the Mediterranean catch rabbitfish (18 percent of the catch), panadora (13 percent), noct (12 percent), shrimps (8 percent), crabs (7 percent), Mullidae (8 percent), sea bream (6 percent), rays (5 percent), cuttlefish (5 percent), octopus (4 percent), and small amounts of other fishes (10 percent). Gillnet fisheries operating in the Mediterranean catch jacks (39 percent), tunas (26 percent), sea bream (9 percent), *Pomatomus saltatrix* (8 percent), and small amounts of other fishes (18 percent). The main reason for discarding catch caught by trammel nets is due to catching small sized organisms and unwanted species, including pufferfish, *trigla* spp., bivalves and algae. No discarded sizes or species were recorded from gillnet fisheries.

3.10 ESTIMATING FOOD LOSS AND WASTED RESOURCES FROM GILLNET FISHERY OF LAKE VICTORIA

Yahya Mgawe, Fisheries Education and Training Agency, Ministry of Livestock and Fisheries Development, United Republic of Tanzania

The total fish landing in 2013 from Lake Victoria was 235 530 tonnes. In 2012, there were 602 landing sites in the Tanzanian coastline of Lake Victoria. There were 141 364 gillnets of more than 6 inch (15 cm) mesh size, and 210 753 with a mesh size of less than 6 inches, in 2012. There are four types of common gillnet designs used for fishing for Nile perch on Lake Victoria, and a fifth type used to target tilapia. A typical Nile perch gillnet vessel will catch 20–50 Nile perch per trip, and will fish in waters 14–40 m depth. Between 10–15 percent of the catch in Nile perch gillnet fisheries will spoil and have a lower value. The main reason for discarding fish is complete spoilage, otherwise, partially spoiled fish are salted for rural domestic market and regional market, but at reduced value. About 1 out of 50 caught fish is discarded due to low quality. Pre-catch losses such as due to predation or dropping out during hauling can be estimated by using underwater visual census camera (UWVCC). Most of the fishing gear types, including fine-meshed nets and monofilaments, being used in this fishery are illegal. Therefore, it needs more effort and thorough use of exploratory methods to generate data and information required to estimate food losses. Methods used to identify and quantify the extent of food loss from gillnet are: exploratory/informal fish loss assessment method (E/IFLAM), load tracking method, and questionnaire loss assessment method (QLAM). Data on estimates of lost, abandoned and/or discarded gillnets is mainly generated through exploratory semi-structured interviews (SSIs) and number of recovered nets from trawling operations. One to two sets of gillnets are recovered by trawlers each month. Estimates of ghost fishing mortality of abandoned, lost and discarded gillnets could be captured through SSIs and extrapolation using secondary data index.

3.11 GILLNET FISHERIES OF NEW ENGLAND

Michael Pol, Massachusetts Division of Marine Fisheries, United States of America

Bottom sink gillnets are the predominant type of gillnet used in New England, the United States of America. Large meshes of 139–203 mm are used by 100 or fewer vessels, with 2–3 crew per vessel. Extralarge meshes of greater than 203 mm are used by 130 or fewer vessels, also with 2–3 crew per vessel. Main fishing grounds are in the Gulf of Maine, Cape Cod Bay, and the northern edge of Georges Bank. A typical gillnet fleet will include 12 panels, where each panel is 91 m in length. Tie downs may be used when targeting monkfish and skates. The large mesh fishery catches about 7.0 million kg/year mainly of pollock (saithe), Atlantic cod, and spiny dogfish. The extralarge mesh fishery catches about 3.4 million kg/year of large skates, and about 1.5 million kg/year of monkfish. Fallout occurs, but has only been estimated for marine mammals. Seal depredation also occurs, but if not observed as discarded, then it is not quantified. Seals may scare potential catch away. Depredation by sea lice also occurs, but if not observed as discarded, then it is also not quantified. About 27 percent of the catch in the large-mesh fishery is discarded, of which about three-quarters of discards is spiny dogfish, due to a lack of market, or to being quota limited. In the extralarge mesh gillnet fishery, about 21 percent of the catch is discarded. About 69 percent of discarded catch from the extralarge mesh fishery is skates, which are discarded due to lack of market, quota limits, and quality. The remainder of discards from the extralarge gillnet fishery is monkfish (7 percent), due to quality, and spiny dogfish (4 percent) due to a lack of market and quality. Regulations may also be a source of food loss: (i) because this is a multispecies fishery with stocks at varying levels of sustainability, this leads to discarding; and (ii) low levels of observed hauls creates the opportunity for unrestrained discarding, which is exacerbated by small quotas. Market forces also can contribute to discarding: (i) a lack of domestic markets for spiny dogfish and skate in the United States of America; and (ii) barriers to export spiny dogfish to the European Union (Member Organization). Abandoned, lost and discarded fishing gear (ALDFG) also results in food loss. An estimated 101 nets/km^2 are ALDFG in these fishing grounds. The derelict gear decreases in capacity by about 15–20 percent within 15–20 weeks. The largest concern in this region is ALDFG from lobster pot fisheries.

4. Background presentations for working group sessions

There were three background presentations designed to prepare for the working group sessions.

4.1 GILLNET AND TRAMMEL NET FISHING GEAR CHARACTERISTICS AND FISHING PRACTICES THAT ARE RELEVANT TO UNDERSTANDING SOURCES OF FOOD LOSS AND WASTE

Michael Pol, Massachusetts Division of Marine Fisheries, United States of America

Gillnets and trammel nets might be appropriately described as the simplest designs of fishing gear. They are basically a sheet of webbing in a frame. They may require no gear movement or bait. Vessels can be mechanized, motorized or non-motorized. The nets can be fixed, drifting, floating, sweeping, benthic, pelagic and other designs. They are used globally, from the tropics to polar regions. The catching mechanism is due to the movement of organisms into the gear, i.e. the movement of fish exposes them to the gear. Temperature, speed and visibility are factors that significantly explain susceptibility to capture. Monofilament is almost invisible underwater. There is possibly some attraction due to knots. Catching modes include: gilling, where the mesh is behind the gill cover; wedging, where the fish cannot pass through; snagging, where the fish is caught by the mouth or teeth; and entangling, where the fish is caught by the fins, spines or other parts.

In trammel nets, the fish pushes the inner sheet through an outer sheet. Food loss can occur through pre-catch mortalities. It can also occur through discarding or downgrading, capture in ALDFG, and collateral mortalities such as from habitat degradation and various sublethal stressors. Food loss can be avoided and reduced by adjusting gear designs**.** The hanging ratio of a net can be defined as the length of the frame line to the length of webbing. For example, more or less flotation, change in location in the water column, adding or reducing weight, altering meshes (size, shape, colour, depth, twine diameter, twine material), and modifying the endline height or hanging ratio can all change rates of food loss. Increased gear size selectivity can be achieved through using appropriate mesh size, which is moderately difficult. Mesh size adjustment can also reduce fallout. Increasing species selectivity via gear modifications is difficult. Avoiding "charismatic" animals can be achieved via use of pingers, breakaway lines, and scaring devices. Reducing or eliminating ghost fishing efficiency of ALDFG can be accomplished by using biodegradable materials in select components of the gear. Solutions to food loss need to account for the fishery-specific context, i.e. there are no generalized solutions. In some cases, positive incentives are more appropriate, in others negative incentives are best, or a combination thereof. Solutions need to be collaborative. Creating a culture of no gear loss, such as by creating incentives for recovery of and reporting ALDFG, and developing full markets such as for use as fishmeal to eliminate discarding are part of the solutions.

4.2 FINDINGS FROM THE PRELIMINARY TRIAL OF THE DRAFT DATA COLLECTION FORM FOR AN ASSESSMENT OF FOOD LOSS DURING GILLNET AND TRAMMEL NET FISHING OPERATIONS CONDUCTED BY CIFT

Saly N. Thomas, ICAR-CIFT, India

The "draft data collection form for an assessment of food loss during gillnet and trammel net fishing operations" was designed to obtain information on sources and levels of food loss during fishing operations by gillnet and trammel net fisheries. Objectives of the pre-testing study were to assess the utility of the draft form with respect to:

- relevance of the questions for extracting the desired data;
- clarity/ambiguity, if any, in the questions;
- need for deletion, addition and/or modification of the questions;
- interview time required per respondent.

The gillnet fishing sector of India is characterized by three distinct subsectors: mechanized, motorized and non-motorized. These vary in terms of target resource, fishing implements, area of operation and soak time. Hence, 33 respondents representing the three sectors were selected for inclusion in the trial. There were three sampling sites in Kerala, and one each in Gujarat and Tamilnadu. The trial was conducted between 17 January and 7 February 2015. A detailed report from the trial is included in this publication. Puffer fish was the only non-market fish released, while jellyfish, starfish, squilla and juveniles of crabs were the non-market invertebrates released or discarded. Catch that have no market demand and banned to retain only were released or discarded. Predation on the catch was a major problem faced by all the three gillnet sectors, and the depredation on the catch was mainly by puffer fish, squids, cuttlefish, sharks and dolphins. One main issue raised with the draft form was the time taken for interviews (interviews took an average of 80 minutes, ranging from 45 to 120 minutes). Respondents were reluctant to reply when almost similar questions relating to quantification of ALDFG were put to them. It was difficult to obtain quantitative data. Questions on current speed at the fishing ground were found to be not answerable by the fishers. It was difficult to obtain answers to questions on delicate issues of marine mammal and turtle captures.

Recommended revisions to the data form were to add questions on fish loss due to dropping from the net during hauling, and on unwanted vertebrates other than fishes, such as snakes. Other recommended changes were to conduct interviews during the closed fishing season, and to make the form more concise and shorter so that fishers would not become impatient in participating.

4.3 POST-HARVEST LOSS ASSESSMENT: A METHODOLOGY AND SOME FISHING GEAR-RELATED FISH-LOSS DATA IN TROPICAL FISHERIES

Yvette Diei-Ouadi, FAO

A methodology for estimating post-harvest fishery losses was developed in the early 1990s in Africa and Asia, and the methodology was validated in 2006–08 via an FAO-led regional post-harvest loss assessment programme in Africa, and capacity development and case studies in small-scale fisheries. The methodology was mainstreamed within the FAO Global Initiative Save Food approach to food loss assessment, which is currently implemented in Indonesia. In 2013, the use of a mobile telephone-based data collection system within the FAO component of SmartFish programme was conducted. Advantages of the IT-based data collection method over paper-based methods include:

- quick collection of data/speed of data capture, transmission and processing;
- send and receive information wherever you are;
- location (GPS) captured automatically;

- more accurate data collected;
- near real-time data collection;
- faster decision-making
- easy to use / adopt;
- staff turnover better handled;
- cheaper running costs, paper backup.

This initiative within SmartFish is yet to be consolidated but is already off to a good start. Among the difficulties encountered was the particular software and the control over the data analysis and feeding results back to the field workers. In assessing the losses, it looks at various patterns that constitute the sustainable value chains.

There are three main components to the post-harvest food loss assessment method: (i) E/IFLAM; (ii) load-tracking method; and (iii) QLAM. The E/IFLAM is for exploration when unaware of problem or possible solution. The load tracking method is for descriptive assessment when there is awareness of the problem. The QLAM is for validation assessment once the problem is clearly defined. Data from case studies, including from Lake Victoria and the Indian Ocean, document high post-harvest losses in gillnet fisheries. Commonly reported causes of food losses are predation, escapement during hauling, soak time, net entanglement, bad navigation conditions, water pollution or warm temperatures, handling conditions on board, and harvesting immature fish. During interviews, the fishers would scarcely mention the length of time the net spends in the water, but this is actually a great contributor to losses and could make a significant difference with active gear types. There is a linkage between food loss occurrence and for fishers to increase their fishing effort as a coping strategy. Two key conclusions from the studies were that it is important to include the entire value chain in assessing food loss, and within different fishing seasons (lean and bumper seasons).

5. Working group session and plenary discussion

5.1 WORKING GROUP SESSION

During the second day of the workshop, the participants formed two working groups.

Group 1 discussed and reported on methodologies for assessing the following sources of food loss:

- Loss of fishery products results from pre-catch (pre-harvest harvest, viz., before being brought on board) mortalities, when organisms are caught, or collide with the gear, and die but are not brought onboard when the gear is retrieved. For example, organisms may be caught and die in the gear and be removed by predators or scavengers before gear retrieval. Or organisms may escape from the gear but die later due to stress or injury resulting from the interaction (i.e. avoidance mortality).
- Discards. Upon haulback of the gear and in the subsequent stages, catch might be discarded or downgraded due to poor quality or economic or regulatory reasons.

Group 1 participants identified the following sources of pre-catch losses:

- removed (die) by predators, before being brought on board;
- reduced health condition of fish (disease, enhanced by stress of capture);
- physical injury (collision/contact with gear): scale loss, gill damage from twine, fins, puncture or injury from other fish trying to escape (e.g. catfish, rays, skates); (market value is also affected); injury caused during struggle;
- slipping out (fish is caught, but escapes during struggle caused by hauling – more likely with slender or slippery fish, such as eels);
- escaped due to net damage, caused by:
  - o hauling in rocky areas or by caught shells;
  - o propeller of hauling vessel;
  - o passing vessel or gear conflict – (a common problem in this region with floating nets);
  - o shipwreck or other underwater structures (e.g. submerged trees in reservoirs);
  - o entanglement of large organisms or large catches;
  - o bad weather, or strong current leads to balling up of gear, problems that cause cutting of gear.

Group 1 participants described the following methodologies to estimate different sources of pre-catch losses:

- Fall out from net:
  - o quantify occurrence by direct observation;
  - o interview source/key informant to identify likely areas / hot spots;
  - o validate by direct observations from deck by scientist, observer, trained, key informant/fisher;
  - o validate underwater *in situ* by snorkel, diver (scuba), remotely operated vehicle or camera. Sonar, however, is not possible or is difficult.

- Data needs to estimate pre-catch losses include:
  - o for escapes: species, number, size/weight, injury/vitality,
    - note: use confidence level of species identification when using key informants;
  - o onboard catch needs identification, along with effort measures (trip, gear, haul, catch data);
  - o identify source of predation, including from dolphins, whales, seals, turtles, birds, isopods.
- Gear damage: method will vary by local custom/practice:
  - o experimental fishing;
  - o observation on commercial vessel;
  - o interviews.

Group 1 participants identified the following methods to estimate delayed mortalities:

- Direct measures (complicated):
  - o fish with a gillnet in a confined area;
  - o laboratory investigation using models;
  - o acoustic or other tagging underwater.
- Indirect measures:
  - o look for evidence of mortality: dead fish skeletons.

Group 1 described the following causes for discarding and physical losses:

- poor quality: spoiled or damage that occurs underwater;
- regulatory:
  - o catches of banned species (e.g. sharks, snakes, turtles, marine mammals, birds) are ecosystem losses but, by definition, not food loss – recording is useful.
    - note: is it food if people would eat, but regulations do not permit? (e.g. in Africa, a turtle would be eaten, but regulations forbid this);
  - o insufficient storage or ice leading to high-grading or inferior preservation quality;
  - o species may have market but no scope is available for processing requirement or a specialized market;
  - o contamination from poor hygiene leading to spoilage, including from high or variable temperature, poor housekeeping, and no ice, storage, or insulated boxes. contamination may also result from undecked vessels and resulting crushing;
- marketable, but inadequate price or not worth effort to retain;
- damage during removal from the net;
- economic or qualitative loss (fish kept, but full price not achieved):
  - o note: processing into fishmeal is a food loss;
  - o reduced price due to reduced quality.

Group 1 participants described the following methodologies to estimate different sources of post-catch and discard losses:

- at sea:
  - o at haulback, determine discard mortality through controlled experiments; concerns and needs include:
    - holding cages/tanks,
    - challenge of finding controls,
    - should be studied, but not initially;
  - o interview key informants to document:
    - specific handling techniques onboard,
    - type and quantity of storage space, ice quantity, temperature monitoring,
    - amount of volume that requires alternative or inferior preservation or discard;

- subsequent stages:
  - o interview landing centre observers/port agents to determine fate of landed fish,
  - o track individual lots,
  - o collection of tissue samples to identify time of death and quality,
    - note: tissue sampling may also need to be done on board,
    - note: it is possible to experimentally determine proper handling by changes in biochemistry under varying handling techniques,
  - o interview traders/auctioneers as key informants on price, quality, and fates of landed organisms,
  - o key informant interviews to document on board,
    - note: institutes can develop objective quality indices and best practices.

Group 2 discussed and reported on methodologies for assessing the following sources of food loss:

- Post-release fishing mortality, also called delayed mortality, which occurs when catch is landed on board and then released alive but stressed or injured to a degree that causes the organism to die later.
- Ghost fishing mortality by ALDFG, which is particularly problematic in gillnet, trammel net and other passive fishing gear types.
- Collateral sources of fishing mortality, those that are indirectly caused by various ecological effects of fishing. For example, cumulative sublethal stressors from fishing or habitat degradation mortality may result in collateral mortalities.

PLATE 1
Breakout groups 1 (top) and 2 (bottom) at work

Regarding post-release mortalities, the following points were raised by Group 2:

- In general, post release is not considered a very significant issue with finfish (in gillnet and trammel net fisheries) because in most cases fish are not released.

- There are special cases when the fish have to be released (by legislation).
- Furthermore, in general there is little chance for the fish to survive (because the capture process is damaging).
- Need to establish how much post release exists in gillnet fishery and how many (quantity) survives the capture and release process – long-term survival.
- Need criteria to define when the released fish are considered as food:
  - local, national and global definitions;
  - changing consumer preferences over time.

Methodologies to estimate post-release survival identified by Group 2 were:

- different tagging and tracking tools;
- survival studies in captivity (sea-cage, tanks, etc.);
- reflex impairment methods (indices, eye reflexes, gills, muscles) – can be done on deck and do not require any monitoring;
- skin injury, scale loss, etc.

Group 2 identified the following considerations related to ghost fishing mortalities:

- Ghost fishing occurs widely on fishing grounds where gillnet and trammel net fishery is common.
- It is considered a serious concern – and difficult to address.
- More information is urgently needed:
  - more information required on qualitative and quantitative aspects of ghost fishing as a matter of top priority;
  - varies with different bottom conditions;
  - ghost fishing should not be limited to gillnet and trammel net fishing only but should include also other passive fishing gear types (e.g. pots, longlines) when they constitute a major part of a fishery;
  - a more holistic view is needed to cover the overall impact of ghost fishing.

Methodologies to estimate ghost fishing mortality identified by Group 2 were:

- participatory and scientific programs through community consultations/ interactions;
- underwater observations;
- simulated ghost fishing experiments (the conditions);
- mitigating strategy: prevention better than cure;
- which will require:
  - awareness raising of communities,
  - regulatory framework,
  - buy back arrangements,
  - net trade to assess the consumption in community or in the sector.
- observers, logbook maintenance.

Regarding collateral sources of fishing mortality, Group 2 identified the following considerations:

- far too many issues some of which are too big to be engaged or addressed in the short term;
- many long-term implications;
- some gillnet related concerns:
  - overfishing in gillnets,
  - fishing in sensitive areas like breeding grounds,
  - selective removal of large fishes;
- pollution, climate change and habitat degradation – issues that are important yet difficult to be addressed in short term.

5.2. PLENARY DISCUSSIONS

During plenary discussions, the participants reviewed – based on the working group outputs and discussion – each item in the data collection form and modified the form in order to come up with an agreed methodology for assessing food loss from gillnet and trammel net fishing operations. The final form, which was revised by workshop participants via email following the workshop, is contained in Appendix 3.

Participants rank-ordered each of the five categories of sources of food loss. Pre-catch and ghost fishing mortality were considered the highest importance in gillnet and trammel net fisheries, followed by onboard losses, while collateral and post-release losses were considered to be of lowest importance. Estimates of pre-catch losses were considered to be difficult to obtain, but useful information could be collected through having key informants identify hotspots and through direct observation. Estimating onboard food loss was considered to be achievable through: (i) direct observation onboard and at landing centres; (ii) key informants at the landing centres; (iii) assessing food quality by sample collection on board and at landing centres; and (iv) through laboratory analysis. Estimating ghost fishing mortality is difficult through direct observations by onboard scientific observers. However, the problem could be approached by interviewing key informants.

Participants also identified countries and individual fisheries that are optimal and suitable for case studies to pilot a food loss assessment methodology and food loss mitigation methods and next steps. During a final session of the workshop on the third day, some participants described their plans to estimate food loss from gillnet and trammel net fishing in their respective institution and work. A summary of these planned activities follows.

Michael Pol, Massachusetts Division of Marine Fisheries, United States of America. Possibly conducting individual or group interviews with New England gillnet fishers and contacting the National Marine Fisheries Service Marine Debris Program to discuss the FAO initiative on food loss.

Anukorn Boutson, Department of Marine Science, Faculty of Fisheries, Kasetsart University, Thailand. Reducing food loss, including loss from bycatch and discards, and from ghost fishing, will be addressed in future research in gillnet and trammel net fisheries, and also trap fisheries. The coastal area of Rayong Province in Thailand was identified as a potential site for the research. This research will include:

- case studies of bycatch and discards, and of fishing gear loss and mechanism to induce ghost fishing;
- the physical change of the gear during the ghost fishing process;
- quantitative and qualitative assessments of bycatch and discards, and ghost fishing mortality;
- field survey for data collection and fisher interview to assess the distribution of ghost fishing gear in the study site;
- impacts of ghost fishing on food loss and other resources;
- investigate the reason of discards and fishing gear loss;
- investigate the economic loss of discards and ghost fishing.

Yahya Ibrahim Mgawe, Fisheries Education and Training Agency, Ministry of Livestock and Fisheries Development, Bagamoyo, United republic of Tanzania. In 1999, the United Republic of Tanzania started the assessment of post-harvest fish loss in Lake Victoria. Harvest loss from gillnets in Lake Victoria will be done along with the ongoing programme on post-harvest loss.

Wudianto, Research Center for Fisheries Management and Conservation, Ministry of Marine Affairs and Fisheries, Indonesia. Identification of food loss from lobster gillnets and shrimp trammel nets will be addressed in ongoing case studies.

Bikram Jit Roy, Marine Fisheries Survey and Management Unit, Bangladesh. In gillnetting, the harvest loss and loss while moving the catch from boat to the landing centre can be addressed by using the data collection form.

Nguyen Viet Nghia, Research Institute for Marine Fisheries, Viet Nam. Gillnets and trammel nets operated in selected centres in coral area will be focused for collecting data on food and gear loss.

India. One centre from east and west coast of India will be selected to study the food and gear loss in shrimp gillnet, trammel net and tuna gillnet. As inland fishing is very important in India, one freshwater reservoir also will be covered. A combined effort from CIFT, Integrated Coastal Management and Dr Vivekanandan would address the technical and socio-economic aspects of food loss and gear loss from gillnetting in India.

6. Next steps

The workshop participants agreed on the following:

- Select a few countries to use the agreed questionnaire and to collect data from identified gillnet and trammel net fisheries. Validation of the data will be done in a two-step process: (i) collection of data and finding the hot spots; and (ii) validation of these observations.
- Once the methodology for assessment of food loss and resource wastage is refined for gillnet and trammel net fisheries, it will be used for other fisheries as well.

