

Supplementary material for

# Application of Systems Engineering and Sustainable Development Goals towards sustainable management of fishing gear resources in Norway

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## Content:

**Appendix A1:** Templates used for collecting information from stakeholders in the system of fishing gear resources in Norway.

**Appendix A2:** Description of Relevant Regulatory Framework (International, Regional and National) for Commercial Fishing Gears.

## **Appendix A1**

### **Description data collection templates from system stakeholder groups for the system of Fishing Gear resources management in Norway**

#### **1) Data collection templates and questionnaire for FG producers**

- **Production of FGs and Material Science**

Literature review and stakeholder analysis was performed to understand the production, supply and material science of the selected FGs. Fishing equipment suppliers in Norway typically import the raw material from Asia. The imported raw material is further used to produce the customizable fishing equipment. The active gears such as Trawls, Purse and Danish seines are manufactured by selected major FG companies whereas passive gears like gillnets, lines and traps are supplied by many small-scale suppliers. The passive gears are also used for leisure fishing in Norway that is excluded from the MFA study. To estimate the annual sale of FGs, seven major FG suppliers in Norway are identified and structured interviews and site visits were conducted to collect the data. **Table S2** presents the template used to collect the relevant information from FG suppliers in Norway between 2017-2018. The information is then processed and used to calculate the mass flow of plastics in study-1 (Analysis step of SPADE method).

Personal communication with the Norwegian suppliers was used to identify the material science of selected FGs. Polyamide (PA), Polyethylene (PE), Polypropylene (PP) are majorly used plastic polymers to manufacture the FGs. Poly Vinyl Chloride (PVC) and other metals namely, lead, steel, iron, copper and Aluminum is commonly used in making ropes, wires, winches, trawl doors, hooks and other associated parts of FGs.

**Table A1.1:** Template used to extract information from FGs equipment producers and suppliers. The information was obtained regarding the material composition, mass fractions of plastic polymer types, approx. weight of each FG unit and total weight sold for each FG type in 1 year and associated uncertainties.

Main FG Equipment	Sub categories and parts of FGs	Estimated % composition of total weight <sup>1</sup>				% Composition of Ropes in FG Type <sup>2</sup>	Total Weight sold in 2016 <sup>3</sup> (tons)	Total Weight of plastics in FGs with ropes sold by Suppliers in 2016 <sup>4</sup> (tons)	Estimation of Uncertainty in Composition of plastics in FGs (%)		
		% Nylon (PA)	% PP, PE and other plastics	% Metals	% Other material				Min	Max	Uncertainty
Trawls	Pelagic-/midwater trawl	30-50%	30-50%	2-5%	1-2%	5 %	465	468,8	60 %	100 %	20 %
	Bottom/demersal trawl (Cod Fishing)										
	Semi-demersal trawl (shrimp fishing)										
	Trawl doors										
	Trawl wire										

<sup>1</sup> Composition of plastic polymers in selected FGs is estimated through aggregating the information received from the major Norwegian suppliers of respective FG type. The variation in % composition of FGs is due to different sources of raw materials used by Norwegian FG suppliers. Furthermore, Trawls and Traps show considerable uncertainty in plastic content owing to various designs and production processes.

<sup>2</sup> The ropes are sold separately, to include ropes in the FG types, contents of ropes in FG type is calculated using the data from FG manufacturers.

<sup>3</sup> Estimated through the summation of 2016 sales data from major FG suppliers/manufacturers in Norway.

<sup>4</sup> To estimate the mass of plastic (MoP), quantity of plastics in FGs and ropes is aggregated. The weight of metal and other material in the FGs are excluded.



## **2) Data collection templates and questionnaire for Fishers**

First, a structured draft of questionnaire was created to extract information on handling and management of selected FGs throughout their life cycle. The experts in the field of fishery (Fishers Association), FG manufacturers, environment and resources consultants and researchers in marine and fishery sciences were contacted and were asked to evaluate and comment on the language, structure and clarity of the designed questionnaire for fishers. The objective of the survey was to capture the pattern under which Norwegian fishers operate and manage their FGs but also design a survey, quick to fill-up and corresponding to the fisher's experiences. The consensus was reached after two rounds of revisions as per Delphi method and a set of 13-questions, consisting of both qualitative and quantitative questions, were finalized covering following topics:

- Norwegian fishers and fishing vessels
- Owned FGs by each fishing company
- Purchase patterns for new FGs
- Repair pattern and frequency of FGs
- The average lifespan of selected FGs
- Average loss probability of selected FGs
- Waste management of FGs

Data collection occurred between July 2017 and January 2018. To avoid the bias and confusion in the responses, face-to-face survey with fishers is preferred over online questionnaire. To reach many fishers from diverse regions at the same time fishery-related exhibitions or conferences in the selected four study sites are targeted to conduct the questionnaire. The data collected from the questionnaire, statistical methods used for data analysis and outcomes are found in

Deshpande PC, Brattebø H, Fet AM. A method to extract fishers' knowledge (FK) to generate evidence for sustainable management of fishing gears. *MethodsX*. 2019 Jan 1;6:1044-53.

<https://doi.org/10.1016/j.mex.2019.05.008>

## **3) Data collection templates and questionnaire for Ocean clean-up activities**

In Norway there are two registered programs targeting removal of ALDFG from the ocean (removal of FGs from ocean from Fishing for Litter (FFL) program and annual FG removal by the Norwegian Directorate of Fisheries). The amounts and mass fractions of FGs removed annually through these programs are obtained through meetings, semi-structured interviews and structured questionnaire presented in following Tables. The total MoP removed from the ocean is the sum of FGs collected through the clean-up programs. The data was collected through personal interviews and surveys with the relevant agencies. Furthermore, the preliminary results are validated with the managers of respective retrieval operations to estimate the uncertainty using expert judgement.

**Table A1.2: Data collection template for Ocean Clean-up Surveys organized by the Norwegian Directorate of Fishing**

<b>Fishing Gear Type Retrieved from the Ocean/Beach clean-up</b>	<b>Weight Min (kg)</b>	<b>Weight Max (kg)</b>	<b>Average Weight (kg)</b>	<b>Average Weight Recovered (tons)</b>	<b>Uncertainty (expert opinion)</b>
Trawls (units) <sup>a</sup>					
Longlines (meters) <sup>b</sup>					
Gillnets (units) <sup>a</sup>					
Traps /Pots (units) <sup>a</sup>					
Ropes (meters) <sup>c</sup>					
...					

**a:** The Norwegian Directorate of Fishing reports recovered trawls, gillnets and traps in terms of number of units recovered.

**b:** The Norwegian Directorate of Fishing reports recovered ropes and longlines in terms of number of meters recovered.

**c:** The expert judgement was used to estimate the weight range of recovered trawls during the retrieval operations. The weight range is lesser than the average weight of a single trawl as only parts of trawls are typically recovered during the retrieval operations.

**Table A1.3: Data template from Fishing for Litter program (FFL)**

<b>Year</b>	<b>Total number of vessels</b>	<b>Total weight collected from the ocean (tons/yr)</b>	<b>FG related waste sent to WMFs for recycling (tons/yr)</b>	<b>Material Composition of FG related waste sent for recycling</b>			
				<b>% Plastics</b>	<b>% moisture</b>	<b>% metal</b>	<b>% other</b>

#### **4) Data collection template for beach clean-up operations in Norway**

The records of fishing-related waste collected from the beaches through beach clean-up operations by Hold Norge Rent (HNR) and Lofoten Avfallselskap (LAS) was used to quantify the MoP in FGs collected from the beaches in study