Appendix 1 – **Workshop agenda**

Wed, 8 April	**Day One**
08.30	Opening ceremony
09.30	Background and objectives of the workshop
09.45	Workshop background paper – Avoiding and reducing food loss during gillnet and trammel net fishing operations
10.00	Break
Presentation from participants	
10.15	Dr. E. Vivekanandan, India east coast
10.30	Dr. P. Pravin, India west coast
10.45	Dr. Bikram Jit Roy, Bangladesh
11.00	Dr. Wudianto, Indonesia
11.15	Dr. Anukorn Boutson, Thailand
11.30	Dr. Nguyen Viet Nghia, Viet Nam
11.45	Ms. Azza Elganainy, Egypt (presented by P. Suuronen, FAO)
12.00	Lunch
13.30	Dr. Yahya Mgawe (Tanzania)
13.45	Mr. Mike Pol (New England, USA)
14.00	Discussion
Background presentations in preparation for working group session	
14.30	Gillnet and trammel net fishing gear characteristics and fishing practices that are relevant to understanding sources of food loss and waste – Mr. Mike Pol
14.45	Findings from the preliminary trial of the draft data collection form for an assessment of food loss during gillnet and trammel net fishing operations conducted by CIFT – Dr. Saly N. Thomas
15.00	Post-harvest loss assessment: A methodology and some fishing gear-related data – Dr. Yvette Diei-Ouadi
15.20	Break
15.35	Discussion
16.00	Introduction to working group session – grouping, terms of reference, and expected outputs for each group
16.15	Summary of Day 1
16.30	Preliminary meeting of working group – preparation for next day's working group session
17.00	Close of Day 1
	Welcome dinner
Thu, 9 April	**Day Two**
Working group session	
08.00	**Group 1** participants discuss and report on methodologies for assessing food loss from pre-catch and discarded catch. **Group 2** participants discuss and report on methodologies for assessing food loss from post-release delayed mortality, ghost fishing by abandoned, lost and discarded fishing gear, and indirect (collateral) sources of fishing mortality

10.00	Break
10.15	Continuation of working group session
Presentation of working group output and discussion	
11.00	Group 1 presentation
11.15	Group 2 presentation
11.30	Discussion
12.00	Lunch
Plenary discussion: Review, revision and finalization of draft data collection form	
13.30	Based on the working group outputs and discussion, the participants will review each item in the data collection form and add, delete or revise in order to come up with an agreed methodology for assessing food loss from gillnet and trammel net fishing operations
15.00	Break
15.15	Continuation of plenary discussion
18.00	Close of the day
Fri, 10 April	**Day Three**
08.00	Field visit
12.00	Back to hotel for lunch
13.30	Discussion and agreement on final version of data collection form
14.30	Plenary discussion on plans for moving forward with estimating food loss in gillnet and trammel net fishing
15.30	Break
15.45	Continuation of plenary discussion
16.30	Wrap up and conclusions
17.00	Close of the workshop

Appendix 2 – **List of participants**

Name	**Address**
Michael Pol	Senior Scientist Massachusetts Division of Marine Fisheries New Bedford, **USA** Email: mike.pol@state.ma.us
Anukorn Boutson	Lecturer Faculty of Fisheries Kasetsart University 50, Ngamwongwan Rd. Lardyao, Jatujak, Bangkok **Thailand** 10900 Email: ffisakb@ku.ac.th
Nguyen Viet Nghia	Vice Director Research Institute for Marine Fisheries 224 Le Lai, Hai Phong **Viet Nam** Email: nghia.rimf@gmail.com
Azza Abdel Hamid Mohamed Ahmed El Ganainy (unable to participate but paper presented)	Head of Fisheries Biology Lab. National Institute of Oceanography and Fisheries P.O. Box 182, Suez **Egypt** Email: azzaelgan@yahoo.com
Wudianto	Senior Researcher Research Center for Fisheries Management and Conservation, MMAF Indonesia Gedung Balitbang II, Jl. Pasir Putih II Ancol Timur Jakarta Utara **Indonesia** Tel: +628161946426 Email: wudianto_prpt@indo.net.id and wudianto59@gmail.com
Bikram Jit Roy	Scientific Officer Marine Fisheries Survey and Management Unit, C.G.O Building-2, 6th floor Agrabad, Chittagong **Bangladesh** Email: jitroy1964@yahoo.com

Yahya Ibrahim Mgawe	Chief Executive Fisheries Education and Training Agency Ministry of Livestock and Fisheries Development P.O Box 83, Bagamoyo **Tanzania** Email: ymgawe@yahoo.com
Venkatesh Salagrama	Integrated Coastal Management 64-16-3A Pratap Nagar KAKINADA Andhra Pradesh **India** Email: vsalagrama@gmail.com
Saly N. Thomas	Principal Scientist Fishing Technology Division Central Institute of Fisheries Technology Willingdon Island, Matsyapuri P.O. Cochin - 682 029, Kerala **India** Email: salynthomas@gmail.com
Leela Edwin	Principal Scientist & Head Fishing Technology Division Central Institute of Fisheries Technology (CIFT) Willingdon Island, Matsyapuri P.O., Cochin-682 029 **India** Email: leelaedwin@gmail.com
P. Pravin	Principal Scientist Fishing Technology Division Central Institute of Fisheries Technology (CIFT) Willingdon Island, Matsyapuri P.O., Cochin-682 029 **India** Email: pravinp2005@gmail.com
E. Vivekanandan	Emeritus Scientist Madras Research Centre Central Marine Fisheries Research Institute Chennai 600 028 **India** E-mail: evivekanandan@hotmail.com
Eric Gilman (Remote participant)	FAO consultant Hawaii Pacific University 3661 Loulu Street Honolulu, Hawaii 96822 **United States of America** Email: FisheriesResearchGroup@gmail.com

Susana Siar
Fishery Industry Officer
Fishing Operations and Technology Branch (FIRO)
Food and Agriculture Organization of the United Nations (FAO)
Viale delle Terme di Caracalla
00153 Rome
Italy
Email: susana.siar@fao.org

Petri Suuronen
Fishery Industry Officer
Fishing Operations and Technology Branch (FIRO)
Food and Agriculture Organization of the United Nations (FAO)
Viale delle Terme di Caracalla
00153 Rome
Italy
Email: petri.suuronen@fao.org

Yvette Diei-Ouadi
Fishery Industry Officer
Products, Trade and Marketing Branch (FIPM)
Food and Agriculture Organization of the United Nations (FAO)
Viale delle Terme di Caracalla
00153 Rome
Italy
Email: yvette.dieiouadi@fao.org

Appendix 3 – Data collection form for estimating food loss from gillnet and trammel net fishing

Step 0: Secondary data collection

Step 1: Measurement of fishing gear

Step 2: Group interview or key informant interview

Step 3: Individual fisher interview

Step 4: Direct observation of pre-catch mortalities

Step 5: Quality Assessment (onboard, during travel to landing center, and at the landing center) and direct observation. This step includes information on weather, temperature, facilities including storage facilities on board.

STEP 1: MEASUREMENT OF FISHING GEAR

1. Gear type
☐ Gillnet
☐ Trammel net
☐ Combination gillnet/trammel net[1]

2. Panel
a. Length of float line: ______________meters or fathoms
b. Height: _________________________meters or meshes
c. Number of layers in trammel net: _________________
d. Trammel net ratio of stretched length of inner to outer panels (vertical slack): _________________________
e. Tie down line? YES/NO If yes, height: ________meters

3. Mesh
a. Full stretched mesh length[2]: __________________ cm
b. Netting type[3]: _________________________________
c. Twine material[4]________________________________
d. Twine ply number/diameter ___________________mm
e. Color ____
f. Distance between 'pickups'[5]___________________ cm
g. Number of meshes between pickups[5]: ______________

4. Float line
a. Material ______________________________________
b. Length _____________________________________ m
c. Diameter _________________________________ mm
d. Color ____

5. Float
a. Material _____________________________________
b. Length ____________________________________ cm
c. Width at thickest section ______________________ cm
d. Color ____
e. Shape _______________________________________
f. Distance between floats _______________________ cm
g. Number of meshes between floats ___________________

1 For trammel nets and combination gillnets/trammel nets, complete separate forms for the interior and exterior layers.
2 For knotted netting, the full length of mesh is the distance between the centres of two opposite knots in the same mesh when fully extended. The opening of mesh is the longest inside distance between two opposite knots in the same mesh when fully extended. ISO 1107 – Fishing nets – Netting – Basic terms and definitions, 2003.
3 E.g., multifilament (several small filaments twisted together), monofilament (single strand), multi-strand monofilament (multimonofilament, multiple strands of monofilament twisted loosely together), super multimonofilament (constructed the same as multimonofilament but the threads are thinner and more numerous).
4 E.g., nylon (polyamide), polyester, gel spun polyethylene
5 A 'pickup' is a point on the headrope where the webbing is attached.

6. Master float characteristics (if used)
a. Material ______________________________
b. Length _____________________________ cm
c. Width at thickest section __________________ cm
d. Color _________________________________
e. Shape ________________________________
f. Number of master floats per panel _______________

7. Leadline/sinkerline
a. Material _______________________________
b. Diameter ___________________________ mm
c. Color _________________________________
d. Lead core or weights/sinkers attached? _______________
e. Distance between weights (if weights attached): ____cm
f. Meshes between weights (if weights attached): ____
g. Number of weights per panel (if weights attached): ____
h. Weight of 1 weight/sinker: _______________ g
i. Weight of 1 meter of leadline _______g

8. Weight characteristic per panel (if weights attached)
a. Material _______________________________
b. Weight amount: ________________________ kg

9. Anchor characteristics (if used)
a. Material _______________________________
b. Weight amount: ________________________ kg

STEP 2. GROUP INTERVIEW OR KEY INFORMANT INTERVIEW

1. Fishing Grounds
a. Typical light levels at fishing grounds: ___________________________

b. Typical sea state at fishing grounds: ____________________________

c. Typical current speed at fishing grounds: _________________________

d. Substrate type(s): ____

e. Do you frequently encounter debris that entangles in nets? YES/NO

f. Do your nets get entangled on subsurface features? YES/NO

g. List gear types or other gears used at your fishing grounds: ________________
____

2. Fishing Gear and Methods
a. Sketch the gear when soaking. Identify location in the water column (in relation to sea surface and substrate), number of panels per fleet, location of anchors if used, if attached to vessel or other object (sweeping), if drifting, location and length of tiedowns if used, height and length of panel, number of floats per panel, number of weights per panel if used, and how panels in a fleet are joined together. (Use separate page)

b. Are fleets parallel, perpendicular, other? _________________________

c. Distance between fleets: ________ meters

d. Main fishing ground: ____

e. Most common fishing depth: _________________________________

f. Method to set and haul (e.g., hauling equipment power, hauling speed): _______
____

g. Number of days per fishing trip: _________

h. Number of fleets set per trip: __________

i. Number of fleets set per day:____________

j. Number of trips per year: _______________

k. Number of panels fished per fleet: ________

l. Average soaking time: __________hours

m. Net patrolled? YES/NO

3. Abandoned, Lost and Discarded Fishing Gear
a. List gear components that you typically discard (throw gear overboard): ____

b. Material: ____

c. How much gear do you discard (identify amount of each gear component that is discarded)?
Per trip or year: ___________________________kg or panel

d. What is the main reason you discard gear? ____

e. List gear components that you typically abandon (gear set for fishing left on purpose): ____

f. How much gear do you abandon (identify amount of each gear component that is discarded)?
Per trip or year: ___________________________kg or panel

g. What is the main reason you abandon gear? ____

h. Does season have an effect on abandoning of gear? If yes, how? ____

i. How much gear do you lose (gear set for fishing is left and can't locate and retrieve it)?
Per trip or year: _____________________kg or panel

j. What is the main reason you lose gear? ____

k. Does season have an effect on loss of gear? If yes, how? ____

4. Selling of catch, sharing arrangement, and loss of catch
a. Where do you sell your catch?
☐ Landing center
☐ At sea

b. What is the sharing arrangement for the catch?
_____Boat owner
_____Skipper/captain
_____Crew
_____Other

c. Have you experienced loss of catch due to capsizing? YES/NO
If YES:
How many panels per year? _____________
What season? _____________________
What is the reason for capsizing? ___________________________

STEP 3. INDIVIDUAL FISHER INTERVIEW

Date:
Interviewer name:
Fisher name:
Fishing vessel name (if vessel is used):
Length and horsepower of vessel:
Based from seaport(s)/landing center:

1. Gear type
☐ Gillnet
☐ Trammel net
☐ Combination gillnet/trammel net[6]

2. Fisher Experience in this Fishery
a. Position on vessel (e.g., captain, first mate) (if vessel is used): ____________
b. Number of years fishing using this gear type: ______
c. Years in gillnet or trammel net fishing from this seaport/landing center: ______

3. Gear attachment
☐ Anchored
☐ Staked
☐ Drifting (both ends unattached)
☐ Sweeping (one end free, one end attached, e.g. to a vessel)

4. Setting depth
☐ Surface
☐ Midwater
☐ Bottom

5. Setting of net
☐ Float line at the surface
☐ Float line within _____m of the surface
☐ Midwater
☐ Leadline within a few cm but not on the bottom
☐ Leadline on the bottom

6. Typical soak time: ________hours

7. Total fish landing per trip: ________kg
Most common species: ____
____
☐ Sold at sea
☐ Sold at landing site

8. Discarded and Released Catch
a. How many finfish are discarded per trip/haul: ____number/kg
Most common species: ____

[6] For trammel nets and combination gillnets/trammel nets, complete separate forms for the interior and exterior layers.

b. How many live finfish are released per trip/haul: ______number/kg
Most common species: ____

c. How many invertebrates (crustacean, mollusks, etc) are discarded per trip/haul? _____ number/kg
Most common species: ____

d. How many live invertebrates are released per trip/haul? _____number/kg
Most common species: ____

e. Identify causes of discarding/releasing catch, and assign score from most to least important (1=most important)
_______No market demand
_______Retention ban
_______Over quota
_______Spoiled upon hauling
_______Damaged from the fishing method or gear
_______Damaged from partial depredation
_______Could damage the rest of the catch during storage
_______Insufficient room for storage

f. Other catch that are caught and released, please specify:

Other catch caught and released	Number typically caught per trip/haul	Percent alive upon hauling/retrieval	Most common species

g. What are the predators on catch?
Seals YES/NO
Seabirds YES/NO
Cetaceans YES/NO
Squid YES/NO
Crab YES/NO
Sharks YES/NO
Pufferfish YES/NO
Isopods YES/NO
Other – please identify: ______________________________________

h. Number/kg of catch depredated per trip/haul/year: ______________

9. Fish lost during hauling of the net
a. Kg of fish slipped out during hauling (typical): ________
Most common species: ____
____

10. Abandoned, Lost and Discarded Fishing Gear

a. List gear components that you typically discard (throw gear overboard):

b. Material: ____
____

c. How much gear do you discard (identify amount of each gear component that is discarded)?
Per trip or year: _________________________kg or panel

d. What is the main reason you discard gear? _________________________________
____

e. List gear components that you typically abandon (gear set for fishing left on purpose): ____
____

f. How much gear do you abandon (identify amount of each gear component that is discarded)?
Per trip or year: _________________________kg or panel

g. What is the main reason you abandon gear? ________________________________
____

h. Does season have an effect on abandoning of gear? If yes, how?
____
__

i. How much gear do you lose (gear set for fishing is left and can't locate and retrieve it)?
Per trip or year: ___________________kg or panel

j. What is the main reason you lose gear? ____________________________________
____

k. Does season have an effect on loss of gear? If yes, how? ______________________
____

11. SORTING, STORAGE ON BOARD AND TRANSPORT

a. Do you sort your catch? YES/NO
If YES:
☐ By size
☐ By species
☐ By price
☐ By quality

b. How do you store the catch on board?
☐ Insulated boxes
☐ Fish hold
☐ Storage on deck
Other: _______________
Storage capacity: _____kg

c. How do you preserve your catch on board?
☐ Ice
☐ Salt
☐ Drying
☐ Other: ____
___

d. What is the average time it takes to transport the fish from the fishing ground to the landing site: ______hours

BACKGROUND PAPERS

Avoiding and reducing food loss during gillnet and trammel net fishing operations

Eric Gilman[1], Petri Suuronen[2], Susana V. Siar[2]
[1] Consultant, Honolulu, Hawaii
[2] Fishing Operations and Technology Branch (FIAO), FAO Fisheries and Aquaculture Department

ABSTRACT

Reducing food loss is necessary to improve food security and to reduce the adverse ecological effects of food systems. Food is lost during all stages along supply chains of capture fishery products, during capture operations, postharvest handling and processing, storage, distribution and consumption. Loss of fishery products reduces the sustainable production of fishery resources, threatening the long-term capacity to provide food, and reduces economic opportunities for the capture fisheries sector.

Gillnets and trammel nets are main fishing gears used in tropical fisheries associated with significant loss of fishery resources and food. These two gear types are primarily used in artisanal, small-scale, household-based fisheries. There is a paucity of data on the extent and magnitude of these losses and of methods to assess loss during fishing operations for these gear types. This study identified the various sources and causes for fishery products to be lost during the harvesting stage of the supply chain, during the setting, soaking and retrieval of fishing gear, by marine and inland gillnet and trammel net fisheries. The study also identified the types of resources that are lost due to each cause, and during which stage of fishing operations each cause of loss occurs. Alternative methods to estimate levels of loss during gillnet and trammel net fishing operations, and their relative benefits and costs, were identified. A tentative list was developed of priority marine and inland areas for inclusion in an assessment of loss during fishing operations of gillnet and trammel net fisheries.

Five broad categories of sources of loss during fishing operations were described. (i) Loss of fishery products results from pre-catch mortalities, when organisms are caught, or collide with the vessel or gear, and die but are not brought onboard when the gear is retrieved. For example, organisms may be caught and die in the gear and be removed by predators or scavengers before gear retrieval. Or organisms may escape from the gear but die later due to stress or injury resulting from the interaction. (ii) Ghost fishing mortality by abandoned, lost or otherwise discarded fishing gear (ALDFG) is an additional source of food loss, which is particularly problematic in gillnet, trammel net and other passive fishing gears. Various fishery-specific intentional and unintentional causes for fishing gear to be abandoned, lost or discarded were reviewed. (iii) Upon haulback of the gear, dead catch might be discarded due to various economic or regulatory reasons. (iv) Post-release fishing mortality occurs when catch is landed onboard and then released alive but stressed or injured to a degree that causes the organism to die later. And, (v) Collateral sources of fishing mortality, a fifth source of losses, are those that are indirectly caused by various ecological effects of fishing. For example, cumulative sub-lethal stressors from fishing may result in collateral mortalities.

A method was presented that provides a first order estimate of the level and causes of losses during gillnet and trammel net fishing operations. The assessment method employs a combination of an inventory of fishing gear and fisher interviews. A draft form to be used for the inventory and fisher interviews is presented. Inventories and expert surveys can provide a critically important first-order, qualitative understanding of basic characteristics of fishing gear and methods and causes of food loss when previously little or no information was available. Findings from a first order food loss assessment could then be validated and augmented through more rigorous assessment methods. Information from the gear inventory can also enable a comparison of current gear designs and fishing methods to gear technology best practices to determine if modifications could be introduced to mitigate problematic sources of loss, including bycatch of endangered, threatened and protected species. To this end, gear technology methods to modify gillnet and trammel net selectivity, to augment catch of target species and reduce catch of unwanted species, sizes and sexes, were described.

Research and monitoring methods to estimate levels of loss from each source were reviewed. Relative to the other sources of loss during fishing operations, there has been good progress in the development of research methods to estimate pre-catch and post-release mortality. These include several at-sea and laboratory experimental methods, and using explanatory variables to predict the probability of pre-catch and post-release morbidity and mortality. There has likewise been relatively good progress in developing methods to estimate ghost fishing mortality in passive gears, including trammel nets and gillnets. Methods have been developed to estimate the density of ALDFG retaining fishing efficiency in a spatially explicit area, duration of ghost fishing efficiency, and total ghost fishing mortality level per unit-of-effort of ALDFG over the full period that the derelict gear continues to retain fishing efficiency, which combined, provides inputs needed to estimate total ghost fishing mortality at a fishing ground per unit of time. The complexity and indirect link between collateral, indirect effects of fishing operations and mortalities, including from cumulative and synergistic effects of fishing operations, has largely prevented the development of methods that provide accurate estimates of mortality levels and rates. Considerations for the collection of monitoring data via logbook programmes, onboard human observers and electronic monitoring to support robust estimates of loss during fishing operations were described.

1. INTRODUCTION

1.1 Study scope and purpose

Food is lost during all stages along fishery product supply chains, during capture operations, postharvest handling and processing, storage and distribution, and consumption (Jeeva *et al.,* 2006; Krishna *et al.,* 2007; FAO, 2014a; HLPE, 2014). Reducing food loss, including wasted food, has been identified as necessary to improve food security, and to reduce the adverse ecological effects of food systems (FAO, 2012a,b; HLPE, 2014). Lost food from marine and inland fisheries reduces the sustainable production of fishery resources, threatening the long-term capacity to provide food, and reduces economic opportunities for the capture fisheries sector (Kelleher, 2005). Marine and inland capture fisheries are a major contribution to food security, nutrition, employment and household income, particularly in developing countries (Smith *et al.,* 2005; Welcomme *et al.,* 2010). Seafood is the most highly globally traded food commodity, and if sustainably governed, has a higher capacity to contribute to sustainably meeting growing human demand for animal protein relative to terrestrial sources, especially if avoidable sources of food loss are reduced or eliminated (FAO, 2010a; Godfray *et al.,* 2010; Pereira et al. 2010; Smith *et al.,* 2010; Welcomme *et al.,* 2010; Pelletier *et al.,* 2011).

The Food and Agriculture Organization of the United Nations (FAO) has been mandated by Member Countries and the United Nations General Assembly, as the lead competent authority, to address food loss and waste, including from bycatch and discards. In 2011, FAO, under instructions from the Committee on Fisheries (COFI), developed *International Guidelines on Bycatch Management and Reduction of Discards*, a global voluntary instrument (FAO, 2011). FAO's Fishing Operations and Technology Branch (FIRO) is the lead unit for conducting bycatch and discard-related work, including studies, mitigation, and development of best practices. This study is a part of FIRO's *Food Loss and Waste Reduction Programme*. The programme has three objectives: (i) Develop a methodology to estimate lost resources in fishing operations; (ii) Use the methodology to undertake case studies with selected fishing gears in selected countries, refine the methodology based on the findings, and identify technological and management options to reduce lost resources from fishing operations; and (iiii) Test the management and technological options in selected fisheries. The overall goal is to minimize the loss of food in fishing operations.

To contribute to advancing the first programme objective, and in response to a recent call for FAO to develop common protocols and methods to measure food loss and waste and analyze their causes (HLPE, 2014), this study identified sources and causes of the quantity of lost fishery products that had the capacity to be retained and consumed by humans or that could have been used as feed for aquaculture or animal industries, that occur during the harvesting stage of the supply chain by marine and inland gillnet and trammel net fisheries[1]. This included loss that results during the setting, soaking and retrieval of fishing gear. This study also identified what fishery resources are lost due to each cause, and during which stage of fishing operations each source occurs. Alternative methods to estimate levels of loss, and their relative benefits and costs, from each identified source were identified.

Gillnets and trammel nets are some of the main fishing gears used in tropical and sub-tropical fisheries associated with significant loss of fisheries resources and food (Jeeva *et al.,* 2006; FAO, In Prep.). There is, however, a paucity of data on the magnitude of these losses, and of methods to assess loss during fishing operations for these gear types.

The study scope excluded sources of loss, including waste, further down the supply chain after fishing operations (FAO, 2014d; HLPE, 2014). The study scope did not include qualitative food loss, which relates to the reduction of nutritional value, economic value, food safety, and consumer appreciation (FAO, 2014d; HLPE, 2014). The study did not consider other sources of loss during the harvest stage, including not achieving optimum value, for instance, because fishing practices or elements of the fisheries management system do not meet sustainable sourcing policies of major buyers in markets paying premium prices (Seafood Choices Alliance, 2007; FAO, 2008; Food Marketing Institute, 2014). The study scope also did not include various deficits in fisheries management systems that prevent achieving stock-specific and multi-species maximum sustainable and economic yields as a source of lost fishery products.

---

[1] The definition of the quantity of lost food during fisheries capture operations used in this report was adapted from broader definitions of food loss and waste from FAO's *Definitional Framework of Food Loss* (FAO, 2014d). FAO (2014d) defined quantitative food loss as, "the decrease in mass of food." FAO (2014d) elaborated that food waste is a component of food loss and is, "the removal from the FSC [food supply chain] of food which is fit for consumption, by choice, or which has been left to spoil or expire as a result of negligence by the actor." The High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security (HLPE) adopted slightly different definitions of food loss and waste, defining food loss as, "a decrease, at all stages of the food chain prior to the consumer level, in mass, of food that was originally intended for human consumption, regardless of the cause," and food waste as, "food appropriate for human consumption being discarded or left to spoil at consumer level, regardless of the cause" (HLPE, 2014).

1.2 Catching process, design and operation of drift and set gillnets and trammel nets

Marine and inland drift and set gillnets and trammel nets are types of passive fishing gears that are used worldwide. There are both extensive industrial and artisanal, small-scale, household-based marine and inland gillnet and trammel net fisheries (Hubert, 1983; Welcomme *et al.*, 2010; Shester and Micheli, 2011; FAO, In Prep.). The capture process relies on the movement of organisms into the gear, where they become gilled, enmeshed or entangled (Bjordal, 2002). Gillnets and trammel nets can be anchored and stationary on a variety of substrates, including flat ground, on the edges and slopes of canyons, and on reefs, wrecks and other structures. Gillnets can also be drifting (both ends unattached) or sweeping (one end attached, for instance, to a vessel, the other end unattached) at the sea surface, mid-water or near or on the seabed (MacMullen *et al.*, 2003; FAO, In Prep.). There are also staked gillnets, encircling gillnets and combination gillnets/trammel nets.

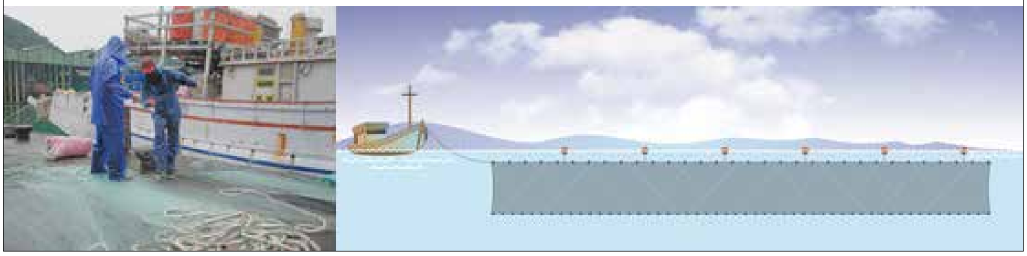
Because they rely on target species swimming into the net, gillnets and trammel nets are designed to minimize visibility. They might be used in areas with low light levels or high turbidity (Bjordal, 2002). Since the 1960s, nets have been made with synthetic twine usually of nylon (polyamide), either as multifilament thread or monofilament or multi-monofilament line, which is much less visible, more durable and requires less maintenance than nets made of non-synthetic fiber (Moore, 2008; Macfadyen *et al.*, 2009).

FIGURE 1
Removing a salmon from a gillnet (Bristol Bay, Alaska; NOAA photo library, K. Ducey)

To maintain a roughly vertical profile, gillnets, trammel nets and combination set gillnet/trammel nets 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). 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 for deploying gillnets and trammel nets (Hubert, 1983; Bjordal, 2002; Hall *et al.*, 2009). 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, either by hand (Figure 1) or machine.

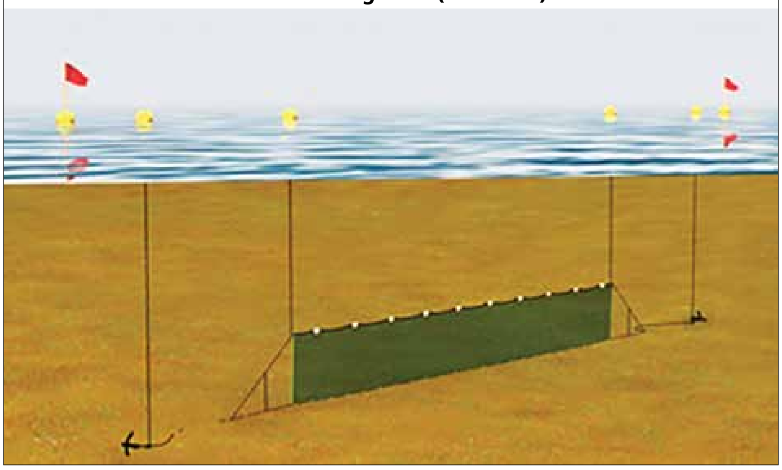
A fleet of gillnets is constructed of a series of connected panels of meshes made from fine thread, with reinforcing ropes along the sides. Gillnets typically have a hanging ratio ≥ 0.5. A fish can become caught in a gillnet when it swims into a mesh, struggles to free itself, and the twine of the mesh slips under the opercula (gill covers) preventing escape, i.e., the fish becomes ‘gilled’. A fish can also become wedged around its body inside a mesh, or parts of its body (fins, teeth, or other projection) may become entangled in the twine. Drift gillnets (driftnets), set at or below the sea surface, can be connected to a fishing vessel and drift with the current (Figure 2).

FIGURE 2
Left, fishers prepare a driftnet (Su-ao Fishing Harbor, Taipei; E. Gilman); right, a driftnet deployed subsurface is attached to a vessel and drifts with the current (SEAFDEC)



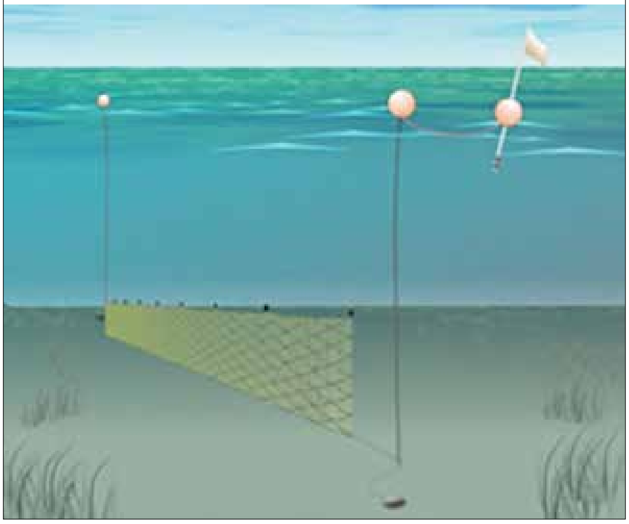
Set or anchored gillnets are deployed at or near the seabed. They are kept stationary using anchors or weights at both ends (Figure 3). Tiedowns may be used, connecting the float and lead lines at intervals along the length of the net. Tiedowns create bag of slack webbing which aids in entangling demersal fish species (Price and Van Salisbury, 2007). Gillnets are also designed with panels stretched between stakes, deployed in intertidal zones in areas with a large tidal range (Nedelec and Prado, 1990). Encircling gillnets are used to 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. Once the fish are caught, the net is then hauled to retrieve the catch (Nedelec and Prado, 1990).

FIGURE 3
Bottom set gillnet (SEAFDEC)



Trammel nets usually have three panels of meshes, but occasionally have two layers (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 swims into a trammel net, it pushes a small mesh through an adjacent larger mesh and becomes entangled. As a result of this catching process, trammel nets are less size-selective relative to gillnets (Bjordal, 2002), and like gillnets, are not species-selective (e.g., Goncalves *et al.,* 2008). Trammel nets typically have a hanging ratio < 0.5 (Uhlmann and Broadhurst, 2013). Like set gillnets, trammel nets are typically anchored on the substrate in shallow, nearshore areas (Figure 4). Drift trammel nets are also used near the substrate. They may be set as a single panel or occasionally in fleets of a string of connected panels.

FIGURE 4
Bottom set trammel net (SEAFDEC)



There are also combination gillnet-trammel nets, with a gillnet in the upper portion and trammel net in the lower portion. They are typically set anchored on the substrate (Nedelec and Prado, 1990). The gillnet portion might target pelagic and/or semi-demersal species, while the trammel net portion targets demersal species.

2. SOURCES OF LOSS DURING GILLNET AND TRAMMEL NET FISHING OPERATIONS

Table 1 and Fig. 5 identify the sources of food loss during fishing operations by gillnet and trammel net fisheries, the various causes of each category of source of loss, the stages of fishing operations when each source and cause of loss occurs, and the type of resources that are lost from each source and cause. The stage indicates during which phase of fishing operations each source of loss occurs, including during the gear set, soak and haul, or when the vessel is transiting. Transiting refers to when the vessel is moving between the seaport and fishing grounds, and moving between fishing sites. The various causes of loss during each of the sources identified in Table 1 and Figure 5 are described in detail in the chapter.

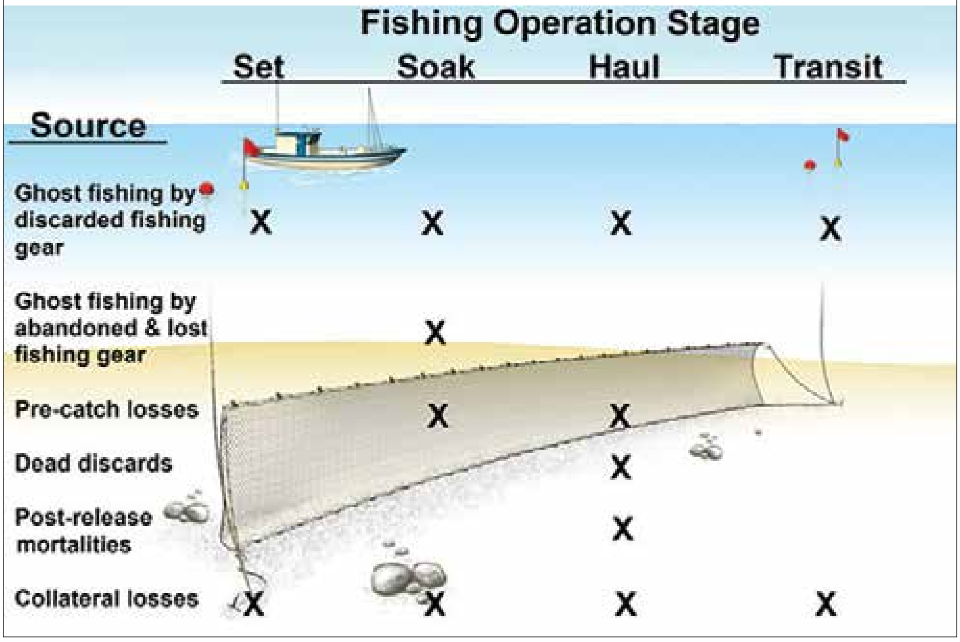
TABLE 1
Stages of fishing operations when each source of loss occurs, categories of sources of loss during fishing operations by gillnet and trammel net fisheries, the various causes of each category of source of loss, and the type of resources that are lost from each source

Stage	Source	Cause	Resources Lost[1]
Setting, soaking, hauling, transiting	Discarded fishing gear	Gear is intentionally thrown overboard at sea. In some cases discarded gillnets and trammel nets can result in ghost fishing mortality. Discarding gear at sea might be deemed more practical or economical to onshore disposal, including when no portside reception facilities are available. Gear might be discarded if there is insufficient room onboard to store all the gear after space used to store nets when starting a trip is subsequently used as the fish hold.	Market and non-market
Gear soak	Abandoned fishing gear	Gear that has been set for fishing is intentionally left at sea and not retrieved. In some cases abandoned gillnets and trammel nets can result in ghost fishing mortality. Causes for gear abandonment include: gear becomes snagged on wrecks and natural submerged feature, inclement weather makes it too dangerous to retrieve the gear, when operating illegally and a risk of detection occurs, insufficient time to locate and retrieve the gear, too difficult to retrieve the gear such as when the gear is snagged on submerged features.	Market and non-market

Stage	Source	Cause	Resources Lost[1]
Gear soak	Lost fishing gear	Gear that has been set for fishing is unintentionally left at sea and is not subsequently located and retrieved. In some cases lost gillnets and trammel nets can result in ghost fishing mortality. Causes of gear loss include: gear conflicts especially with mobile gears, removal of marker buoys such as by passing vessels, breakage or malfunction of tracking systems, gear becomes snagged on wrecks and natural submerged feature, and damage by marine organisms, Improper gear designs and materials, and improper fishing methods, such as setting in areas where gear is likely to interact with mobile gear or be snagged on bottom features, are other causes of lost gear.	Market and non-market
Gear soak	Pre-catch losses	Gilled, entangled and enmeshed live organisms escape from the gear and later die due to the interaction.	Market and non-market
Gear soak	Pre-catch losses	Gilled, entangled and enmeshed organisms die and fall out from the gear and are not brought onboard the fishing vessel.	Market and non-market
Gear soak	Pre-catch losses	Gilled, entangled and enmeshed organisms die and completely decompose while in the gear.	Market and non-market
Gear soak	Pre-catch losses	Gilled, entangled and enmeshed organisms die in the gear and are then depredated and completely removed from the gear.	Market and non-market
Haulback	Pre-catch losses	Gilled, entangled and enmeshed live and dead organisms escape or fall out of the gear during hauling; live escapees later die due to the interaction.	Market and non-market
Haulback	Dead discards and post-release mortalities of catch released alive	Quality unfit for human consumption. e.g., spoiled due to too long gear soak or poor water quality, or damaged due to fishing method or gear design.	Market and non-market[2]
		No or limited market for species, size or sex.	Non-market
		Retention ban on species, size or sex.	Market and non-market
		Relatively low value for species, size or sex, including high-grading to make room in the hold for higher value catch.	Market
		Regulatory requirements including quota-induced high-grading and over quota discarding.	Market and non-market
		No market for catch damaged due to fishing method.	Market
		No market for catch damaged due to partial depredation.	Market
		Discard lower value market species to attempt to lure species that depredate catch and/or damage the gear away from the fishing grounds.	Market
		Species of relatively low value that could damage the rest of the catch during storage.	Market
		Insufficient room in the hold (e.g., final set of a trip).	Market
Setting, soaking, hauling, transiting	Collateral mortalities	Mortalities resulting from indirect effects of fishing operations. Collateral sources of fishing mortality include: habitat degradation and loss, changes in community structure and processes from selective removals and from masses of ALDFG, obstacle for access to critical habitat, spread of invasive alien species, facilitated predation, and cumulative and synergistic sub-lethal stressors from interactions with the fishery.	Market and non-market

[1] Market: target and incidental species, sizes and sexes of fish, invertebrates and other marine and freshwater resources that are typically retained.
Non-market: species, sizes and sexes of organisms that typically are not retained for market, regulatory or other reasons, including non-retained endangered, threatened and protected species.
[2] Non-retained organisms that are caught and died in the gear or that were stressed or injured during the fishing operation that are released alive but die after release due to the stress/injury sustained during the fishery interaction might have not been caught , have escaped, or been caught and released alive and survived given different gear design and methods. This represents a loss of natural resources that currently would not be used for human consumption or as feed for aquaculture or animal industries.

FIGURE 5
Sources of lost food for direct human consumption, feed markets, and non-market marine resources during fishing operations by gillnet and trammel net fisheries, and the stages of fishing operations when each source of loss occurs



2.1 Pre-catch losses

Pre-catch losses occur when organisms are caught, or collide with the vessel or gear, and die but are not brought onboard when the gear is retrieved (Chopin and Arimoto, 1995; Broadhurst *et al.*, 2006; Gilman *et al.*, 2013a). Pre-catch losses may also occur when organisms escape from the gear but die later due to stress or injury resulting from the interaction. Catch may die and fall from the gear before the gear is retrieved, may completely decompose while in the gear, and fishers may intentionally release a portion of or the entire catch prior to landing onboard (Lockwood *et al.*, 1983; Gilman, 2011; FAO, In Prep.). There is evidence that a large proportion of caught organisms can drop out of gillnets during retrieval (Holst *et al.*, 1998; Jeeva *et al.*, 2006; Gilardi *et al.*, 2010). For example, Gilardi *et al.* (2010) observed 13 percent of invertebrates, 32 percent of fish and 21 percent of seabirds that were caught in derelict nets fell out of the gear during the process of retrieving the net. Jeeva *et al.* (2006) observed that a proportion of catch of commercial fishes in inland reservoir gillnet and hook-and-line fisheries of Orissa, India was lost due to catch falling out of the gear. Catch in gillnet and trammel net fisheries has been observed to 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).

Depredation constitutes pre-catch loss when an organism dies as a direct result of the fishing operation but is not present upon gear hauling because predators or scavengers remove it from the gear (Jeeva *et al.*, 2006; Gilman *et al.*, 2013a). Depredation is the partial or complete removal of catch from the gear by predators and scavengers. Various predators and scavengers have been observed to depredate catch from anchored marine and inland gillnets (Kaiser *et al.*, 1996; Matsuoka *et al.*, 2005; Jeeva *et al.*, 2006; Rafferty *et al.*, 2012).

Several factors that have been observed to have a significant effect on the probability of pre-catch mortality in other gear types might also be applicable to gillnets and trammel nets. Studies in trawl and pelagic longline fisheries have observed that smaller size classes of several finfish species have higher vulnerability to pre-catch mortality

(Ingólfsson *et al.,* 2007; Campana *et al.,* 2009, Epperly *et al.,* 2012; Tenningen *et al.,* 2012). Variability in pre-catch losses between species has also been documented in trawl and pelagic longline fisheries (Ingólfsson *et al.,* 2007; Epperly *et al.,* 2012). Significant variation in pre-catch mortality has also been observed in trawl and pelagic longline fisheries by season; time of day of fishery interactions; variability in fishing methods, such as soak duration; and gear design (Suuronen *et al.,* 1995; Suuronen and Erickson, 2010; Epperly *et al.,* 2012; Gilman *et al.,* 2012, 2013a).

2.2 Ghost fishing mortality from ALDFG

Abandoned, lost or otherwise discarded fishing gear (ALDFG), also called derelict fishing gear, poses substantial ecological and socio-economic problems, including loss from direct mortalities from ghost fishing. Ghost fishing occurs when ALDFG continues to catch and kill organisms (Kaiser *et al.,* 1996; Matsuoka *et al.,* 2005; Macfadyen *et al.,* 2009; FAO, 2010a; Uhlmann and Broadhurst, 2013). Ghost fishing is of particular concern for marine megafauna with K-selected life-history strategies (Laist, 1995, 1997; FAO, 2010b; Gilman *et al.,* 2010; Good *et al.,* 2009, 2010; IWC, 2013). Ghost fishing also results in the loss of market catch. 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 (FAO, In Prep.). Ghost fishing is thought to be most problematic in passive fishing gear, including gillnets and trammel nets, after setting (Gilman *et al.,* 2013a).

Various factors affect the ability, efficiency and duration of derelict gear to ghost fish. The condition of the gear when lost, abandoned or discarded is important, including whether it was set for fishing or otherwise discarded and unlikely 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, relative abundance of biofouling organisms, and presence of debris and particulate matter can be significant explanatory factors. These factors can affect ghost fishing mortality rate and duration, for instance, by determining whether the derelict gear is eventually disabled by a passing vessel or fishing gear, or by exposure to storms, currents, or other environmental forces (Erzini *et al.,* 1997; Revill and Dunlin, 2003; Sancho *et al.,* 2003; Matsuoka *et al.,* 2005; Akiyama *et al.,* 2007; Gilman *et al.,* 2013a; FAO, In Prep.).

There are intentional and unintentional causes for fishing gear to be abandoned, lost or discarded (Macfadyen *et al.,* 2009; FAO, In Prep.). Abandoned fishing gear results when gear that has been set for fishing is intentionally left at sea and not retrieved. Lost fishing gear results 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. Gear is discarded when fishers intentionally throw unwanted components overboard at sea. Fishers may lose gear due to gear conflicts, when there is contact with passing vessels or active gear. For instance, 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). Anchored gillnets and trammel nets can also be damaged from entanglement with passive gears, including demersal longlines and traps (Erzini *et al.,* 1997; MacMullen *et al.,* 2003). Fishers may lose gear when marker buoys are removed, which can occur when surface gear is cut by passing vessels and when tracking systems malfunction or break. Gear can also be lost and abandoned when the gear becomes snagged on wrecks and natural submerged features (Breen, 1990; MacMullen *et al.,* 2003; Macfadyen *et al.,* 2009; Ayaz *et al.,* 2010; FAO, 2010a). Damage by marine organisms can also lead to gear loss (e.g., Vanderlaan *et al.,* 2011).

Improper gear designs and materials can also lead to gear loss, such as from not properly maintaining gear and not replacing worn gear components such as gear used to locate the fishing location. Improper fishing methods can also result in gear loss. For instance, new entrants might set passive gear in areas where there is a high probability of interaction with mobile gears, may use long soak times during which anchored gear moves from its original position, may set gear where strong currents are prevalent, and may select grounds where the gear is likely to be snagged on bottom features. Gear can be lost due to inclement weather or strong currents. 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). Fishermen 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). Crew may discard unwanted components of gear at sea when deemed more practical or economical to disposal onshore, especially when port reception facilities are unavailable. Setting excessive gear can also result in discarding gear. For instance, there may be insufficient room onboard for all of the gear, such as when the space used to store nets when starting a trip are subsequently used as the fish hold (Hareide *et al.,* 2005; Macfadyen *et al.,* 2009).

2.3 Discard and post-release mortalities

Upon haulback of the gear, live and dead catch might not be retained and instead be thrown overboard due to various economic or regulatory reasons (Gilman *et al.,* 2014; ICES, 2014). Gillnet and trammel net fisheries have low discard rates and levels relative to some other gear types (Kelleher, 2005)[2]. Fishers may discard dead and release live catch due to market considerations, such as discarding species and sizes lacking markets. They may also discard and release damaged and spoiled catch with low or no value, and species that can damage the rest of the catch during storage (Jeeva *et al.,* 2006; Krishna *et al.,* 2007; FAO, 2014a; Gilman *et al.,* 2014; Kiiru and Munuti, 2014).

For example, Jeeva *et al.* (2006) estimated that between 6.5 percent and 8.9 percent of catch of commercial fishes in inland reservoir gillnet and hook-and-line fisheries of Orissa, India was lost due to spoilage from the inflow of muddy water, too long gear soak time, and catch being damaged due to poor handling practices. An estimated 4.5 percent of the value, and USD $1 100 per vessel per year of tilapia is lost in Kenyan (Migori, Homabay and Siaya Counties) inland fisheries due to spoilage from too long a gear soak time (Kiiru and Munuti, 2014).

Catch can be damaged due to partial depredation, discussed previously, as well as from poor fishing methods (Jeeva *et al.,* 2006; Krishna *et al.,* 2007). For example, Krishna *et al.* (2007) found that 7.7 percent of interviewed artisanal marine capture fishers of Kerala, India lost or discarded catch that was depredated by larger species. Indirectly related, Krishna *et al.* (2007) also found that artisanal gillnet fishers discarded a portion of their catch in an effort to keep porpoises away from and damaging their gear when the porpoises are likely depredating catch from or aggregated near the gear.

High discard rates due to markets existing for only a narrow range of fishery products is primarily an issue in developed countries. There is also, however, evidence of discarding unmarketable and lower-value species and sizes of catch in developing countries (Jeeva *et al.,* 2006; Krishna *et al.,* 2007; Gilman *et al.,* 2014). For instance, Krishna *et al.* (2007) found that 69 percent of interviewed fishers participating in

[2] Gillnet and trammel net fisheries were estimated to have a relatively low annual global discard level for the 1992-2001 period of 29 000 tonnes, less than 1 percent of the estimated total level of global discards (Kelleher, 2005). Gillnet and trammel net fisheries were also estimated to have a low discard rate (0.5 percent weighted average) relative to several gear types, such as shrimp trawl (62 percent), pelagic longline (29 percent), mobile trap/pot (23 percent), and dredge (28 percent) (Kelleher, 2005).

artisanal marine capture fisheries of Kerala, India reported discarding juveniles of market species. Developing or augmenting markets for currently non-utilized or underutilized species, sizes and sexes (e.g., "bycatch bank" in Iceland) to create demand for their supply at sustainable mortality rates, could reduce discarding resulting from limited or lack of markets and avoid dumping of retained but unwanted bycatch following landing (Clucas 1997; Hall *et al.,* 2000; Kelleher 2005; Gilman *et al.,* 2014).

Another reason for discarding and releasing catch is high-grading, discarding lower-value catch to make room in the hold for higher value catch, when room in the hold is a limiting factor, and the perceived difference in net value between discards and retained catch is greater than the cost to replace the discard (Arnason 1994; Alverson *et al.,* 1994; Hall 1996; Kelleher 2005; Krishna *et al.,* 2007). For example, Krishna *et al.* (2007) found that 51 percent of interviewed fishers of motorized marine capture fishing vessels in India discarded lower value species during a season with high catch levels of higher value catch. Part of the catch may need to be discarded and released during the final set of a trip if there is insufficient room for storage.

Quality, including spoiled catch that is unfit for human consumption, provides another reason to discard catch. Market species caught in gillnets and trammel nets can spoil within days to weeks of being captured (MacMullen *et al.,* 2003; Sancho *et al.,* 2003; Jeeva *et al.,* 2006; Santos *et al.,* 2003b, 2009). In some cases, spoilage and subsequent discarding of market species results from inefficiently long soak times, which in some cases might be due to new entrants to the fishery lacking experience (e.g., MacMullen *et al.,* 2003; Jeeva *et al.,* 2006). Adverse weather has also been identified as a cause of spoilage in inland gillnet fisheries, such as due to the heavy inputs of muddy water (Jeeva *et al.,* 2006).

Furthermore, output controls can create incentives for discarding. Discarding sublegal individuals can occur to comply with measures for species-based minimum landing sizes. Discarding may be conducted to meet prescribed catch composition (measures setting limits on the percent catch composition by species). And, discarding may be conducted to comply with restrictions on retention by sex, such as in some crab fisheries (Arnason, 1994; Alverson, *et al.,* 1994; Hall, 1996; Poos, *et al.,* 2010). While likely less common in most gillnet and trammel net fisheries, quota-induced high-grading has been predicted to occur in some gillnet fisheries when a vessel reaches a species-based quota, and discards lower value grades to enable retaining higher value grades (e.g., Kristifersson and Rickertsen, 2009). Over quota discarding occurs in multispecies fisheries when a quota for one species is reached, but quotas for other species are not in place or have not been reached, and the vessel discards additional catch of the species for which the quota has been reached.

Retention bans of certain species, sizes or sexes, such as of endangered, threatened and protected species, are another cause for discarding and releasing catch. Gillnets and trammel nets can catch endangered, threatened and protected species, including seabirds, sea turtles, marine mammals, elasmobranchs, and some bony fishes (Laist, 1995, 1997; Kaiser *et al.,* 1996; Macfadyen *et al.,* 2009; FAO, 2010b; Gilman *et al.,* 2010; Good *et al.,* 2009, 2010; CMS, 2011; IWC, 2013).

Post-release fishing mortality occurs when catch is landed onboard and then released alive but stressed or injured to a degree that causes the organism to die later. Post-release mortality may occur due to fatal wounds or increased probability of fatal diseases resulting from injuries sustained during the fishery interaction (Davis, 2005; Frick *et al.,* 2010; Gilman *et al.,* 2013a; ICES, 2014). The types and severity of injuries are highly specific to fishing gear, operational modes, environmental conditions, species and size, and handling and release practices (Davis, 2002; Broadhurst *et al.,* 2006; Benoit *et al.,* 2010, 2012).

Many factors that affect the probability of survival of live releases are similar to those affecting escapees. Released organisms, however, experience additional stress and injury from being handled and released. Additional stressors include the method employed to lift them onto the vessel deck, air exposure, on-deck handling practices, duration out of the water, physical conditions onboard such as air temperature, the release method, and tackle remaining attached to the organisms upon release (Davis, 2002; Broadhurst *et al.,* 2006; Benoit *et al.,* 2010, 2012; Swimmer and Gilman, 2013; ICES, 2014). As with pre-catch losses, the probability of post-release mortality has been observed, primarily in trawl and longline fisheries, to vary significantly between species, and by size and sex within a species (Broadhurst *et al.,* 2006; Frick *et al.,* 2010; Suuronen and Erickson, 2010; Curran and Beverly, 2012; Epperly *et al.,* 2012).

2.4 Collateral losses

Collateral sources of fishing mortality are those that are indirectly caused by various ecological effects of fishing (ICES, 2005; Gilman *et al.,* 2013a). Examples in this category are diverse, complex and difficult to quantify. This is because there is high uncertainty in inferring what the predominant factors were that caused the collateral mortality (Gilman *et al.,* 2013a).

For example, loss and degradation of habitat from fishing can result in collateral mortalities. In addition to habitat damage from direct contact by fishing gear, ALDFG that sinks to the seabed also can degrade benthic habitats (FAO, 2010a). Derelict fishing gear can alter microhabitats such as by obstructing reef crevices. ALDFG can entrap fine sediment, smothering benthic communities. And ALDFG can obstruct water flow, creating anoxic areas, which, if prolonged, can cause substantial mortalities (Hall *et al.,* 2000; Levin *et al.,* 2009; Macfadyen *et al.,* 2009). In-use fishing gear and ALDFG can scour and abrade the seabed and associated communities, including sensitive habitats like coastal seagrass beds and coral reefs, and benthic cold water coral reefs and sponge fields, when dragged by currents and wind or during retrieval (Al-Jufaili *et al.,* 1999; Donohue *et al.,* 2001; Asoh *et al.,* 2004; FAO, 2010a; Gilardi *et al.,* 2010).

Selective removal, which concentrates fishing mortality on a narrow subset of an ecosystem's components between and with trophic levels, can alter community structure and size-frequency distributions. This in turn can cause ecological and evolutionary change and loss, reduce ecosystem stability and alter ecosystem function and structure (Hall, 1996; Zhou *et al.,* 2010). For example, pelagic fisheries that selectively remove apex predators, such as in some driftnet fisheries, can cause a top-down trophic effect by releasing pressure and increasing abundance of mid-trophic level species. This alters the ecosystem size structure with a decline in abundance of large-sized species of fish and increase in abundance of smaller-sized species, and may alter the length frequency distribution of populations subject to fishing mortality (Hinke *et al.,* 2004; Ward and Myers, 2005; Gilman *et al.,* 2012; Polovina *et al.,* 2009, 2013).

Fishing gear, including ALDFG, may be located in areas where it poses an obstacle for access to critical habitat, including for foraging, fish spawning grounds, turtle nesting areas, and migration routes (Gilman *et al.,* 2010).

Fishing vessels and gear, including ALDFG and other marine debris, transport invasive alien species. Invasive aliens can disrupt community structure and processes, including causing niche contraction, declines in abundance and local extirpations of native species (Derraik, 2002; Galil, 2007; Macfadyen *et al.,* 2009; FAO, 2010a).

Mass concentrations of ALDFG and other sources of marine debris accumulate in pelagic ecosystems at ocean convergence zones for extended periods of time. This might alter community structure and processes (Derraik, 2002; Macfadyen *et al.,* 2009; FAO, 2010a).

There may be increased predation of live escapees, organisms released alive, and organisms that are injured or disturbed by fishing gear in some way, referred to as 'facilitated predation' (Goñi, 1998; ICES, 2005; Gilman *et al.,* 2013a). These organisms die as an indirect effect of the fishing operation. For instance, escapees and live released organisms can be displaced from suitable habitat for shelter and may experience predation near the sea surface and in the water column as they return to their preferred habitat (Broadhurst *et al.,* 2006). Or, the organisms may be injured or have impaired behavior as a result of the fishery interaction, increasing the probability of predation (Davis, 2005; Davis and Ottmar, 2006).

Cumulative sub-lethal stressors from fishing, including when an organism repeatedly avoids capture or is repeatedly caught and released alive, may eventually lead to mortality. For example, territorial organisms and those with restricted-ranges that routinely overlap with a type of fishing gear may repeatedly escape from the gear, learn to modify their behaviour to avoid the gear, or may experience multiple captures and releases (Davis, 2002; Broadhurst *et al.,* 2006; Suuronen and Erickson, 2010).

Interactions among individual stressors from fishing operations can also result in indirect mortality (Davis, 2002; Broadhurst *et al.,* 2006). For example, an organism may be caught and released injured, be displaced from suitable habitat, and, because fishing operations have degraded habitat, the organism may lack shelter from predators and foraging habitat where it can recover from the injury, increasing the probability of mortality due to these synergistic effects of multiple stressors from fishing operations. Mortality may ultimately be the result of predation, lack of prey, disease, secondary infections, or a combination of these and other stressors (Gilman *et al.,* 2013a).

3. ASSESSMENT METHOD TO PROVIDE FIRST ORDER ESTIMATES OF LEVELS AND CAUSES OF LOSS DURING FISHING OPERATIONS

Several studies have been conducted in recent decades to estimate quantities of food loss in agricultural and fisheries sectors, primarily at national levels, via desktop literature review, stakeholder interviews and analyses of existing datasets (Jeeva *et al.,* 2006; FAO, 2014a). For fisheries loss assessment case studies and methodologies, the focus has been on post-harvest components of the supply chain (e.g., Ashley, 1993; Ward, 1996; Ward and Ryder, 1996, 1997; Ward and Jeffries, 2000; Akande and Diei-Ouadi, 2010; Diei-Ouadi and Mgawe, 2011).

Some studies, however, estimated losses during fishing operations. For instance, Jeeva *et al.* (2006) estimated loss during harvest and post-harvest operations in inland fisheries in India via interviewing fishers. Kiiru and Munuti (2014) estimated loss in inland fisheries for omena and tilapia in three counties of Kenya through a literature review, fisher interviews and observations of supply chain operations. Krishna *et al.* (2007) estimated harvest and post-harvest loss in marine capture fisheries of Kerala, India by observing operations and interviewing fishers. Here we build on these few past studies by describing a method to provide a first order estimate of the level and causes of lost food during gillnet and trammel net fishing operations for individual identified sources and causes identified in Table 1.

3.1 First order assessment of food loss during gillnet and trammel net fishing operations

A first order assessment of levels and causes of loss during gillnet and trammel net fishing operations can be conducted through a combination of an inventory of fishing gear employed by a sample of vessels in a fishery in combination with interviewing fishers (e.g., Gilman *et al.,* 2013b). A draft form for collecting data on food loss during the capture process of gillnet and trammel net fisheries is in Appendix 1, *Draft Data Collection Form for an Assessment of Food Loss during Gillnet and Trammel Net*

Fishing Operations. Information on the various elements that are potentially significant explanatory variables affecting levels of loss during gillnet and trammel net fishing operations are to be collected via an inventory of net design and materials (Part A of the Form) and by interviewing fishers to collect information on their fishing methods and causes of loss during fishing operations (Part B of the Form) (Holst *et al.,* 1998; Hall *et al.,* 2009).

Gear inventories and expert surveys can provide a critically important, first-order, qualitative understanding of basic characteristics of fishing methods and causes of loss of a fishery when previously little or no information was available (MacMullen *et al.,* 2003; Gilman *et al.,* 2010, 2013b). Findings from the first order assessment can then be validated through methods that provide more certain results, such as directed experiments and analyses of observer data. For examples of more robust assessment methods, FAO (In Prep.) reviews alternative methods to estimate ghost fishing mortality rates and levels from marine gillnet and trammel net fisheries, and ICES (2014) reviews experimental methods (captive observations, vitality assessments, and tagging and biotelemetry methods) to estimate post-release losses.

3.2 State of knowledge for assessing levels of loss from pre-catch losses, discard and post-release removals, ghost fishing mortality and collateral sources of fishing mortality

Relative to the other sources of loss during fishing operations, there has been good progress in the development of research methods to estimate pre-catch and post-release mortality. These include various experimental methods as well as using explanatory variables to predict the probability of pre-catch and post-release mortality.

3.2.1 Assessing condition and vitality

The probability of pre-catch and post-release mortality can be accurately predicted by observing the condition and vitality of an organism, including indicators of catch quality (e.g., Hattula *et al.,* 1995). Biochemical indicators of mortality and morbidity include assessing plasma constituents for the degree of blood loss, muscle and other tissue damage and physical stress. These indicators have been used, for example, for sea turtles caught in Atlantic gillnet fisheries in the United States of America (Snoddy and Williard, 2010; Swimmer and Gilman, 2012). Reflex action mortality predictors (RAMP) measure the degree of impairment of reflexes following gear interaction that is correlated with stress (Davis and Ottmar 2006; Davis, 2005, 2007). Bio-electrical impedance analysis measures resistance and reactance of tissue to applied electrical current, providing an indication of the severity of injury and stress incurred during fishery interactions (Cox and Heintz, 2009; Cox *et al.,* 2011). Condition indices have been developed for Pacific halibut based on wounding, and for sharks based on revival time following release (e.g., Trumble *et al.,* 2000; Hueter *et al.,* 2006).

The advantage of using fish vitality indicators onboard versus on captive organisms is that the former is done under commercial fishing conditions (Benoit *et al.,* 2010). Using fish condition and vitality (e.g., wounding, plasma constituents) to predict delayed mortality after escapement or release can be unreliable because there can be inconsistent responses to different types of fishing-related stressors (Davis, 2002). Categorizations of wounding are also typically subjective, introducing bias in mortality estimates (Gilman *et al.,* 2013a).

3.2.2 Estimating probability of pre-catch mortality

Various methods have been employed to estimate pre-catch losses in trawl, longline and purse seine fisheries and in laboratory settings (Broadhurst *et al.,* 2006; Gilman *et al.,* 2013a). It might be feasible to adapt these for application in gillnet and trammel net fisheries. For example, a removable cage used in trawl-escape mortality studies (e.g., Suuronen *et al.,* 2005; Ingólfsson *et al.,* 2007) could be used as a starting point for developing a trap design that could capture escapees from gillnets and trammel nets, to estimate pre-catch mortality rates and levels.

3.2.3 Laboratory studies of captive organisms

Laboratory experiments are a cost-effective method to study stress responses and injuries, and to predict or confirm results of field studies on pre-catch and post-release mortality (Broadhurst *et al.,* 2006; ICES, 2014). Laboratory studies of pre-catch mortality that assessed injuries to fish passing through netting meshes of towed gear could be adapted for use with passive net gears.

Laboratory studies enable assessing the significance of single factors in causing injury, stress and mortality, and allow a systematic determination of the general behavioural, biological and physiological characteristics of stress response up to mortality in different species, which is rarely possible in at-sea experiments (e.g., Olla *et al.,* 1997; Davis, 2002). Laboratory experiments have also been used to calibrate measures of fish condition and vitality, such as wounding and behavioural impairment that serve as indicators of the probability of post-release mortality (Davis, 2005). However, it is difficult to simulate all potential capture stressors in the laboratory. Furthermore, holding organisms in captivity may cause behavioural and stress responses that differ from those under commercial fishing conditions.

3.2.4 Estimating probability of post-release mortality by observing released organisms in captivity

A common method to estimate post-release mortality rates is to place caught organisms into captivity and observe their fate (Swimmer and Gilman, 2012; ICES, 2014). In most post-release mortality studies, organisms were caught, retrieved, handled, and then monitored while being held either in tanks placed at the sea surface, onboard fishing vessels, or in cages at depths consistent with the species' natural vertical distribution (Broadhurst *et al.,* 2006).

Including control animals in survival experiments provides a basis for separating fishery-induced mortality from mortality caused by stressors associated with being held in captivity and other possible contributing sources, including natural mortality (Swimmer and Gilman, 2012; ICES, 2014). Holding released organisms in captivity is problematic for estimating post-release survival rates because various parameters with a significant effect on survival probability can deviate from conditions of the organism's natural habitats, confounding observations of mortality rates (Neilson *et al.,* 2012; Gilman *et al.,* 2013a). To account for these potentially significant factors, information is required on the condition of individual organisms upon capture, including the manner of capture and injuries incurred, and information on methods employed to manage the organisms while in captivity (Gilman *et al.,* 2013a).

3.2.5 Estimating probability of post-release mortality through electronic tagging

Advanced electronic tags have been used to estimate post-release survival across species and sizes. For example, post-release mortality rates have been estimated from satellite data collected from tags attached to organisms caught and then released (Chaloupka *et al.,* 2004; Swimmer *et al.,* 2006; Godley *et al.,* 2008; ICES, 2014). The two main types of satellite tags used are platform terminal transmitters (PTTs) and pop-up satellite archival tags (PSATs), including sources of uncertainty, and importance of the duration of studies and employment of 'control' treatments, are reviewed by Godley *et al.* (2008) and Musyl *et al.* (2011).

3.2.6 Estimating probability of post-release mortality via capture-mark-recapture

Capture-mark-recapture and capture-mark-dead recovery studies may have the potential to estimate post-release mortality of some organisms caused by interactions in gillnet and trammel net fisheries in some regions (ICES, 2014). Recapture rates of released organisms would need to be sufficiently high over short study time periods (months) required for post-release studies. There would also need to be a relatively high probability of recapture at the study site (Trumble *et al.,* 2000; Gilman *et al.,* 2013a). Siira *et al.* (2006) describe a type of tag that enables repeated capture and release events for individual organisms, of potential use for studies of post-release mortality in gillnet and trammel net fisheries that interact with species that with small ranges and thus are likely to be captured repeatedly.

3.2.7 Estimating probability of post-release mortality via assessment of significantly explanatory variables

Predicting the probability of post-release mortality of a species or higher taxonomic group can be done by assessing variables thought to affect the probability of mortality. For example, the type and severity of injuries have been used to predict sea turtle post-release survival in pelagic longline gear by considering the location of hooking, whether gear remains attached upon release, the length of trailing line, whether line was ingested, and whether turtles were comatose upon retrieval and resuscitated prior to release (Chaloupka *et al.,* 2004; Ryder *et al.,* 2006; Gilman *et al.,* 2006, 2007; Parga, 2012).

3.2.8 Estimating ghost fishing mortality from ALDFG

There has been good progress in developing methods to estimate ghost fishing mortality in passive gears, primarily in trammel nets, gillnets and traps, relative to other passive gears and relative to active gears (Gilman *et al.,* 2013a; FAO, In Prep.). An estimate of the total level of ghost fishing mortality in a spatially explicit site over a selected time period can be made given data on the: density of ALDFG 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 (FAO, In Prep.).

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 in a selected area. Fisher surveys have been the most common method to estimate gear loss rates (MacMullen *et al.,* 2003; Ayaz *et al.,* 2010; Kim *et al.,* 2014). Rates of ALDFG generated from illegal, unreported and unregulated (IUU) fishing can potentially be substantially different from estimates obtained from legal fisheries if a main cause of ALDFG by the IUU sector is abandonment of gear when operating illegally and a risk of detection occurs (Imamura, 2011). Few studies have estimated rates of gear abandonment and discarding. Estimates have not been based on data from experiments, observer programs or logbook programs, which could validate first-order estimates from fisher surveys (FAO, In Prep.). However, because ALDFG can be carried by currents out of the area where it was abandoned, lost or discarded, and because ALDFG can likewise be carried into an area from afar (e.g., Ebbesmeyer *et al.,* 2012), information on gear abandonment/loss/discarding rates likely 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.

A more accurate method to estimate the density of ALDFG in a spatially explicit area is through surveys of fishing grounds (FAO, In Prep.). Towing 'creeper' grappling devices is a commonly used method to estimate ALDFG density in a sampled area of a fishing ground (Kang, 2003; MacMullen *et al.,* 2003; Misund *et al.,* 2006; Large *et al.,* 2009). Various *in situ* survey methods have also been used to survey for derelict gear. These include observations by divers, sonar, video and photography, deployed from marine vessels, towed structures, manned submersibles and underwater ROVs (Carr and Cooper, 1987; MacMullen *et al.,* 2003; Revill and Dunlin, 2003; Ayaz *et al.,* 2010). Estimates obtained from surveys of a subset of a fishing ground can then be extrapolated to the entire fishing grounds. 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) (FAO, In Prep.).

A number of methods have been used 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 (Kaiser et al 1996; Erzini *et al.,* 1997; Sancho *et al.,* 2003; Tschernij and Larsson, 2003; Matsuoka *et al.,* 2005; Nakashima and Matsuoka, 2004, 2005; Ayaz *et al.,* 2006; Akiyama *et al.,* 2007; FAO, In Prep.). Short-period ghost fishing mortality rates have been estimated by counting the number of organisms that became newly captured since a previous observation, with monitoring conducted *in situ* or via repeated net retrieval (Kaiser *et al.,* 1996; Erzini *et al.,* 1997; Ayaz *et al.,* 2006; Akiyama *et al.,* 2007).

There are several sources of uncertainty associated with the various methods used to estimate short-term catch rates in derelict nets. 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 (FAO, In Prep.). Estimates made through periodic retrieval of a subset of derelict nets may underestimate ghost fishing mortality rates as a large proportion of catch can drop out during net retrieval (FAO, In Prep.).

Exponential regression decay models have been fit 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 (Kaiser *et al.,* 1996; Erzini *et al.,* 1997; MacMullen *et al.,* 2003; Nakashima and Matsuoka, 2004; Ayaz *et al.,* 2006; Akiyama *et al.,* 2007; FAO, In Prep.). Duration of fishing efficiency has been estimated through 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 (Kaiser *et al.,* 1996; Erzini *et al.,* 1997; MacMullen *et al.,* 2003; Sancho *et al.,* 2003; Tschernij and Larsson, 2003; Nakashimi and Matsuoka, 2004, 2005; Ayaz *et al.,* 2006; FAO, In Prep.).

3.2.9 Assessing collateral losses

There is limited understanding of collateral mortality rates or broader community-level changes caused by fishing (Gilman *et al.,* 2013a). The complexity and indirect link between collateral, indirect effects of fishing operations and mortalities, including from cumulative and synergistic effects of fishing operations, has largely prevented the development of methods that provide accurate estimates of mortality levels and rates (ICES, 2005; Gilman *et al.,* 2013a). Understanding of the probability of mortality from repeated interactions is limited to a small number of studies in trawl fisheries on a small range of species (Ryer *et al.,* 2004; Jorgensen *et al.,* 2005; Ingolfsson *et al.,* 2007; Caddy and Seijo, 2011). Ryer et al. (2004) estimated predation probability following simulated escapement and live releases in trawl gear. Jorgensen et al. (2005) and Ingolfsson *et al.* (2007) electronic-tagged and released young cod in a fishing ground where these fish were caught intensively with bottom trawls to estimate mortality resulting from repeated escapement. Caddy and Seijo (2011) estimated mortality levels from repeated escapement from trawl tows by calculating a simple multiplier effect. It may not be possible, however, to estimate mortality probability resulting from more complex scenarios.

3.2.10 Estimating losses from monitoring data from logbook and observer programmes

Data from monitoring programmes can be used to estimate food loss levels that occur during fishing operations. For data-deficient fisheries lacking monitoring programmes, information to estimate the sources of food loss can be obtained via short-period monitoring by onboard observers to obtain an index-level of coverage (Gilman, 2009). Or, information might be available through domestic or regional logbook and onboard observer programmes, if data collection protocols include the collection of information needed to estimate loss (Gilman *et al.,* 2014; FAO, 2002, In Prep.). Having data collected and reported by independent onboard observers to meet scientific and compliance objectives likely produces more accurate and detailed information than collected and reported in logbooks by crew. Crew may lack the time and training to meet needed data reporting protocols, and may have an economic disincentive to record accurate data, e.g., to avoid catch or size limits (FAO, 2002). Random placement of observers on vessels in a fishery, and balancing (sampling proportionately) across ports and vessel categories, optimizes having fleet-wide extrapolations accurately characterize the entire fleet, so as to avoid statistical sampling bias (Bravington *et al.,* 2003). Some fishing vessels, however, may be too small to accommodate an additional person, and may be determined to be unsafe for observer placement. It may also prove logistically difficult to place observers on vessels when there are numerous seaports, some of which are in remote areas.

The fishery-specific objectives of analyses (e.g., required levels of accuracy and precision of estimates), the frequency of occurrence of catch events for all species of interest, amount of fishing effort, and distribution of catch determine the requisite onboard observer coverage rate and sampling methods employed by observers (Hall 1999; FAO, 2002). In general, the variability in precision and biases in catch estimates decrease rapidly as the observer coverage rate increases to 20 percent, assuming that the sample is balanced and that there are no observer effects (Hall 1999; Lennert-Cody 2001; Lawson 2006; Arnande *et al.,* 2012). At lower coverage rates, catch estimates may have large uncertainties for species with low capture rates, and may result in high uncertainty even for species that are more commonly caught if a small sample size is observed per stratum (e.g., by port, vessel category, season). But even low coverage rates likely would be sufficient to determine when and where catch occurs (Bravington *et al.,* 2003; Gilman *et al.,* 2014).

Electric monitoring (EM) systems can use onboard cameras, global positioning systems, sensors and data loggers to collect a wide variety of information, including on loss. And EM systems include programs for analyzing resulting EM data, typically implemented by an independent authority. Data from EM can include information on haulback disposition, discarded and released catch, gear discarding and retrieval of derelict gear, supporting an assessment of food loss (Lowman *et al.,* 2013; SPC, 2013a,b). EM can complement traditional human onboard observer programs. In fisheries where vessels are unsuitable for various reasons to place a human observer, EM may offer an alternative monitoring approach, as vessel specification requirements for EM are much lower than what is needed for placing a human observer. Data from EM can also be used to compare with logbook and human observer data. Optimal EM equipment specs, and the way the equipment is installed, can account for vessel-specific fishing operations, the types of data that are to be collected, and ways to avoid crew tampering with the equipment (Restrepo, 2012).

At a regional level, few monitoring programmes collect requisite data to estimate comprehensively loss during fishing operations. Gilman *et al.* (2014) found that less than half of regional fisheries management organizations (RFMOs) have regional observer programmes that collect data on discards. Also, to benchmark regional measures for monitoring and mitigating ALDFG and ghost fishing from marine capture fisheries, including marine gillnet and trammel net fisheries, FAO (In Prep.) assessed data collection protocols and management measures to prevent and remediate ALDFG and ghost fishing of RFMOs and other relevant intergovernmental organizations with the competence to establish binding controls for regional marine capture fisheries. Of ten intergovernmental organizations with competence over fishery resources captured in an active gillnet or trammel net fishery, two (Indian Ocean Tuna Commission, IOTC, No Date; Joint Norwegian-Russian Fisheries Commission, Directorate of Fisheries, 2012) require data collection related to ALDFG from gillnet or trammel net fisheries. The South Pacific Regional Fisheries Management Organisation has also adopted a measure requiring reporting gillnets lost in the SPRFMO Convention Area. Gillnetting, however, is not a gear type used to catch SPRFMO-covered fishery resources (SPRFMO, 2013, 2014). Harmonizing data collection protocols to estimate food loss during fishing operations where they are in place, and filling gaps for those intergovernmental organizations lacking procedures to collect this information, would contribute to improved monitoring to support estimates of loss from regionally-managed gillnet, trammel net and other capture fisheries (Gilman *et al.,* 2014; FAO, In Prep.).

3.3 Loss due to suboptimal selectivity: modifying gear designs to increase catch of market species and reduce unwanted catch, including of endangered, threatened and protected species

An additional application of data collected from inventorying gear designs and fishing methods is to identify methods to modify selectivity to augment catch of target species (e.g., Holst *et al.,* 1998) while increasing gear selectivity to reduce unwanted catch (e.g., Gilman *et al.,* 2010). If an assessment identifies problematic levels of loss are occurring during fishing operations, then gear designs and fishing methods used by a fishery can be compared with gear technology best practices to determine if modifications could be introduced to mitigate sources of loss.

There is a broad range of potentially significant explanatory variables for catch rates of both market and non-market species, including each aspect of the gear design and materials, and fishing methods, which will vary substantially between as well as within fisheries. One constant is that modifying gillnet mesh size will affect size (girth) selectivity for finfish[3], but not between-species selectivity (Holst *et al.,* 1998; Valdemarsen and Suuronen, 2003; Suuronen *et al.,* 2012). Changing trammel net mesh sizes of the inner panel will have a smaller effect on size selectivity than in a gillnet, as trammel nets catch organisms primarily via entanglement (i.e., trammel nets are less size selective relative to gillnets), and as with gillnets, changing mesh size will not affect species selectivity (Purbayanto *et al.,* 2000; Bjordal, 2002; Goncalves *et al.,* 2008). Hanging ratio is another gear design factor that can significantly affect selectivity. A decrease in hanging ratio reduces the catch rate of fish by entanglement, a catch process more important for trammel nets than gillnets (Holst *et al.,* 1998). As a final example, increasing the vertical slack in trammel nets, the ratio between the stretched length of the inner and outer panels, will increase fishing efficiency via entanglement up to a

[3] Nets with larger meshes are predicted to have a greater fishing efficiency for larger fish relative to smaller mesh size nets' fishing efficiency for smaller fishes. This is because larger fishes are understood to have a higher probability of encountering nets than smaller sized fishes (Holst *et al.,* 1998).

threshold point when too high slack can increase visibility of netting in the lower part of the net (Holst *et al.,* 1998). Discussed in the previous chapter, as an example of the effect of a fishing method on loss and catch efficiency, excessive soak time can result in loss due to spoilage of market species, loss of gear and possibly ghost fishing, and can also result in higher rates of pre-catch mortality (Holst *et al.,* 1998; MacMullen *et al.,* 2003; Jeeva *et al.,* 2006; Kiiru and Munuti, 2014). Furthermore, excessive gear soak time can exceed the duration for gear saturation (meshes adjacent to a caught organism cannot catch additional organisms, and the presence of catch in the net may enable other organisms to avoid capture) (Holst *et al.,* 1998).

Various gear technology methods have been proposed to increase gillnet selectivity to reduce catch rates of endangered, threatened and protected species (FAO, In Prep.). For example, reducing net mesh size, reducing gillnet profile (vertical height), and eliminating or reducing the length of anchored gillnet tiedowns have been used to reduce turtle capture in gillnet and trammel net fisheries (Gearhart and Eckert, 2007; Price and Van Salisbury, 2007; Eckert *et al.,* 2008; Gilman *et al.,* 2010). Increasing gillnet filament diameter, modifying the weaves (e.g., using multi-monofilament 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 *et al.,* 2007; Thorpe and Frierson, 2009). Deploying driftnets 2m 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 *et al.,* 2001). Making nets more visible, such as through altering net color, using thicker twine diameter, and attaching corks or other visual markers within the net, has been shown to effectively 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 either because the materials increase acoustic reflectivity when using echolocation, because they increase the net's visibility or because the infused metals increase twine stiffness (Trippel *et al.,* 2003; Koschinski *et al.,* 2006; Werner *et al.,* 2006; Larsen *et al.,* 2007). Acoustic pingers and alarms have also been used to reduce marine mammal bycatch in gillnets and other fishing gear (e.g., Koschinski *et al.,* 2006; Werner *et al.,* 2006). Illuminating nets with chemical or battery-operated lightsticks might reduce bycatch of sea turtles and other vulnerable taxa (Wang *et al.,* 2010).

4. PRIORITY SITES FOR LOSS ASSESSMENT CASE STUDIES

4.1 Introduction and methods

This chapter provides a tentative list of priority marine and inland areas for an assessment of food loss during fishing operations of gillnet and trammel net fisheries. Information that might be collected during such an assessment could include: (i) Causes of food loss during the harvesting stage; (ii) What resources are lost due to each source; (iii) The magnitude of each category of resources that are lost; and (iv) During which stage of fishing operations does each cause of loss occur.

Three filters were employed to identify priority areas: (i) Volume of reported landings from marine gillnet fisheries, included because fisheries supplying the largest landings from gillnet fisheries are of importance for global seafood production; (ii) The percent of total reported landings from marine capture fisheries that was comprised of landings from marine gillnet fisheries, included because gillnet fisheries are likely of relatively high socio-economic importance to those areas deriving a relatively large proportion of their marine capture fisheries landings from gillnet fisheries; and (iii) Regions where inland fisheries are of relatively high importance. Data were obtained from SAUP (2011) as reported in CMS (2011).

4.2 Results and discussion

Reported landings from total and gillnet marine capture fisheries, by exclusive economic zone (EEZ), selected portions of EEZs, and high seas areas, in 2006, are available from SAUP (2011) and CMS (2011). The following domestic areas had the ten highest reported landings from marine gillnet fisheries in 2006: Russia Pacific Ocean, Myanmar, India, Vietnam, Eastern Indonesia, China, western Indonesia, Bangladesh, Norway, and Japan main islands (CMS, 2011; SAUP, 2011). The following high seas areas had the five highest reported landings from marine gillnet fisheries in 2006: western and central Pacific Ocean, eastern Indian Ocean, northwest Pacific Ocean, southeast Pacific Ocean, and western Indian Ocean (CMS, 2011; SAUP, 2011).

The following domestic areas had the 19 highest values for the proportion of total marine capture landings comprised of landings from marine gillnet fisheries in 2006 and gillnet landings made up ≥60percent of total reported landings: Montserrat Island, United Kingdom; Cayman Islands, United Kingdom; Pitcairn Group of Islands, United Kingdom; Timor-Leste; windward Netherlands Antilles – islands of Sint Maarten (constituent country of The Netherlands), Saba (municipality of The Netherlands) and Sint Eustatius (municipality of The Netherlands); Bangladesh; Somalia; Myanmar; Vietnam; Navassa Island, Haiti or USA; Brunei; Haiti; Anguilla, United Kingdom; Guinea; Cambodia; Suriname; British Virgin Islands, United Kingdom; Madagascar; and Sierra Leone (CMS, 2011; SAUP, 2011). The following high seas areas had the five highest values for the proportion of total marine capture landings comprised of landings from marine gillnet fisheries in 2006 and gillnet landings made up ≥32percent of total reported landings: Arctic Sea, eastern Indian Ocean, northwest Pacific Ocean, western central Atlantic Ocean, and western and central Pacific Ocean (CMS, 2011; SAUP, 2011).

Data on reported landings from inland gillnet fisheries and from marine and inland trammel net fisheries were unavailable (FAO, 2014c). Most inland fisheries employ multiple gears, such that available statistics do not identify landings by specific gear type, and much of the catch from inland fisheries is not accounted for due to the small-scale nature of the fisheries, where a large proportion of landings is used for subsistence consumption or local markets (Smith *et al.,* 2005; Welcomme *et al.,* 2010). The contributions of each of the FAO major inland fishing areas to total inland catches in 2012 was 68.38 percent from Asia, 23.26 percent from Africa, 3.49 percent from South America, 3.25 percent from Europe, 1.46 percent from North and central America, and 0.16 percent from Oceania (FAO, 2014b,c). Inland fisheries are of critical importance for food security, employment and household income in developing countries of Africa, Asia and Latin America (Welcomme *et al.,* 2010). For example, almost all fish consumed in Mali, Chad and East Africa are produced by inland fisheries (Sarch and Allison, 2000). About 75 percent of animal protein consumed by urban and rural families in Malawi comes from inland fisheries (Smith *et al.,* 2005). Inland fisheries of the Lower Mekong basin are extremely important for food security, where, for example, in Laos and Cambodia, inland fish make up 48 percent and 79 percent of animal protein, respectively (Smith *et al.,* 2005; Welcomme *et al.,* 2010). Floodplain households of the Brazilian Amazon derive an estimated 30 percent of their income from inland fisheries (Smith *et al.,* 2005). Inland waters of industrial countries in Europe, North America and Australia are dominated by recreational fisheries with low harvest levels (Arlinghaus *et al.,* 2002; Smith *et al.,* 2005; Welcomme *et al.,* 2010). Recreational fishing in inland waters is increasingly important in some parts of Asia, Latin America and Southern Africa (Welcomme *et al.,* 2010).

Subsequent analyses to identify specific areas and individual fisheries to include in a study of food loss during fishing operations of gillnet and trammel net fisheries might include how to obtain balance or otherwise representation of each FAO Major Inland and Marine Fishing Area (FAO, 2014b). Furthermore, to ensure that the study adequately characterizes sources of loss specific to shallow and deep fishing techniques, and sources of loss specific to the two gear types, fisheries could be selected to ensure balance and representation of both set and drift gillnet fisheries, and of trammel net fisheries, and fisheries that occur in both shallow, coastal areas and in deep-water, offshore marine areas.

5. REFERENCES

Akande, G., Diei-Ouadi, Y. 2010. *Post-harvest Losses in Small-Scale Fisheries: Case Studies in Five Sub-Saharan African Countries*. FAO Fisheries and Aquaculture Technical Paper 550. Food and Agriculture Organization of the United Nations, Rome.

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.

Al-Jufaili, S., Al-Jabri, M., Al-Baluchi, A., Baldwin, R., Wilson, S., West, F., Matthews, A. 1999. Human impacts on coral reefs in the Sultanate of Oman. *Estuarine, Coastal and Shelf Science* 49: 65–74.

Alverson, D.L., Freeberg, M.H., Murawski, S.A., Pope, J. 1994. *A Global Assessment of Fisheries Bycatch and Discards*. Fisheries Technical Paper No. 339. Rome, Italy: Food and Agriculture Organization of the United Nations.

Arlinghaus R, Mehner T, Cowx I. 2002. Reconciling traditional inland fisheries management and sustainability in industrialized countries, with emphasis on Europe. *Fish and Fisheries* 3: 261-316.

Arnande, M. , Chassot, E., Chavance, P., Murua, H., Delgado de Molina, A. and Bez, N. 2012. Precision in bycatch estimates: the case of tuna purse-seine fisheries in the Indian Ocean. *ICES Journal of Marine Science*, doi.10.1093/icesjms/fss106.

Arnason, R. 1994. On catch discarding in fisheries. *Marine Resource Economics* 9: 189-207.

Ashley, S. 1993. *Report of a Visit to Tanzania to Establish a Post-harvest Loss Monitoring System for the Lake Victoria Fishery*. NRI Report R1965. Natural Resources Institute, Chatham, England.

Asoh, K., Yoshikawa, T., Kosaki, R. and Marschall, E. 2004. Damage to cauliflower coral by monofilament fishing lines in Hawaii. *Conservation Biology 18:* 1645-1650.

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.

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.

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.

Benoît, H., Hurlbut, T., Chassé, J. 2010. Assessing the factors influencing discard mortality of demersal fishes in four fisheries using a semi-quantitative indicator of survival potential. *Fisheries Research* 106: 436-447.

Benoît, H., Hurlbut, T., Chassé, J., Jonsen, I. 2012. Estimating fishery-scale rates of discard mortality using conditional reasoning. *Fisheries Research* 125-126: 318-330.

Bjordal, A. 2002. The use of technical measures in responsible fisheries: regulation of fishing gear. Pp. 21-48 IN Cochrane, K. (Ed.). *A Fishery Manager's Guidebook: Management Measures and their Application*. FAO Fisheries Technical Paper 424. Food and Agriculture Organization of the United Nations, Rome.

Borges, L. (2013), The evolution of a discard policy in Europe. *Fish and Fisheries*. doi: 10.1111/faf.12062.

Bravington, M., Burridge, C., Toscas, P. 2003. *Design of Observer Program to Monitor Bycatch Species in the Eastern Tuna and Billfish Fishery*. Secretary of the Pacific Community, Noumea, New Caledonia.

Breen, P. 1990. A review of ghost fishing by traps and gillnets. Pp. 571–599 IN Shomura, R., Godfrey, M. Eds. *Proceedings of the 2nd International Conference on Marine Debris, 2–7 April 1989, Honolulu, Hawaii, USA*. Available online, http://swfsc.noaa.gov/publications/tm/swfsc/noaa-tm-nmfs-swfsc-154_p571.pdf, accessed 14 May 2014. NOAA Technical Memorandum 154. Southwest Fisheries Science Center, National Marine Fisheries Service, La Jolla, USA.

Broadhurst, M., Suuronen, P., Hulme, A. 2006. Estimating collateral mortality from towed fishing gear. *Fish and Fisheries* 7: 180-218.

Caddy, J., Seijo, J. 2011. Destructive fishing practices by bottom gears: a broad review of research and practice. *Ciencia Pesquera* 19: 5-58.

Campana, S., Joyce, W., Manning, M. 2009. Bycatch and discard mortality in commercially caught blue sharks *Prionace glauca* assessed using archival satellite pop-up tags. *Mar. Ecol. Prog. Ser.,* 387: 241-253.

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.

Chaloupka, M., Parker, D., Balazs, G. 2004. Modelling post-release mortality of loggerhead sea turtles exposed to the Hawaii-based pelagic longline fishery. *Marine Ecology Progress Series* 280: 285–293.

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

Clucas, I. 1997. *A Study of the Options for Utilization of Bycatch and Discards from Marine Capture Fisheries*. FAO Fisheries Circular No. 928. Food and Agriculture Organization of the United Nations, Rome.

CMS. 2011. *Assessment of Bycatch in Gill Net Fisheries*. Prepared by Waugh, S., Filippi, D., Blyth, R., Filippi, P. UNEP/CMS/Inf.10.30. Convention on Migratory Species, Bonn, Germany.

Cox, M., Heintz, R. 2009. Electrical phase angle as a new method to measure fish condition. *Fishery Bull*etin 107: 477–487.

Cox, M., Heintz, R., Hartman, K. 2011. Measurements of resistance and reactance in fish with the use of bioelectrical impedance analysis: sources of error. *Fishery Bull*etin 109: 35-47.

Curran, D., Beverly, S. 2012. Effects of 16/0 circle hooks on pelagic fish catches in three South Pacific albacore longline fisheries. *Bulletin of Marine Science* 88: 485-497.

Davis, M. 2002. Key principles for understanding fish bycatch discard mortality. *Canadian Journal of Fisheries and Aquatic Science* 59: 1834–1843.

Davis, M. 2005. Behaviour impairment in captured and released sablefish: ecological consequences and possible substitute measures for delayed discard mortality. *Journal of Fish Biology* 66: 254–265.

Davis, M. 2007. Simulated fishing experiments for predicting delayed mortality rates using reflex impairment in restrained fish. *ICES Journal of Marine Sci*ence 64: 1535–1542.

Davis, M., Ottmar, M. 2006. Wounding and reflex impairment may be predictors for mortality in discarded or escaped fish. *Fisheries Research* 82: 1-6.

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

Diei-Ouadi, Y., Mgawe, Y. 2011. *Post-harvest Fish Loss Assessment in Small-scale Fisheries*. FAO Fisheries and Aquaculture Technical Paper 559. Food and Agriculture Organization of the United Nations, Rome.

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. Available online, http://www.fiskeridir.no/english/content/download/26509/241119/version/5/file/20120119-Reporting-and-control-territorial-waters.pdf, accessed 30 March 2014. Directorate of Fisheries, Bergen, Norway.

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.

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.

Epperly, S., Watson, J., Foster, D., Shah, A. 2012. Anatomical hooking location and condition of animals captured with pelagic longlines: the grand banks experiments 2002-2003. *Bulletin of Marine Science* 88: 513-527.

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 Alarve (southern Portugal). *Marine Ecology Progress Series* 158: 257-265.

FAO. 2002. *Guidelines for Developing an At-Sea Fishery Observer Programme*. Davies, S., Reynolds, J. (Eds). FAO Fisheries Technical Paper No. 414. Food and Agriculture Organization of the United Nations, Rome.

FAO. 2008. *Ecolabels and Marine Capture Fisheries: Current Practices and Emerging Issues*. Globefish Research Programme. Volume 91. Available online, http://www.nmfs.noaa.gov/ocs/mafac/meetings/2008_07/docs/GLOBEFISH_Ecolabels_marine_capture_fisheries.pdf, accessed 1 July 2014. Food and Agriculture Organization of the United Nations, Rome.

FAO. 2010a. *The State of World Fisheries and Aquaculture 2010*. ISBN 978-92-5-106675-1. Food and Agriculture Organization of the United Nations, Rome.

FAO. 2010b. *Guidelines to Reduce Sea turtle Mortality in Fishing Operations. FAO Technical Guidelines for Responsible Fisheries*. Prepared by Gilman, E., Bianchi, G. Available online, http://www.fao.org/docrep/012/i0725e/i0725e.pdf, accessed 1 July 2014. ISBN 978-92-106226-5. FAO, Rome.

FAO. 2011. *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 Descaters.* Food and Agriculture Organization of the United Nations, Rome.

FAO. 2012a. *Greening the Economy with Agriculture*. Available online, http://www.fao.org/docrep/015/i2745e/i2745e00.pdf, accessed 19 August 2014. Food and Agriculture Organization of the United Nations, Rome.

FAO. 2012b. *Towards the Future We Want. End Hunger and Make the Transition to Sustainable Agricultural and Food Systems*. Available online, http://www.fao.org/docrep/015/an894e/an894e00.pdf, accessed 19 August 2014. Food and Agriculture Organization of the United Nations, Rome.

FAO. 2014a. *Food Loss Assessments: Causes and Solutions. Kenya. Banana, Maize, Milk, Fish*. Case Studies in Small-scale Agriculture and Fisheries Subsectors. Available online, http://www.fao.org/fileadmin/user_upload/save-food/PDF/Kenya_Food_Loss_Studies.pdf, accessed 2 July 2014. Food and Agriculture Organization of the United Nations, Rome.

FAO. 2014b. *CWP Handbook of Fishery Statistical Standards. Section H: Fishing Areas for Statistical Purposes*. Available online, http://www.fao.org/fishery/cwp/handbook/h/en, accessed 19 March 2014. Coordinating Working Party on Fishery Statistics, Food and Agriculture Organization of the United Nations, Rome.

FAO. 2014c. *Fishery and Aquaculture Statistics. FAO Yearbook 2012*. ISBN 978-92-5-008293-6. Food and Agriculture Organization of the United Nations, Rome.

FAO. 2014d. *Definitional Framework of Food Loss*. Available online, http://www.fao.org/fileadmin/user_upload/save-food/PDF/FLW_Definition_and_Scope_2014.pdf, accessed 24 September 2014. Food and Agriculture Organization of the United Nations, Rome.

FAO. In Prep. *Abandoned, Lost and Discarded Gillnets and Trammel Nets. Methods to Estimate Ghost Fishing Mortality Rates and Levels and Status of Regional Monitoring and Controls*. Prepared by Gilman, E., Chopin, F., Suuronen, P. Food and Agriculture Organization of the United Nations, Rome.

Food Marketing Institute. 2014. *Fishery Improvement Projects: How Retailers and the Supply Chain Advance Seafood Sustainability*. Prepared by Bartholomew, N. Available online, http://www.fmi.org/forms/store/ProductFormPublic/search?action=1&Product_productNumber=3121, accessed 3 July 2014. Food Marketing Institute, Arlington, Virginia, USA.

Frick, L., Reina, R., Walker, T. 2010. Stress related physiological changes and post-release survival of Port Jackson sharks (*Heterodontus portusjacksoni*) and gummy sharks (*Mustelus antarcticus*) following gill-net and longline capture in captivity. *Journal of Experimental Marine Biology and Ecology* 385: 29-37.

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. Wider Caribbean Sea Turtle Conservation Network, Beaufort, North Carolina, USA.

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. (Ed.). 2009. *Proceedings of the Technical Workshop on Mitigating Sea Turtle Bycatch in Coastal Net Fisheries. 20-22 January 2009, Honolulu, U.S.A.* 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: Gland, Switzerland; Honolulu, Bangkok, and Pascagoula, USA. ISBN 1-934061-40-9.

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

Gilman, E., Brothers, N., Kobayashi, D. 2007. Comparison of the efficacy of three seabird bycatch avoidance methods in Hawaii pelagic longline fisheries. *Fisheries Science* 73: 208-210.

Gilman, E., Chaloupka, M., Read, A., Dalzell, P., Holetschek, J., Curtice, C. 2012. Hawaii longline tuna fishery temporal trends in standardized catch rates and length distributions and effects on pelagic and seamount ecosystems. *Aquatic Conservation: Marine and Freshwater Ecosystems* 22: 446-488.

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.

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

Gilman, E., Passfield, K., Nakamura, K. 2014. Performance of regional fisheries management organizations: ecosystem-based governance of bycatch and discards. *Fish and Fisheries* 15:327-351.

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

Gilman, E, Zollett, E., Beverly, S., Nakano, H., Shiode, D., Davis, K., Dalzell, P., Kinan, I. 2006. Reducing sea turtle bycatch in pelagic longline gear. *Fish and Fisheries* 7: 2-23.

Godley, B., Blumenthal, J., Broderick, A., Coyne, M., Godfrey, M., Hawkes, L., Witt, M. 2008. Satellite tracking of sea turtles: Where have we been and where do we go next? *Endangered Species Research* 4: 3-22.

Godfray, H., Beddington, J., Crute, I., et al. 2010. Food security: The challenge of feeding 9 billion people. *Science* 327: 812-818.

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. 1999. Estimating the ecological impacts of fisheries: What data are needed to estimate bycatches? Pp.175-184 IN Nolan, C. (ed.). *Proceedings of the International Conference on Integrated Fisheries Monitoring. Sydney, Australia, 1-5 February 1999*. Food and Agriculture Organization of the United Nations, Rome.

Hall, M., Alverson, D., Metuzals, 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. Pp. 68-70 IN Gilman (Ed.). *Proceedings of the Technical Workshop on Mitigating Sea Turtle Bycatch in Coastal Net Fisheries. 20-22 January 2009, Honolulu, U.S.A.* 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: Gland, Switzerland; Honolulu, Bangkok, and Pascagoula, USA. ISBN 1-934061-40-9.

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*. Available online, http://www.seafish.org/media/Publications/DEEPNETfinalreport.pdf, accessed 1 May 2014. Bord Iascaigh Mhara, Fiskeridirecktoratet, NEAFC, Sea Fish Industry Authority, Joint Nature Conservation Committee, Marine Institute Foras na Mara.

Hattula, T., Luoma, T., Kostiainen, R., Poutanen, J., Kallio, M., Suuronen, P. 1995. Effects of catching method on different quality parameters of Baltic herring (*Clupea harengus* L.). *Fisheries Research* 23: 209-221.

Hayase, S., Yatsu, A. 1993. Preliminary report of a squid subsurface driftnet experiment in the North Pacific during 1991. *Int. North Pac. Fish. Comm. Bull*. 53:557-576.

Hinke J, Kaplan I, Avdin K, Watters G, Olson R, Kitchell J. 2004. Visualizing the food-web effects of fishing for tunas in the Pacific Ocean. Ecology and Society 9: 10.

HLPE. 2014. *Food Losses and Waste in the Context of Sustainable Food Systems*. High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security, Rome.

Holst, R., Madsen, N., Moth-Poulsen, T., Fonseca, P., Campos, A. 1998. *Manual for Gillnet Selectivity*. Available online, http://www.constat.dk/Papers/Gillman.pdf, accessed 13 June 2014.

Hubert, W. 1983. Passive capture techniques. Pp. 95-112 In: Nielson, L.,. Johnson, L. (Eds.). *Fisheries Techniques*. American Fisheries Society, Bethesda.

Hueter, R., Manire, C., Tyminski, J., Hoenig, M., Hepworth, D. 2006. Assessing mortality of released or discarded fish using a logistic model of relative survival derived from tagging data. *Transactions of the American Fisheries Society*. 135: 500-508.

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*. ICES CM 2005/B:08. Available online http://brage.bibsys.no/imr/bitstream/URN:NBN:no-bibsys_brage_3568/1/B08.pdf, accessed 5 July 2014. International Council for the Exploration of the Sea, Copenhagen.

ICES. 2014. ICES CM 2014/ACOM:51. *ICES WKMEDS Report 2014. Report of the Workshop on Methods for Estimating Discard Survival (WKMEDS), 17-21 February 2014*. International Council for the Exploration of the Sea, Copenhagen.

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

Ingólfsson, Ó., Soldal, A., Huse, I., Breen, M. 2007. Escape mortality of cod, saithe and haddock in a Barents Sea trawl fishery. *ICES Journal of Marine Science* 64: 1836-1844.

IOTC. No Date. *IOTC Regional Observer Scheme. Observer Trip Report*. Available online, http://www.iotc.org/files/proceedings/2010/wros/IOTC%20Observer%20Trip%20Report.zip, accessed 28 Feb. 2014. Indian Ocean Tuna Commission, Mahé, Seychelles.

IWC. 2013. *Report of the 2013 IWC Scientific Committee Workshop on Marine Debris*. SC/65a/Rep06. International Whaling Commission, London. Jeeva, J., Khasim, D., Srinath, K., Unnithan, G., Rao, M., Murthy, K., Bathla, H., Ahmad, T. 2006. Harvest losses at various resources of inland fisheries. *Fishery Technology* 43: 218-223.

Jorgensen, T., Ovredal, J., Huse, I. 2005. A new pass-through PIT tag detection system for marine use. In *Proceedings of the Fifth Conference on Fish Telemetry held in Europe, Ustica, Italy, 9-13 June 2003*. (Spedicato, M., Lembo, G. & Marmulla, G., eds), Pp. 261-268. ISBN 92-5-1055301-4. COISPA Teconologia and Food and Agriculture Organization of the United Nations, Rome.

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*. Available online, http://marine-litter.gpa.unep.org/documents/marine-litter-Korea-Kang.pdf, accessed 5 May 2014. United Nations Environment Programme, Nairobi.

Kelleher, K. 2005. *Discarding in the World's Marine Fisheries: An Update*. FAO Fisheries Technical Paper No. 470. Food and Agriculture Organization of the United Nations, Rome.

Kiiru, J., Munuti, S. 2014. Field studies in Migoru, Homabay, Siaya Counties, September – December 2012. Pp. 71-85 in FAO. *Food Loss Assessments: Causes and Solutions. Kenya. Banana, Maize, Milk, Fish*. Case Studies in Small-scale Agriculture and Fisheries Subsectors. Available online, http://www.fao.org/fileadmin/user_upload/save-food/PDF/Kenya_Food_Loss_Studies.pdf, accessed 2 July 2014. Food and Agriculture Organization of the United Nations, Rome.

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.

Krishna, S., Unnithan, G., Nikita, G., Radhakrishnan, N., Bathla, H., Ahmad, T. 2007. Harvest losses in marine fisheries. *Fishery Technology* 44: 117-120.

Kristifersson, D., Rickertsen, K. 2009. Highgrading in quota-regulated fisheries: Evidence from the Icelandic cod fishery. *American Journal of Agricultural Economics* 91: 335-346.

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. Pp. 99-139 IN Coe, J., Rogers, D. (Eds.). *Marine Debris: Sources, Impacts, and Solutions*. Springer, New York.

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

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. *Fish. Res.* 85: 270-278.

Lawson, T. 2006. *Scientific Aspects of Observer Programmes for Tuna Fisheries in the Western and Central Pacific Ocean*. WCPFC-SC2-2006/ST WP-1. Western and Central Pacific Fisheries Commission, Palikir, Federated States of Micronesia.

Lennert-Cody C.E., 2001. Effects of sample size on bycatch estimation using systematic sampling and spatial post-stratification: summary of preliminary results. *IOTC Proceedings* 4: 48-53.

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

Lockwood, S., Pawson, M., Eaton, D. 1983. The effect of crowding on mackerel (*Scomber scombrus* L.) – physical condition and mortality. *Fisheries Research* 2: 129–147.

Lowman, D., Fisher, R., Holliday, M., McTee, S., Stebbins, S. 2013. *Fisheries Monitoring Roadmap*. Available online, http://www.edf.org/sites/default/files/FisheryMonitoringRoadmap_FINAL.pdf, accessed 23 Nov. 2013. Environmental Defense Fund.

Macfayden, G., Huntington, T., Cappel, R. 2009. *Abandoned, Lost or Otherwise Discarded Fishing Gear*. UNEP Regional Seas Reports and Studies 185. FAO Fisheries and Aquaculture Technical Paper 523. ISBN 978-92-5-106196-1. United Nations Environment Programme and Food and Agriculture Organization of the United Nations, Nairobi and Rome.

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*. FANTARED 2. ISBN 0-903941-97-X. Available online, http://www.seafish.org/media/Publications/FANTARED_2_COMPLETE.pdf, accessed 18 April 2014. Sea Fish Industry Authority, Hull, UK.

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

Melvin, E., Parrish, J., Conquest, L. 2001. Novel tools to reduce seabird bycatch in coastal gillnet fisheries. Pp. 161-184 In Melvin, E., Parrish, J. (Eds.). *Seabird Bycatch: Trends, Roadblocks, and Solutions*. AK-SG-01-01i. University of Alaska Sea Grant.

Misund, R., Kolle, J., Haugen, S., Hareide, R. 2006. *The Norwegian Retrieval Survey for Lost Gillnets 2005*. Available online, http://www.fiskeridir.no/content/download/7860/64040/version/1/file/engelsk_mars06.pdf, accessed 12 June 2014. Norwegian Directorate for Fisheries, Bergen, Norway.

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

Musyl, M., Domeier, M., Nasby-Lucas, N., Brill, R., McNaughton, L., Swimmer, J., Lutcavage, M., Wilson, S., Galuardi, B., Liddle, J. 2011. Performance of pop-up satellite archival tags. *Marine Ecology Progress Service* 433: 1-28.

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.

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.

Nedelec, C., Prado, J. 1990. *Definition and Classification of Fishing Gear Categories*. FAO Fisheries Technical Paper No. 222, Revision 1. Food and Agriculture Organization of the United Nations, Rome. 92 pp.

Neilson, J., Busawon, S., Andrushchenko, I., Campana, S., Carruthers, E., Harris, L., Stokesbury, M. 2012. *A Review of Approaches to Assess Survival of Released Catch from Canadian Large Pelagic Longline Fisheries*. DFO. Can. Sci. Advis. Sec. Res. Doc. 2011/091. ISSN 1499-3848. Canadian Science Advisory Secretariat, Fisheries and Oceans Canada, Ottawa, Ontario, Canada.

Olla, B., Davis, M., Schreck, C. 1997. Effects of simulated trawling on sablefish and walleye pollock: the role of light intensity, net velocity and towing duration. *Journal of Fish Biology* 50: 1181–1194.

Parga, M. 2012. Hooks and sea turtles: A veterinarian's perspective. *Bulletin of Marine Science* 88: 731-741.

Pelletier, N., Audsley, E., Brodt, S., et al. 2011. Energy intensity of agriculture and food systems. *Annual Review of Environment and Resources* 36: 223-246.

Pereira, H., Leadley, P., Proença, V., Alkemade, R., Scharlemann, J., Fernandez-Manjarrés, J., Araújo, M., Balvanera, P., Biggs, R., Cheung, W., Cooper, D., Gilman, E, Guenette, S., Hurtt, G., Huntington, H., Mace, G., Oberdorff, T., Revenga, C., Scholes, R, Sumaila, U., Walpole, W. 2010. Scenarios for global biodiversity in the 21st century. *Science* 330 (6010): 1496-1501.

Polovina J, Abecassis M, Howell E, Woodworth P. 2009. Increases in the relative abundance of mid-trophic level fishes concurrent with declines in apex predators in the subtropical North Pacific, 1996-2006. *Fisheries Bulletin* 107: 523-531.

Polovina J, Woodworth-Jefcoats P. 2013. Fishery-induced changes in the subtropical Pacific pelagic ecosystem size structure: Observations and theory. *PLOsOne*; 8: doi:10.1371/journal.pone.0062341.

Poos, J., Bogaards, A., Quirijns, F., Rijnsdorp, A. 2010. Individual quotas, fishing effort allocation, and over-quota discarding in mixed fisheries. *ICES Journal of Marine Science* 67: 323-333.

Price, B., Van Salisbury, C. 2007. *Low-Profile Gillnet Testing in the Deep Water Region of Pamlico Sound, NC*. North Carolina Department of Environment and Natural Resources, Division of Marine Fisheries, Morehead City, North Carolina, U.S.A.

Purbayanto, A., Akiyama, S., Tokai, T., Arimoto, T. 2000. Mesh selectivity of a sweeping trammel net for Japanese whiting *Sillago japonica*. *Fisheries Science* 66: 97-103.

Rafferty, A., BRazer, E., Reina, R. 2012. Depredation by harbor seal and spiny dogfish in a Georges Bank gillnet fishery. *Fisheries Management and Ecology* 19: 264-272.

Restrepo, V. 2012. *Guidance on Electronic Monitoring for Observer Programs to Comply with ISSF Commitments*. ISSF Technical Report 2012-13. Available online, http://iss-foundation.org/wp-content/uploads/downloads/2012/12/ISSF-2012-13-EMS-Guidance.pdf, accessed 23 Nov. 2013. International Seafood Sustainability Foundation, Washington, DC.

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.

Ryder, C., Conant, T., Schroeder, B. 2006. *Report of the Workshop on Marine Turtle Longline Post-Interaction Mortality, Bethesda, Maryland, USA, 15-16 January, 2004*. NOAA Technical Memorandum NMFS-OPR-29. Bethesda, Maryland, USA: National Marine Fisheries Service.

Ryer, C., Ottmar, M., Sturm, E. 2004. Behavioural impairment after escape from trawl cod-ends may not be limited to fragile fish species. *Fisheries Research* 66: 261–269.

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.

Sarch, M., Allison, E. 2000. Fluctuating fisheries in Africa's inland waters: Well adapted livelihoods, maladapted management. IN Proc. 10th Int. Conf. of the Institute of Fisheries Economics and Trade, Corvallis, OR, 9–14 July 2000. Available online, http://osu.orst.edu/dept/IIFET/2000/papers/sarch.pdf, accessed 10 July 2014.

SAUP. 2011. *Landings by Gear Type in the Global Ocean, 2006*. Available online, http://www.seaaroundus.org/global/1/5.aspx, accessed 11 June 2014. Sea Around Us Project, University of British Columbia, Vancouver, BC, Canada.

Seafood Choices Alliance. 2007. *The European Marketplace for Sustainable Seafood*. Available online, http://www.seafoodchoices.eu/resources/documents/SCAEuroMPReport.pdf, accessed 2 July 2014. Seafood Choices Alliance, Paris.

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

Siira, A., Suuronen, P., Ikonen, E., Erkinaro, J. 2006. Survival of Atlantic salmon captured in and released from a commercial trap-net: Potential for selective harvesting of stocked salmon. *Fisheries Research* 80: 280-294.

Smith, L., Khoa, S., Lorenzen, K. 2005. Livelihood functions of inland fisheries: Policy implications in developing countries. *Water Policy* 7: 359-383.

Smith, M., Roheim, C., Crowder, L., et al. 2010. Sustainability and global seafood. *Science* 237: 784-786.

Snoddy, J., Williard, A. 2010. Movements and post-release mortality of juvenile sea turtles released from gillnets in the Lower Cape Fear River, North Carolina, USA. *Endangered Species Research* 12: 235–247.

SPC. 2013a. *An Investigation of E-Reporting and E-Monitoring Potential in the WCPFC Tuna Fisheries.* Available online, http://www.spc.int/oceanfish/en/ofpsection/data-management/wcpfc/e-reportingmonitoring/384-an-investigation-of-e-reporting-and-e-monitoring-potential-in-the-wcpfc-tuna-fisheries, accessed 22 Nov. 2013. Secretariat of the Pacific Community, Oceanic Fisheries Programme, Noumea, New Caledonia.

SPC. 2013b. SPC/WCPFC E-Reporting/E-Monitoring Study – Project Objectives. Available online, http://www.spc.int/OceanFish/en/ofpsection/data-management/wcpfc/e-reportingmonitoring/383-spcwcpfc-e-reportinge-monitoring-study-project-objectives, accessed 22 Nov. 2013. Secretariat of the Pacific Community, Oceanic Fisheries Programme, Noumea, New Caledonia.

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

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

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. *Fish. Res.* 119-120: 135-146.

Suuronen, P., Erickson, D. 2010. Mortality of animals that escape fishing gears or are discarded after capture: Approaches to reduce mortality. In *Behavior of Marine Fishes. Capture Processes and Conservation Challenges*, Chapter 11 (He, P., ed.), pp. 265-294. Oxford, UK: Blackwell Publishing.

Suuronen, P., Lehtonen, E., Jounela, P. 2005. Escape mortality of trawl-caught Baltic cod (*Gadus morhua*) – the effect of water temperature, fish size and cod-end catch. *Fisheries Research* 71: 151-163.

Suuronen, P., Turunen, T., Kiviniemi, M., Karjalainen, J. 1995. Survival of vendace (*Coregonus albula* L.) escaping from a trawl cod end. *Canadian Journal of Fisheries and Aquatic Sci*ences 52: 2527-2533.

Swimmer, Y., Arauz, R., McCracken, M., McNaughton, L., Ballestero, J., Musyl, M., Bigelow, K., Brill, R. 2006. Diving behavior and delayed mortality of olive ridley sea turtles *Lepidochelys olivacea* after their release from longline fishing gear. *Marine Ecology Progress Services* 323: 253-261.

Swimmer, Y., Gilman, E. (Eds.). 2012. *Report of the Sea Turtle Longline Fishery Post-release Mortality Workshop, November 15-16, 2011*. NOAA Technical Memorandum NMFS-PIFSC-34. Available online, http://www.pifsc.noaa.gov/library/pubs/tech/NOAA_Tech_Memo_PIFSC_34.pdf, accessed 15 July 2014. National Marine Fisheries Service, Pacific Islands Fisheries Science Center, Honolulu.

Tenningen, M., Vold, A., Olsen, R. 2012. The response of herring to high crowding densities in purse seines: survival and stress reaction. *ICES Journal of Marine Science* 69: 1523-1531.

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. *Mar Mammal Sci.* 19: 240-243.

Trumble, R., Kaimmer, M.,, Williams, G. 2000. Estimation of discard mortality rates for Pacific halibut bycatch in groundfish longline fisheries. *North American Journal of Fisheries Management* 20: 931-939.

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.

Valdemarsen, J., Suuronen, P., 2003. Modifying fishing gear to achieve ecosystem objectives. Pp. 321–341 IN: Sinclair, M., Valdimarsson, G. (Eds.). *Responsible Fisheries in the Marine Ecosystem*. 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. *Can. J. Fish. Aquat. Sci.* 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.

Ward, A. 1996. *Quantitative Data on Post-harvest Fish Losses in Tanzania. The Fisheries of Lake Victoria and Mafia Island*. NRI Report. Natural Resources Institute, Chathem, England.

Ward, A., Jeffries, D.. 2000. *A Manual for Assessing Post-harvest Fisheries Losses*. Natural Resources Institute, Chatham, UK.

Ward, A., Ryder, J. 1996. Fish loss assessment. How to do it. *DFID BOB Post-Harvest Fisheries Newsletter* 5: 8.

Ward, A., Ryder, J. 1997. How to get accurate quantitative data on post-harvest fish losses in small-scale fisheries using informal data collection techniques. In: James, D. (Ed.). *Asia Pacific Fishery Commission Summary Report and Papers Presented at the Tenth Session of the Working Party on Fish Technology and Marketing, Colombo, Sri Lanka. 4-7 June 1996*. FAO Fisheries Report No 563. Food and Agriculture Organization of the United Nations, Rome.

Ward, P., Myers, R. 2005. Shifts in open-ocean fish communities coinciding with the commencement of commercial fishing. *Ecology* 86: 835–847.

Welcomme, R., Cowx, I., Coates, D., Bene, C., Funge-Smith, S., Halls, A., Lorenzen, L. 2010. Inland capture fisheries. *Phil. Trans. R. Soc. B* 365: 2881-2896.

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.

Zhou, S., Smith, A., Punt, A. et al. 2010. Ecosystem-based fisheries management requires a change to the selective fishing philosophy. *Proceedings of the National Academy of Sciences (PNAS)* 107: 9485-9489.

Appendix 1

Draft Data Collection Form for an Assessment of Food Loss during Gillnet and Trammel Net Fishing Operations

Adapted from Holst et al. (1998) and Hall et al. (2009).

Part A. Inventory to Collect Information on Net Design and Materials

1. Gear type

a. Gillnet, trammel net, or combination gillnet/trammel net?[1]

b. Trammel nets: one or two outside layers?

2. Gear attachment

Is the net (i) Anchored, (ii) Staked, (iii) Drifting (both ends unattached), or (iv) Sweeping (one end free, one end attached, e.g., to a vessel)?

3. Gear depth

Is the net set: (i) Float line at the surface, (ii) Float line within 1m of the surface, (iii) Midwater, (iv) Lead line within few cm but not on the bottom, (v) Lead line on the bottom

4. Panel

a. Length of float line: _____________ meters or fathoms

b. Length of float line after hanging:___ meters or fathoms

c. Height ________________________meters or meshes

d. Trammel net ratio of stretched length of inner to outer panels (vertical slack): ________________________

e. Tie down line YES NO? If yes, height: _______ meters

5. Mesh

a. Whole stretched mesh length[2]: ________________ cm

b. Netting type[3]: ________________________________

c. Twine material[4]: ______________________________

d. Twine diameter ___________________________ mm

---

[1] For trammel nets and combination gillnets/trammel nets, complete separate forms for the interior and exterior layers.

[2] From center of knot to center of knot. Square measure is one-half of whole stretch mesh length

[3] E.g., multifilament (several small filaments twisted together), monofilament (single strand), multi-strand monofilament (multimonofilament, multiple strands of monofilament twisted loosely together), super multimonofilament (constructed the same as multimonofilament but the threads are thinner and more numerous).

[4] E.g., nylon (polyamide), polyester, gel spun polyethylene

e. Color ____

f. Distance between 'pickups'[5] ___________________ cm

g. Number of meshes between pickups[5]: ______________

6. Float line
a. Material ______________________________________

b. Length _____________________________________ m

c. Diameter _________________________________ mm

d. Color ____

7. Float
a. Material _____________________________________

b. Length ____________________________________ cm

c. Width at thickest section ______________________ cm

d. Color ____

e. Shape _______________________________________

f. Distance between floats _______________________ cm

g. Number meshes between floats ___________________

8. Lead line
a. Material ______________________________________

b. Diameter _________________________________ mm

c. Color ____

d. Lead core or weights attached? ___________________

e. Distance between weights (if weights attached): ____cm

f. Meshes between weights (if weights attached): ____ cm

g. Number weights per panel (if weights attached): _____ g

h. Weight per meter of lead line: ___________________ kg

9. Weight characteristics (if weights attached)
a. Material ______________________________________

b. Weight amount: ______________________________ g

10. Anchor characteristics (if used)
a. Material ______________________________________

b. Weight amount: ______________________________ g

5 A 'pickup' is a point on the headrope where the webbing is attached.

Part B. Fisher Interview to Determine Fishing Methods and Causes of Food Loss

Date:
Interviewer name:
Fisher name:
Fishing vessel name (if vessel is used):
Based from seaport(s):

1. Fisher Experience in this Fishery
a. Position on vessel (e.g., captain, first mate) (if vessel is used): ____________

b. Number years fishing using this gear type (gillnet and/or trammel net): _____

c. Years gillnet or trammel net fishing from this seaport: ____________________

2. Fishing Grounds
a. Typical light levels at fishing grounds: ________________________________

b. Typical sea state at fishing grounds: _________________________________

c. Typical current speed at fishing grounds: ____________________________

d. Substrate type(s): ____

e. Do you frequently encounter debris that entangles in nets? YES/NO

f. Do your nets get entangled on subsurface features? YES/NO

g. List gear types of other gears used at your fishing grounds: _______________

3. Fishing Gear and Methods
a. Sketch the gear when soaking. Identify location in the water column (in relation to sea surface and substrate), number of panels per fleet, location of anchors if used, if attached to vessel or other object (sweeping), if drifting, location and length of tiedowns if used, height and length of panel, number of floats per panel, number of weights per panel if used, and how panels in a fleet are joined together.

b. Are fleets parallel, perpendicular, other? ______________________________

c. Distance between fleets: ____

d. Main fishing ground: ____

e. Most common fishing depth: ____

f. Method to set and haul (e.g., hauling equipment power, hauling speed): _____

g. Number days per fishing trip: _______________________________________

h. Number fleets set per trip: ____

i. Number fleets set per day: ____

j. Number trips per year: ____

k. Number panels fished per fleet: ______________________________________

l. Typical soak time: ____ hours

m. Net patrolled? YES/NO

4. Discarded and Released Catch

a. How many unwanted finfish are typically caught
Per fleet: ____
Percent alive upon haulback: ______________________________
Most common species: _________________________________

b. How many unwanted invertebrates (crustacean, mollusks, etc.) are typically caught
Per fleet: ____
Percent alive upon haulback: ______________________________
Most common species: _________________________________

c. How many seabirds are typically caught
Per fleet: ____
Percent alive upon haulback: ______________________________
Most common species: _________________________________

d. How many sea turtles are typically caught
Per fleet: ____
Percent alive upon haulback: ______________________________
Most common species: _________________________________

e. How many sharks (both market and unwanted species/sizes) are typically caught
Per fleet: ____
Percent alive upon haulback: ______________________________
Most common species: _________________________________

f. How many rays (both market and unwanted species/sizes) are typically caught
Per fleet: ____
Percent alive upon haulback: ______________________________
Most common species: _________________________________

g. How many marine mammals are typically caught
Per fleet: ____
Percent alive upon haulback: ______________________________
Most common species: _________________________________

h. Predation on catch typically by:
• Seals YES NO
• Seabirds YES NO
• Cetaceans YES NO
• Sharks YES NO
• Squid YES NO
• Other – please identify:

i. Have you observed catch being depredated and completely removed from the gear?
YES NO

j. Is catch partially depredated? YES NO
Number market species typically partially depredation per fleet: _____________
Number unwanted species typically partially depredation per fleet: __________

k. Dead discards and live released catch:
Number or weight of market fish discarded or released per fleet: ____________
Number or weight of non-market fish discarded or released per fleet: ________
Number or weight of market invertebrates discarded or released per fleet: _____

Number or weight of non-market invertebrates discarded or released per fleet:
____

l. Identify causes of discarding/releasing catch, and order from most to least important.
___ No market demand
___ Retention ban
___ Over quota:
___ Making room in the hold for higher value catch (high-grading)
___ Spoiled upon hauling
___ Damaged from the fishing method or gear
___ Damaged from partial depredation
___ Could damage the rest of the catch during storage
___ Insufficient room for storage (e.g., final set of a trip)

5. Abandoned, Lost and Discarded Fishing Gear
a. List gear components that you typically discard (throw gear overboard at sea):

b. How much gear do you discard (identify amount of each gear component that is discarded)
Per set: ____________________________
Per trip: ____________________________
Per year: ____________________________

c. What is the main reason you discard gear?

d. List gear components that you typically abandon (gear set for fishing left at sea on purpose):

e. How much gear do you abandon (identify amount of each gear component that is discarded)
Per set: ____________________________
Per trip: ____________________________
Per year: ____________________________

f. What is the main reason you abandon gear?

g. How much gear do you lose (gear set for fishing is left at sea and can't locate and retrieve it):
Panels per set: ______________________
Panels per trip: ______________________
Panels per year: ______________________

h. What is the main reason you lose gear?

Pre-test report: An assessment of food loss from gillnets and trammel nets during fishing operations

Thomas, S.N., Pravin, P., Edwin, L.
ICAR-Central Institute for Fisheries Technology, Matsyapuri, P.O. Cochin – 682 029, India

EXECUTIVE SUMMARY

Food loss in fishing occurs at different points of pre-harvest and harvest stages and there is a need for a sound methodology in order to assess and quantify the losses. In 2014-2015, the food loss assessment and waste reduction programmes of the FAO Fishing Operations and Technology Branch (FIRO) focused on gillnetting. Under this programme, the FAO envisages to validate and to arrive at an agreed methodology, outlining the next steps needed, through a hybrid methodology involving brief field studies and expert workshops. In this context, the FAO-FIRO explored a collaborative initiative with the Central Institute of Fisheries Technology (CIFT) to conduct a pilot field study, meant to assess the wasted resources followed by organization of a workshop. Accordingly, a brief pre-testing exercise was initiated by CIFT, and the findings/observations from the study form the scope of this report.

The objectives of the pre-testing related to finding out the appropriateness of the pre-designed questionnaire with respect to (i) the relevance of the questions for extracting the desired data; (ii) to identify the clarity/ambiguity, if any, in the questions; (iii) to find out the need for deletion/addition /modification of the questions; and (iv) estimation of the time required per respondent. The questionnaire (provided by FIRO) was pre-tested by CIFT at five locations in India, in Tamil Nadu and Gujarat, and the remaining three in Kerala covering mechanized, motorized and non-motorized sectors operating gillnets and trammel nets targeting seer/tuna, sardine, mackerel and shrimp. This survey covered 33 fishing units.

The findings of this brief research are arranged in two broad parts: Part A: Net Design and Materials; and Part B: Fishing Methods and causes of Food Loss. Major observations related to fishing gear were (i) wide-scale use of polyamide monofilament yarn of diameter < 0.40 mm for fabrication of gillnets and trammel nets; and (ii) large fleet length of drift gillnets operated in deeper waters; both having chances of large-scale loss of gear into the sea. Use of monofilament contributes to gear loss because when it becomes worn out, fishers discard it at sea as there are no markets for this portion of the used gear as there are for other used gear components. Relatively long fleets used at deep water sites result in gear loss due to interactions with trawl fishing gear, passing vessels, rough sea conditions, and overload of catch. With regards to lost and wasted fish, no market fishes are discarded while partial depredation of catch emerged as an important contributor to food loss.

The pre-test places special emphasis on the practical issues and constraints in relation to field data collection, including: reducing the time required to complete the questionnaire, conducting surveys during closed fishing season, collecting information

on fish loss due to catch dropping from the net during hauling, add snakes as another possible unwanted vertebrate taxa. The study comes out with some suggestions which may help to take the project to the next level.

1. INTRODUCTION

1.1 Background

Food loss is a central theme of global debates on food security, but food loss in fish harvesting is yet to gain its due place. While there is a rich source of literature on food loss in post-harvest, studies on food loss during pre-harvest and harvest operations of fishing gear are yet to pick up. The more recent food loss assessment and waste reduction programmes of the FAO Fishing Operations and Technology Branch (FIRO) focuses on gillnetting. Under this programme, the FAO envisages a hybrid methodology involving brief field studies and short expert workshops. The workshops are meant to validate and to arrive at a final methodology, outlining of the next steps needed, in relation to identification and quantification of the extent of wasted resources. In this context, the FAO explored a collaborative initiative with the Central Institute of Fisheries Technology (CIFT), and this forms the background of the workshop, wherein this Report has been presented.

The workshop, under reference, draws upon a pilot field study, meant to assess the wasted resources, and to agree on a data collection format (questionnaire). This task was agreed upon by CIFT as per the Letter of Agreement entered into force on 26 December 2014 between the CIFT and the FAO. Accordingly, a brief study was initiated in which the questionnaire (provided by FIRO) was pre-tested by CIFT team. The findings of the study form the scope of this Report.

1.2 The problem

Gillnet, operated in ideal conditions, is supposed to be a selective gear, capturing only targeted species and sizes. However, it rarely happens.

Food loss in gillnetting occurs at different points of pre-harvest and harvest stages in fishing, depending on the design, rigging, mesh size, twine type, dimension of the gear (length and depth), type of operation, area of operation, soak time, and manner of hauling. Despite such knowledge base, there is lack of a sound methodology on quantification, stages or points at which they actually occur. This has constrained scientific understanding of the causes and mitigation measures. There is need for a sound methodology in order to assess and quantify food losses.

Trammel nets, that essentially target shrimps in India's South-West coast, is a gear operated mostly during the monsoon seasons in June to August, when the sea conditions are generally very rough. Selectivity of this gear is low, compared to gillnet, as the chances of getting non-target catch are more.

Besides food loss, loss of gear and accessories in the sea during operations is yet another problem. Gear loss can be either purposeful or abandoning due to unavoidable reasons or due to accidents. Considering all these factors, an assessment of the gear loss, with reference to the seasons, quantity lost and mitigation measures are important.

The problem is significant in India where the use of gillnets has a significant place. Indian fishery sector with around 8 118 km of coastline, 2.02 million sq. km of EEZ engage different fishing methods/gears of which gillnet is very important. As per 2010 statistics, in the marine sector alone 123 181 gillnets were in operation which constitute a mechanized, motorized and non-motorized sector. Gillnetting is also predominant in inland fishing.

1.3 Objectives of the programme

The following formed the objectives of this CIFT-FAO collaborative initiative:

i) Collect data on net designs and materials
ii) Collect data on fishing gear and method of operation
iii) Quantify discarded and released catch
iv) Quantify abandoned, lost and discarded gear

1.4 Objectives of the pre-test

The objective of the pre-testing exercise was to determine the appropriateness of the pre-designed questionnaire with respect to:

i) Relevance of the questions for extracting the desired data;
ii) Clarity/ambiguity, if any, in the questions;
iii) Need for deletion/addition /modification of the questions; and
iv) Interview time required per respondent

2. METHODOLOGY

Data was collected using a draft Data Collection form (Annex 1) adapted from Holst *et al.,* (1998) and Hall *et al.,* (2009).

2.1 Operationalization of the methodology

This initiative involves a clear division of the relative role of the two partner institutions, as follows:

2.1.1 FIRO's role:

FIRO provided the draft data collection form for field testing (Annex 1), as also an indicative minimum sample size.

2.1.2 CIFT's role

2.1.2.1 Selection of respondents

Gillnet fishing sector of India is characterized by three distinct sub-sectors viz., mechanized, motorized and non-motorized, having variation in target resource, area of operation and fleet size of net. Hence, respondents representing these three sub-sectors were selected (Table 1).

Trammel net fishing is confined to few coastal areas and not spread all along the coastline as in the case of gillnets. Trammel nets are mostly operated in the motorized sector and the field testing of the questionnaire was confined to this sector (Table1).

2.1.2.2 Sampling sites:

The pre-testing sites were decided on the basis of the following criteria:

i) Sizeable concentration of the particular type of fishing units
ii) Adequate representation of the particular sub-sector under consideration

i) Cochin fisheries harbour (Kerala):

Cochin Fisheries Harbour (CFH) is the main hub of mechanized gillnetters of the west coast of India. Drift gillnets targeting seer, tuna and tuna like fishes were selected as the representative gear of that centre.

ii) Chellanam mini fishing harbour (Kerala)

Located approximately 20 km from CIFT, Chellanam Mini Fishing Harbour is a base for >200 motorized and non-motorized gillnetters targeting sardine, mackerel, shrimp, mullet etc.

iii) Puthuvype (Kerala)

This centre located 15 km away from CIFT, is a major centre in Puthuvype-Azheekal belt where around 100 trammel net fishing units targeting shrimp are operated. This centre was selected in order to cover data on trammel nets.

iv) Inayam-Kadiyapatanam (Tamil Nadu)

Trammel net fishing is predominant in this area. Located approximately 400 km from Cochin, this location was selected as a representative of a major trammel net fishing centre on the east coast of India.

v) Veraval (Gujarat)

Mechanized gillnetters of Gujarat targeting tuna/seer represent a group employing largest volume of drift gillnet per operation. Here, gillnets of HDPE netting is predominantly used unlike other coasts where polyamide (PA) gillnets are largely in operation.

2.1.2.3 Period of study

The study was conducted between17 January and 7 February 2015.

2.1.2.4 Data collection

The data collection form was initially reviewed by CIFT research team led by Saly N. Thomas and P. Pravin, in order to ascertain data availability and the ease of holding interviews. The team interviewed one respondent each from the three sectors, in order to verify the interview protocol. This was followed by a briefing of two survey teams (three members per team), each comprising of Research Fellows and Technical Officers. The briefing related to the purpose of the survey and how it is to be carried out.

As indicated in the LoA, the questionnaire was translated to local language (Malayalam). Data collection was carried out by interviewing the respondents by the survey team. The survey team was given hard copies of the questionnaire and was asked to go through the questions and to clarify doubts/problems noted if any.

This was followed by interviews with the respondents. Wherever possible, the respondent's telephone number was collected during the interview. Any point not covered or any uncertainties regarding the information collected during the interview were clarified later over phone by the survey team.

2.1.2.5 Size of sample

A total of 45 respondents were interviewed. Out of these, 12 were adjudged as invalid, due to paucity of data extracted. Thus the effective sample size, deducting the invalid samples, was 33. The discussion in the following pages is based on these 33 valid samples.

The following categories of gillnetting units were selected for the survey (Table.1):

TABLE 1
Categories of Gillnetting Units Selected

Category	Valid respondents
Mechanized gillnets: seer/tuna drift gillnets	8
Motorized gillnets: sardine and mackerel gillnets	11
Non-motorized gillnets: sardine and mackerel gillnets	6
Motorized trammel net units	8
Total	**33**

2.1.2.6 Duration of the interview

The average duration of interview per respondent according to particular respondent categories is summarized in Table 2. The average time required to administer the interview schedule was 80 minutes, the shortest being 45 minutes and the longest 120 minutes. Part A of the form (Information on net design and materials) necessitated actual measurement of the components and took comparatively longer time. Part B, item 4 (Discarded and released catch) also took relatively more time to complete.

TABLE 2
Average time requirement to administer the interview

Parts/Sub Sections in the form	Time taken (minutes)		
	Minimum (minutes)	Maximum (minutes)	Average (minutes)
Part A	15	40	25
Part B (1-3)	10	20	15
Part B : 4	12	40	25
Part B : 5	8	20	15
Total	**45**	**120**	**80**

2.1.3 Data processing

The data processing was done using Microsoft Excel.

3. RESULTS

3.1 PART A: NET DESIGN AND MATERIALS

3.1.1 Gear attachment

Gillnets: Gear attachment in gillnets operated from mechanized, motorized and non-motorized vessels was 'sweeping' (one end free, one end attached to vessel) type in 100 percent of the cases.

Trammel nets: Gear attachment was of both sweeping (one end free, one end attached) type and drifting (both ends unattached).

3.1.2 Gear depth:

Gillnets: About 80 percent of the respondents from the mechanized sector targeting seer/tuna set their net with float line within 1.8 to 5 m of the surface depending on the lunar phase while 20 percent set their net varying from surface to bottom depending on the season.

About 60 percent gillnets targeting sardine and mackerel operated from motorized and non-motorized vessels were positioned within 1 to 2 m of the surface and in around 40 percent of the cases lead line touched the bottom.

Trammel nets: Net was set with lead line on the bottom.

3.1.3 Mesh:

Gillnets: Whole stretched mesh length ranged from 3.8 cm to 20 cm. Netting type was polyamide monofilament (diameter 0.16-0.45 mm), polyamide multifilament (210x2x3 to 210x10x13) and HDPE multi (twisted) monofilament (diameter 1 to 1.5 mm) (Table 3).

Trammel nets:

Inner layer: Mesh size of nets targeting shrimps had mesh sizes ranging between 4.0 and 4.8 cm while those targeting fishes had mesh sizes ranging from 5.8 and 6.0 cm. In 80 percent of the cases, netting of polyamide monofilament of 0.2 mm diameter was used. In 20 percent, netting of polyamide multifilament of 210x2x3 was used.

Outer layer: Mesh size ranged from 8 to 24 cm and the webbing material was predominantly polyamide monofilament yarn of 0.32 to 0.4 mm diameter.

TABLE 3
Webbing details of gillnets and trammel nets

Category	Type of material	Diameter (mm)/ Designation	Stretched mesh size (cm)
Seer/tuna gillnet	PA multifilament	210x6x3 to 210x10x3	7.0 to 20.0
	HDPE twisted monofilament	1 to 1.5	
Sardine gillnet	PA monofilament	0.16 to 0.20	3.8 to 4.0
Mackerel gillnet	PA monofilament	0.20 to 0.23	5.0 to 6.0
Trammel net			
Inner	PA monofilament	0.20	4.0 to 6.0
	PA multifilament	210x2x3	
Outer	PA monofilament	0.40	8.0 to 25.0
	PA multifilament	210x3x3	

Ratio of stretched length of inner to outer panel (vertical slack) ranged between 1:1.2 and 1:2.1.

Ratio of stretched mesh size of inner to outer panel ranged between 1:2 and 1:4:1.

3.1.4 Dimensions of the net

Gillnets: Dimensions of the net in terms of float line length and height varied with respect to the target fishery, depth of operation and use of vessel or not (if used, type of propulsion).

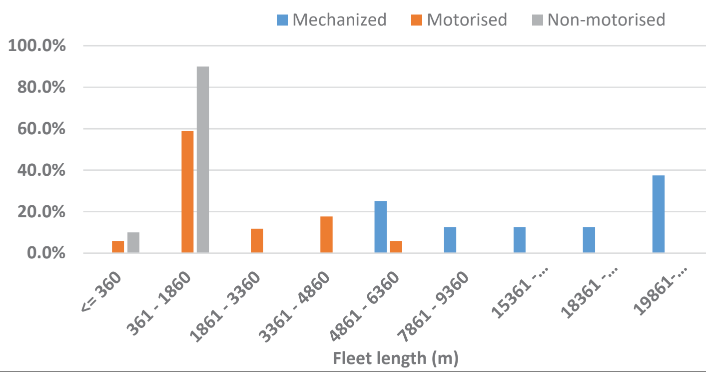
Trammel nets: Length (float line) of net ranged from 540 to 1040 m with mean length of 600 m. The height varied between 1.6 and 8 m with mean height of 4.4 m. Total fleet length of net set per trip in trammel net was comparatively less compared to gillnet. This is due to the time taken to remove the catch from the net.

Fleet length and height of gillnets /trammel net are given in Table 4.

TABLE 4
Dimensions of gillnets and trammel nets

Category	Fleet length (m)		Height (m)	
	Range	Mean	Range	Mean
Mechanized gillnet (seer/tuna)	5100-22000	15083.7	6.5-18	12.1
Motorized gillnet (sardine/mackerel)	360-6000	2315.6	5.4-18	10.2
Non- motorized gillnet (sardine/ mackerel)	288-900	765	3.6-10	6.8
Motorized trammel net	540-1040	600	1.9-8.0	6.2

FIGURE 1
Fleet length of different categories of gillnet units



3.1.5 Rigging pattern:

Gillnets: Except seer/tuna gillnets made of PA multifilament yarn, all the nets were rigged with lead line and weight attached. Seer/tuna gillnets made of PA multifilament yarn were devoid of lead line and sinkers. However, seer/tuna gillnets made of HDPE twisted monofilament are rigged with lead line with weights attached. Average weight per meter of lead line was 0.05 and 0.01 kg in the case of sardine / mackerel gillnets and HDPE tuna/seer gillnets respectively.

Gillnets were rigged with horizontal hanging coefficient (Σ_1) of 0.4-0.71. Sardine and mackerel gillnets had Σ_1 ranging from 0.5 to 0.71 while seer/tuna drift gillnets had Σ_1 ranging between 0.44 and 0.61.

In mackerel/sardine gillnets 'pick-ups' and float attachment points were same while seer/drift gillnets had pick-ups at an average distance of 280 cm while floats were attached at an average distance of 2 333 cm.

Trammel nets: Nets were rigged with float line at the top and lead line with weight attached at the bottom. The horizontal and vertical hanging coefficient of inner and outer layer are given in Table 5. Weight per meter of lead line was 0.03 kg.

TABLE 5
Hanging coefficient of inner and outer layer in trammel nets

Netting type	Σ_1 (range)	Mean
Inner layer	0.42 – 0.45	0.44
Outer layer	0.63 – 0.75	0.67

3.2 PART B: FISHING METHODS AND CAUSES OF FOOD LOSS

3.2.1 Fisher experience in the fishery:

Gillnets: Gillnet fishermen participating in the survey had 5 to 50 years of experience in the fishery with an average of 18.9. Most of the respondents (70 percent) were fishers working on the boat.

Trammel nets: Trammel net fishermen participating in the survey had 10 to 50 years of general fishing experience while the specific experience in trammel net fishing ranged from 5 to 20 years.

3.2.2 Fishing grounds:

Gillnets: About 25 percent of the respondents indicated normal daytime light level at fishing grounds while 75 percent reported night-time dark light level.

In 40 percent of the respondents' opinion, typical sea state was rough while 30 percent opined moderately calm and 30 percent reported that it depended on season.

In the case of current speed, none of the respondents could give the information as they did not possess instruments to measure the parameter. Substrate type was rocky (35 percent), muddy (20 percent), sandy (15 percent), and in 30 percent of cases it was not known as the depth of fishing ground was around 2000 m which was beyond the assessing capacity of the fishermen.

Almost 100 percent of the respondents encountered debris that entangled in nets and 40 percent had experience of nets getting entangled on sub-surface features.

Trawls, long lines and mini purse seines (ring seine) were the other fishing gears in operation at gillnet fishing grounds.

Trammel nets: Rough sea state prevailed at the fishing grounds as the fishing operation was confined to monsoon period when sea condition is generally rough.

Substrate was generally rocky/sandy. Typical current speed at fishing grounds was not able to assess by fishers. With reference to debris entangling the nets, fishers faced the problem >50 percent of the times they set the net. On 75 percent of the time they set net, nets were entangled on sub-surface features mainly rocks.

Gillnets, hook and line and trawl nets were the other gears in operation at trammel net fishing grounds.

3.2.3 Fishing gear and methods

Gillnets: When soaked in water, seer/tuna drift gillnets are positioned with float line within 5 m of the surface and are drifting with one end attached to vessel. Sardine gillnets are also drifting with one end attached to vessel and float line within 1 m of the surface. Mackerel gillnets were positioned with leadline within few cm but not on the bottom. Position of the nets in water is depicted in Figures 2 and 3.

Fleets are set parallel and distance between fleets range from 70 m to 5 km.

Most common fishing depth showed variation with respect to target fishery and type of propulsion (Table 6).

Except in 10 percent of the cases, setting and hauling were done manually. In mechanized sector operating seer/tuna gillnets, 27.5 percent of the respondents used hauling equipment (winch) for hauling the net.

FIGURE 2
Typical design and setting position of a mackerel gillnet operated off Cochin

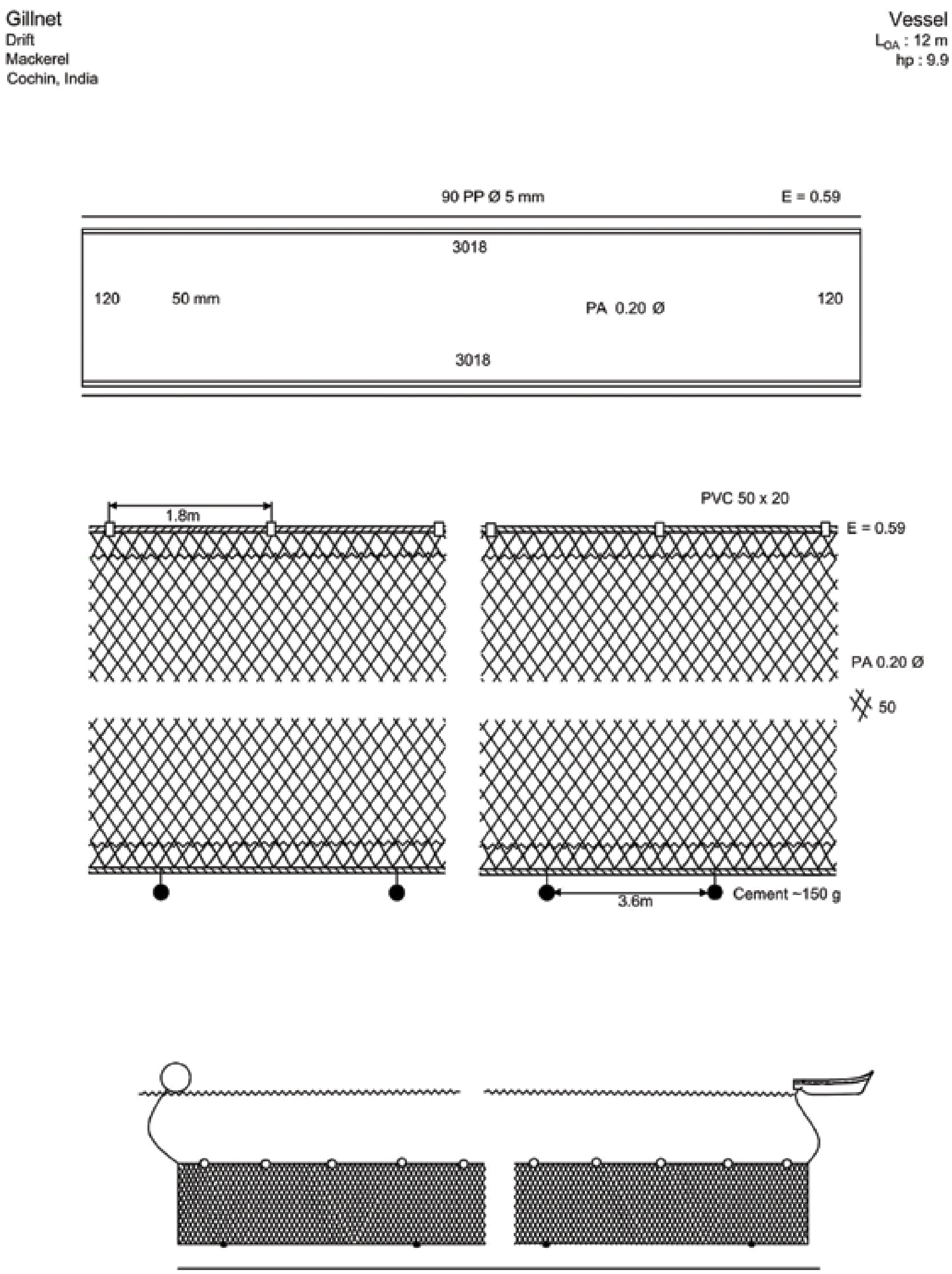


FIGURE 3
Typical design and setting position of a seer gillnet operated off Cochin

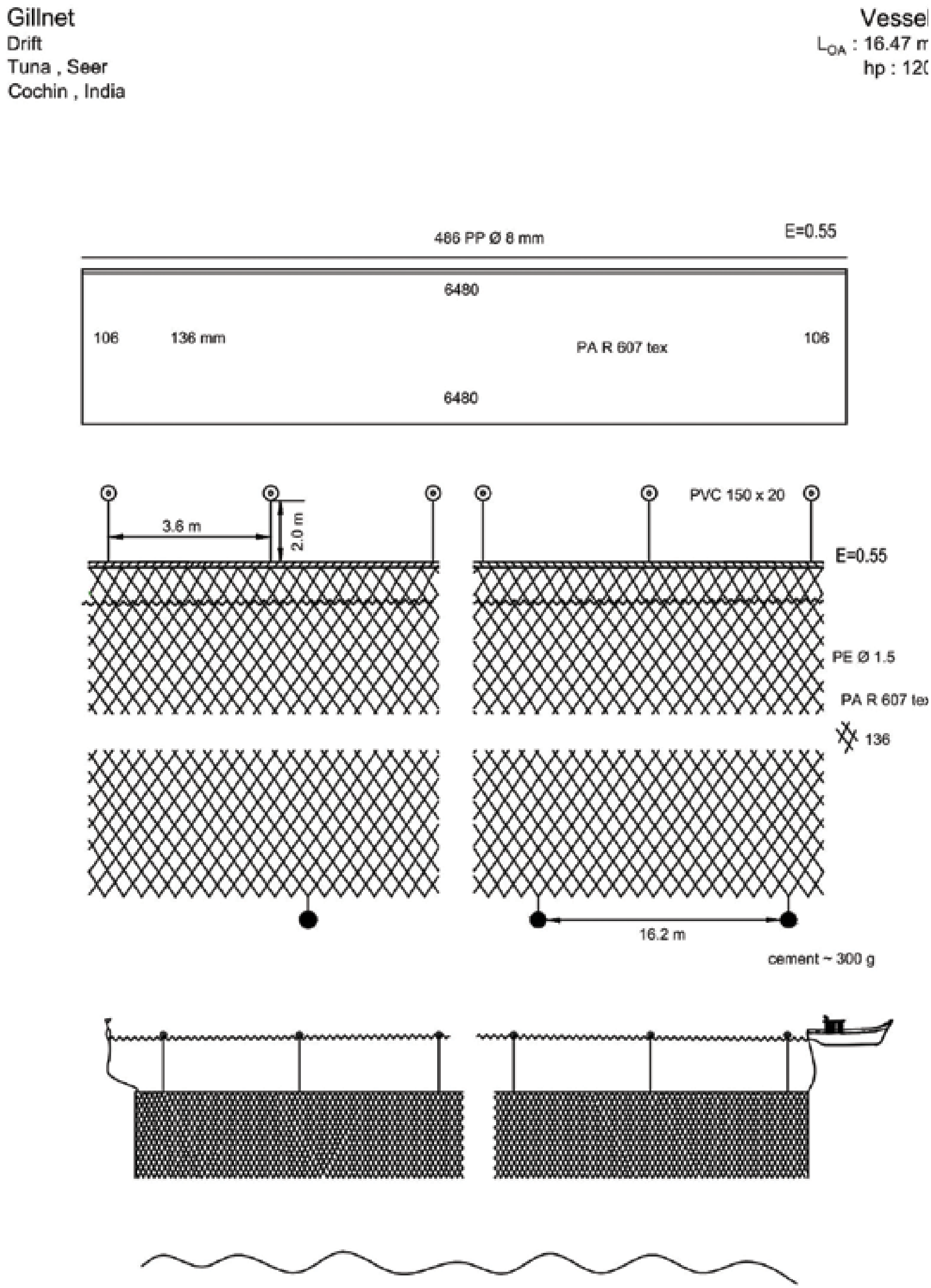
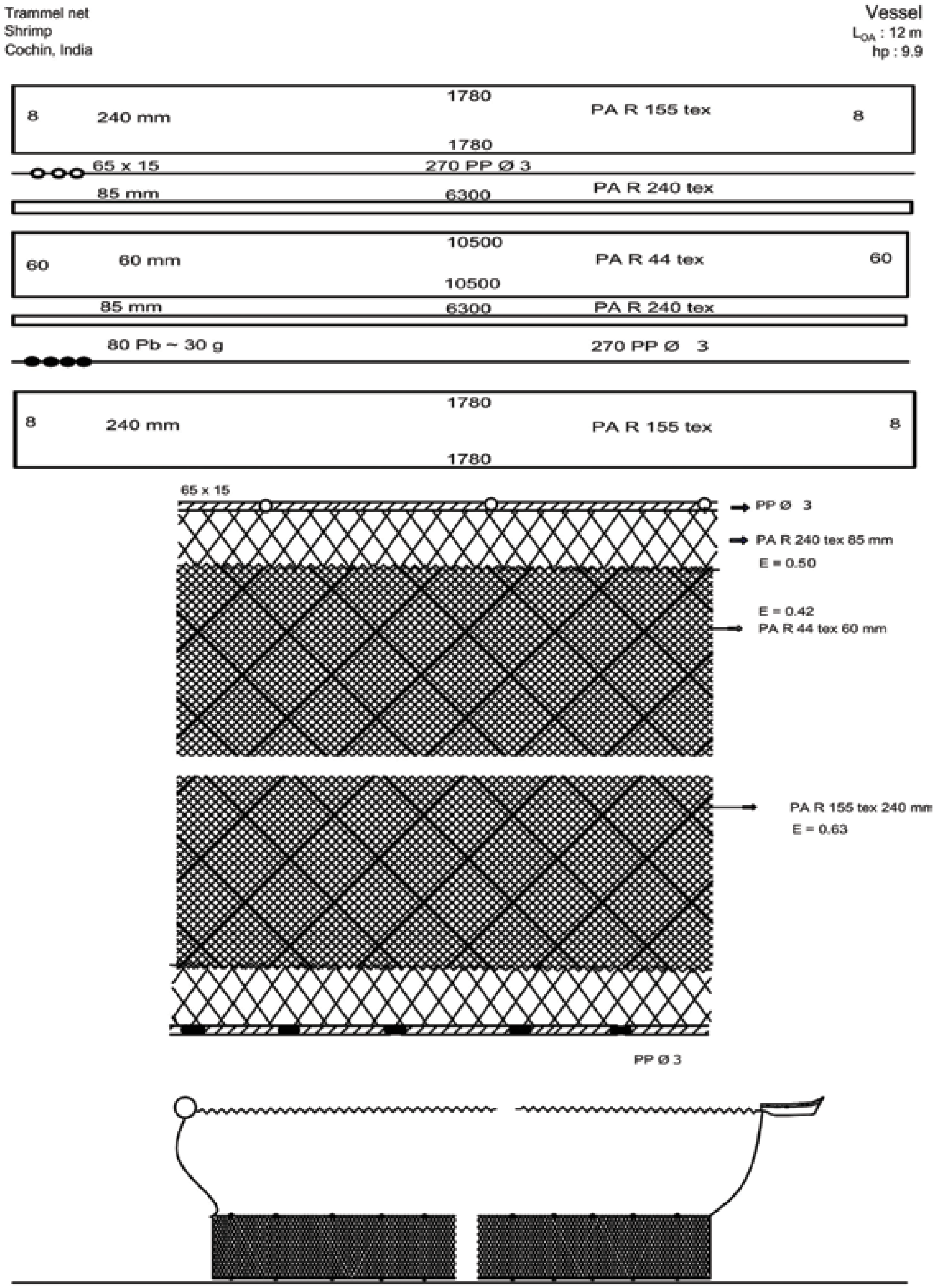


FIGURE 4
Typical design and setting position of a trammel net operated off Cochin



Trammel nets: Position of the net when soaking is depicted in Fig. 4. Nets were set with lead line at the bottom. Fleets were set parallel keeping 5 to 30 m distance in between. Most common fishing depth ranged between 8 and 22 m with a mean depth of 17 m (Table 6).

Setting and hauling of net were done entirely manually.

TABLE 6
Depth of fishing ground of different categories of gillnets and trammel nets

Category	Depth range (m)	Mean depth (m)
Mechanized seer/tuna gillnet	750-2000	1617
Motorized mackerel/sardine gillnet	10-100	41
Non-motorized sardine/ mackerel gillnets	10-18	14.5
Motorized trammel net	8-22	17

3.2.4 Fishing effort (Days/fishing trip, fleets/trip, fleet/day, trips/year, soaking time):

Gillnets: Mechanized sector operating seer/tuna gillnet had fishing trip extending from 18-45 days while non-motorized and motorized sector undertook single day fishing trips only. Data on number of fleets set per trip, per day, number of panels fished per fleet and typical soak time are given in the Table 7.

Trammel nets: Fishing trips were single day with setting of one fleet per trip. Number of trips ranged between 80 and 90 per year as this gear was operated during the monsoon season (June, July and August) only. Typical soak time ranged from 0.5 to 1 hour.

TABLE 7
Fishing effort in different category of gillnetters

Category	Fleets set per trip (No.)	Fleets set per day (No.)	Trips per year (No.)	Panels fished per fleet (No.)	Typical soak time (h)	Days per trip (No.)
Mechanized seer/ tuna gillnet	18-40	1	6-30	25-110	6-9	18-45
Motorized mackerel/ sardine gillnet	1-4	1	68-310	2-25	1-1.5	1
Non-motorized mackerel /sardine gillnet	1	1-2	290-310	1-5	0.5-1.5	1
Motorized trammel net	1	1	80-90	1-2	0.5-1	1

3.3 DISCARDED AND RELEASED CATCH

3.3.1 Unwanted finfish

Gillnets: In the Indian conditions, all finfishes caught are used either for human consumption or for fish meal manufacture, except for very few species such as puffer fish. Of the unwanted finfishes caught, roughly 75 percent of the puffer fish will be alive upon haul back. Most common species of pufferfish caught are *Lagocephalus inermis, Arothron* sp., and *Diodon* sp.

Trammel nets: All finfishes except puffer fish were utilized.

3.3.2 Unwanted invertebrates

Gillnets: Crabs, spiny mollusc, starfish, squilla and jelly fishes were the unwanted invertebrates caught. Quantification of the number caught was difficult to obtain. However, 43 percent of the respondents reported the number caught. It ranged from 1 to 30 per fleet while 2 respondents reported 1 kg per trip. Species wise quantification in terms of number and weight was not known.

Trammel nets: Juvenile crabs, squilla and molluscan shells were the main unwanted invertebrates caught. Their number varied from 5 to 40 per fleet set.

3.3.3 Seabirds

Gillnets: Except one, none of the respondents reported capture of seabirds in the net. One respondent reported capture of one seabird in his PA drift gillnet targeted for tuna once (during his 25 years of fishing experience).

***Trammel nets*:** Seabirds were not caught during any of the operation in trammel nets.

3.3.4 Turtles

Gillnets: Frequency of capture of turtles was high in drift tuna/seer drift gillnets operated in deeper waters. Among the respondents, 61.5 percent reported capture of sea turtles in their nets. In seer/tuna drift gillnets, 1-7 turtles were encountered per trip. In 95 percent of the cases, the turtles were 100 percent alive upon haul back.

Trammel nets: Turtles were occasionally caught in trammel nets. During the survey 50 percent of the respondents reported getting turtles in their net at the rate of one per year (3 months operation), common species being *Chelonia* sp. (green turtle). In 100 percent of the cases, turtles were alive on haul back.

3.3.5 Snakes

Gillnets: Snakes were occasionally caught in the nets which were 100 percent alive upon haul back.

3.3.6 Sharks

Gillnets: Sharks were frequently caught in mechanized tuna/seer drift nets as 73.3 percent of the respondents reported capture of sharks in their nets. Only 24 percent of the sharks were reported to be alive on haul back. Frequently caught species were *Scoliodon* sp.,*Rhizoprionodon* spp. and *Carcharhinus sorrah.*

Trammel nets: Sharks are occasionally caught viz., at the rate of 2 per fleet. None of the sharks caught were alive. *Scoliodon sorrokowah* was the common species caught.

3.3.7 Rays

Gillnets: Compared to sharks, occurrence of rays in gillnet was lower. In 14 percent of the cases, rays were caught. Percent alive upon haul back was 100 percent. Most common species in the catch were *Dasyatis* sp. and *Aetobatus* sp.

Trammel nets: Only 10 percent of the respondents caught rays in their nets, occurrence being one ray in two or three seasons.

3.3.8 Marine mammals

Gillnets: Dolphins were the only marine mammals encountered in gillnet fishery. Among the 33 respondents, 17.5 percent reported capture of dolphins in the gear of 1 to 10 dolphins per year with a mean number of 3 dolphins per fleet per year. None of the dolphins caught in the nets were alive upon haul back. Information on common species was not known.

Trammel nets: Marine mammals were not reported in trammel net catch.

3.3.9 Predation on catch

In none of the cases, complete removal of catch occurred due to predation, while partial removal of the catch was reported by 100 percent of the respondents.

Gillnets: Predation on catch was a serious problem reported by all respondents. Cetaceans and squids were the ones predating on the catch in mechanized tuna/seer driftnets followed by sharks. In sardine and mackerel gillnets operated from motorized and non-motorized vessels which operated mostly in the 100 meter depth zone, predation on the catch was mainly by puffer fish, squids, cuttlefish and sharks.

Number of market species particularly depredated per fleet was difficult to assess. Though fishermen admitted partial removal, they expressed difficulty in quantifying loss with respect to number or weight. Few reported in terms of number, few in percentage of the total catch and few in terms of weight (kg). The loss due to depredation per trip varied from 2 to 25 percent of the catch, 0.5 to 100 kg and 2 to 50 numbers.

Depredation of unwanted species was not applicable in majority of the cases. One fisher reported 8 percent and two reported 1 kg loss.

Trammel nets: Complete removal of catch by predation was not reported while partial removal was reported by 80 percent of the respondents. Predation of catch was mainly by sharks, squids and dolphin.

3.3.10 Dead discards and live released catch:

Gillnets

Market fish: No market fish was released or discarded. Puffer fish was the only non-market fish released and it amounted to 10-15 in number or up to 5 percent of the catch per fleet set.

Market invertebrates: Market invertebrates discarded or released were juveniles of crabs such as *Scylla* spp. and *Portunus* spp.

Non-market invertebrates: In 60 percent of the cases, non-market invertebrates namely jellyfish, starfish, squilla, molluscan shells and crabs were released or discarded. The quantity varied between 1-100 kg; and 10-30 numbers per fleet. Item wise quantity discarded/released was not obtained.

Snakes were another group which was occasionally caught and in 100 percent of the case they were alive on haul back and were released.

Turtles numbering 1 to 7 caught per fleet were released. In all cases, turtles were 100 percent alive upon haul back and were released live. Most common species of turtles caught were green sea turtles (*Chelonia mydas*) and Olive ridley sea turtles (*Lepidochelys olivacea*).

Major causes for discards were 'no market demand' followed by 'retention ban' and 'damaged from depredation' (Table 8).

TABLE 8
Ranking of major causes for discards /released catch

Causes for discards or released catch	Ranking
No market demand	1
Retention ban	2
Damaged from depredation	3
Spoiled upon hauling	4
Could damage the rest of the catch during storage	5

Trammel nets:

Partial removal of catch by predators was admitted by 80 percent of the respondents. Data on quantity of market species in terms of number was difficult to get. About 5 to 10 percent of the catch was depredated per fleet. Weight wise, 4 to 5 kg was depredated per fleet per set. Data on depredation of unwanted species was not available except one reporting 2-4 kg loss/fleet.

Puffer fish was the only species discarded the number being 2-6 per fleet.

Reasons for releases in their order of importance were: (i) no market demand, (ii) retention ban, and (iii) damaged from depredation.

3.4 ABANDONED, LOST AND DISCARDED FISHING GEAR

3.4.1 Gillnets:

3.4.1.1 Gear components discarded at sea:

A few reported that 8-10 years ago they had this practice but not anymore. At present no gear component is discarded at sea or thrown overboard by fishermen purposefully. However, fishermen discarded nets frequently as and when it reached a non-usable stage due to wear and tear caused by usage, damage due to attack of puffer fish, crab etc. However, the net damaged at sea also are brought on shore and sold as scrap to collection spots or agencies for recycling fetching Rs.10 to 40 per kg. Webbing was the main gear component discarded, the main reason being wear and tear damage. About 63 percent of the fishermen reported discarding of webbing. PA monofilament webbing of 0.16 and 0.20 mm diameter are discarded after 3 months use. On an average 49 kg of monofilament netting was discarded by each fisherman every 3 months which was worked out as 168.7 kg per year.

3.4.1.2 Abandoned gear:

Webbing, float, rope and sinkers are occasionally abandoned. In many cases, quantification of the net abandoned was made by the respondents by number of panels lost rather than kg of net lost.Net abandoned ranged from 5 to 1500 kg per year and 2 to 100 panels per year (50 to 5000 m netting). Quantification of net loss was difficult.

Rough sea conditions, attack by puffer fish and crab, entangling with rock and other underwater obstructions were the main reasons for abandoning the gear.

3.4.1.3 Lost gear:

Loss of gear was reported by 86 percent of the respondents. In this case also, quantification of loss was difficult. Five to 1500 kg, 1 to 100 panels, 180 to 450 m netting and associated rope and floats were being lost per year per vessel.

Trawlers and ships passing through, rough sea conditions and entangling of very large fish, dolphin etc. were the main reasons for losing the gear.

In tuna/seer gillnet operated by mechanized vessels in deeper sea conditions, two respondents reported complete loss of the gear (around 1800 kg of polyamide 210x8x3 netting) due to overload of the catch.

TABLE 9

Status of discarded, abandoned and lost gear

Gear material	In terms of kg of netting per year per fisherman	In terms of m of net per year	Remarks
Gear material discarded at sea	Nil	Nil	No discard at sea
Discarded on land	PA Monofilament netting:168 kg	180-960	Given for recycling as scrap
Abandoned	5 -1500	50-5000	
Lost	5-1500	180-450	

3.4.2 Trammel nets

In trammel nets as in gillnets no gear component was discarded at sea purposefully.

3.4.2.1 Discarded gear:

Every year, 10 to 100 kg of netting was discarded due to wear and tear and damage as the net mostly made of polyamide monofilament last for one season (3 months). Damaged netting was sold as scrap for recycling at the rate Rs. 30 to 40 per kg.

3.4.2.2 Abandoned gear:

Per year 5 to 30 kg of netting and associated ropes, floats and sinkers are abandoned per fisherman. Rough sea and entanglement in rock were the main reasons for abandoning the gear.

3.4.2.3 Loss of gear:

Loss of gear was reported by all the respondents. Amount of loss was 5 to 100 kg of net; and 2 to 40 panels of net. Main reasons for loss of gear were rough sea, strong wind, passing ship, predatory fishes, entangling in rocks and other underwater obstructions.

3.5 PRACTICAL ISSUES AND CONSTRAINTS IN PRE-TESTING

The practical issues and constraints experienced during the pre-testing exercise are discussed under the following headings:

Time taken for interview

The questionnaire was lengthy and it took more than one hour to complete one interview. Fishermen showed disinterest as time progressed. They were reluctant to reply when almost similar questions relating to quantification of discarded, abandoned and lost gear were put to them.

3.5.2 Quantitative data on fish loss and gear loss:

Quantitative data on fish and gear loss was found difficult to be collected. While in qualitative terms, the response was adequate, it was difficult to elicit quantitative data.

3.5.3 Questions on current speed at the fishing grounds

Fishermen do not have facility to assess this and hence information was not available.

3.5.4 Timing of the Pre-test

Mechanized gillnetters undertake fishing trips extending 18-45 days. Between two consecutive trips, only 1 or 2 days were available for the crew during which time they were busy with the sale of catch and preparation for the next trip. This implied some constraints on effectiveness of extracting responses from the respondents.

3.5.5 Information on delicate issues

Respondents were reluctant to give information on capture of turtles and mammals coming under ‘retention ban’.

SUGGESTIONS

The questionnaire should include questions on fish loss by way of “drop from the net” during hauling operations.

Question on unwanted vertebrates (other than fishes) such as snakes need to be added

Data collection would derive better results if collected during closed fishing season.

The questionnaire can be more concise as the fishermen were generally impatient to spend more time on answering.

Annex 1

Draft Data Collection Form for an Assessment of Food Loss during Gillnet and Trammel Net Fishing Operations

Part A. Inventory to Collect Information on Net Design and Materials

1. Gear type
a. Gillnet, trammel net, or combination gillnet/trammel net?[1]

b. Trammel nets: one or two outside layers?

2. Gear attachment
Is the net (i) Anchored, (ii) Staked, (iii) Drifting (both ends unattached), or (iv) Sweeping (one end free, one end attached, e.g., to a vessel)?

3. Gear depth
Is the net set: (i) Float line at the surface, (ii) Float line within 1m of the surface, (iii) Midwater, (iv) Lead line within few cm but not on the bottom, (v) Lead line on the bottom

4. Panel
a. Length of float line: _____________ meters or fathoms

b. Length of float line after hanging:___ meters or fathoms

c. Height _______________________meters or meshes

d. Trammel net ratio of stretched length of inner to outer
   panels (vertical slack): _______________________

e. Tie down line YES NO? If yes, height: _______ meters

5. Mesh
a. Whole stretched mesh length[2]: _______________ cm

b. Netting type[3]: ______________________________

c. Twine material[4] _____________________________

d. Twine diameter _____________________________ mm

e. Color _____________________________________

[1] For trammel nets and combination gillnets/trammel nets, complete separate forms for the interior and exterior layers.
[2] From center of knot to center of knot. Square measure is one-half of whole stretch mesh length
[3] E.g., multifilament (several small filaments twisted together), monofilament (single strand), multi-strand monofilament (multimonofilament, multiple strands of monofilament twisted loosely together), super multimonofilament (constructed the same as multimonofilament but the threads are thinner and more numerous).
[4] E.g., nylon (polyamide), polyester, gel spun polyethylene

f. Distance between ‘pickups’[5] ___________________ cm

g. Number of meshes between pickups[5]: ______________

6. Float line
a. Material ______________________________________

b. Length _____________________________________ m

c. Diameter _________________________________ mm

d. Color ____

7. Float
a. Material _____________________________________

b. Length ____________________________________ cm

c. Width at thickest section ______________________ cm

d. Color ____

e. Shape _______________________________________

f. Distance between floats _______________________ cm

g. Number meshes between floats ___________________

8. Lead line
a. Material ______________________________________

b. Diameter _________________________________ mm

c. Color ____

d. Lead core or weights attached? ___________________

e. Distance between weights (if weights attached): ____cm

f. Meshes between weights (if weights attached): ____ cm

g. Number weights per panel (if weights attached): _____ g

h. Weight per meter of lead line: ___________________ kg

9. Weight characteristics (if weights attached)
a. Material ______________________________________

b. Weight amount: ______________________________ g

10. Anchor characteristics (if used)
a. Material ______________________________________

b. Weight amount: ______________________________ g

[5] A ‘pickup’ is a point on the headrope where the webbing is attached.

Part B. Fisher Interview to Determine Fishing Methods and Causes of Food Loss

Date:
Interviewer name:
Fisher name:
Fishing vessel name (if vessel is used):
Based from seaport(s):

1. Fisher Experience in this Fishery
a. Position on vessel (e.g., captain, first mate) (if vessel is used): ____________

b. Number years fishing using this gear type (gillnet and/or trammel net): _____

c. Years gillnet or trammel net fishing from this seaport: ____________________

2. Fishing Grounds
a. Typical light levels at fishing grounds: ________________________________

b. Typical sea state at fishing grounds: _________________________________

c. Typical current speed at fishing grounds: _____________________________

d. Substrate type(s): ____

e. Do you frequently encounter debris that entangles in nets? YES/NO

f. Do your nets get entangled on subsurface features? YES/NO

g. List gear types of other gears used at your fishing grounds: _______________

3. Fishing Gear and Methods
a. Sketch the gear when soaking. Identify location in the water column (in relation to sea surface and substrate), number of panels per fleet, location of anchors if used, if attached to vessel or other object (sweeping), if drifting, location and length of tiedowns if used, height and length of panel, number of floats per panel, number of weights per panel if used, and how panels in a fleet are joined together.

b. Are fleets parallel, perpendicular, other? ______________________________

c. Distance between fleets: ____

d. Main fishing ground: ____

e. Most common fishing depth: ____

f. Method to set and haul (e.g., hauling equipment power, hauling speed): _____

g. Number days per fishing trip: _______________________________________

h. Number fleets set per trip: ____

i. Number fleets set per day: ____

j. Number trips per year: ____

k. Number panels fished per fleet: _____________________________________

l. Typical soak time: ____ hours

m. Net patrolled? YES/NO

4. Discarded and Released Catch
a. How many unwanted finfish are typically caught
Per fleet: ____
Percent alive upon haulback: ________________________________
Most common species: ____________________________________

b. How many unwanted invertebrates (crustacean, mollusks, etc.) are typically caught
Per fleet: ____
Percent alive upon haulback: ________________________________
Most common species: ____________________________________

c. How many seabirds are typically caught
Per fleet: ____
Percent alive upon haulback: ________________________________
Most common species: ____________________________________

d. How many sea turtles are typically caught
Per fleet: ____
Percent alive upon haulback: ________________________________
Most common species: ____________________________________

e. How many sharks (both market and unwanted species/sizes) are typically caught
Per fleet: ____
Percent alive upon haulback: ________________________________
Most common species: ____________________________________

f. How many rays (both market and unwanted species/sizes) are typically caught
Per fleet: ____
Percent alive upon haulback: ________________________________
Most common species: ____________________________________

g. How many marine mammals are typically caught
Per fleet: ____
Percent alive upon haulback: ________________________________
Most common species: ____________________________________

h. Predation on catch typically by:
• Seals YES NO
• Seabirds YES NO
• Cetaceans YES NO
• Sharks YES NO
• Squid YES NO
•Other – please identify:

i. Have you observed catch being depredated and completely removed from the gear? YES NO

j. Is catch partially depredated? YES NO
Number market species typically partially depredation per fleet: _____________
Number unwanted species typically partially depredation per fleet: __________

k. Dead discards and live released catch:
Number or weight of market fish discarded or released per fleet: ____________
Number or weight of non-market fish discarded or released per fleet: ________
Number or weight of market invertebrates discarded or released per fleet: _____
Number or weight of non-market invertebrates discarded or released per fleet: ___

l. Identify causes of discarding/releasing catch, and order from most to least important.
___ No market demand
___ Retention ban
___ Over quota:
___ Making room in the hold for higher value catch (high-grading)
___ Spoiled upon hauling
___ Damaged from the fishing method or gear
___ Damaged from partial depredation
___Could damage the rest of the catch during storage
___ Insufficient room for storage (e.g., final set of a trip)

5. Abandoned, Lost and Discarded Fishing Gear
a. List gear components that you typically discard (throw gear overboard at sea):

b. How much gear do you discard (identify amount of each gear component that is discarded)
Per set: ______________________________
Per trip: ______________________________
Per year: ______________________________

c. What is the main reason you discard gear?

d. List gear components that you typically abandon (gear set for fishing left at sea on purpose):

e. How much gear do you abandon (identify amount of each gear component that is discarded)
Per set: ______________________________
Per trip: ______________________________
Per year: ______________________________

f. What is the main reason you abandon gear?

g. How much gear do you lose (gear set for fishing is left at sea and can't locate and retrieve it):
Panels per set: ______________________
Panels per trip: ______________________
Panels per year: ______________________

h. What is the main reason you lose gear?

Proceedings of the Expert Workshop on Estimating Food Loss and Wasted Resources from Gillnet and Trammel Net Fishing Operations

8–10 April 2015
Cochin, India

This publication provides a summary of the presentations and discussions of the Expert Workshop on Estimating Food Loss and Wasted Resources from Gillnet and Trammel Net Fishing Operations, held in Cochin, India, on 8–10 April 2015. It also includes the methodology for estimating food loss from gillnet and trammel net fishing agreed during the workshop

ISBN 978-92-5-109581-2 ISSN 2070-6103

9 789255 095801

I6675EN/1/01.17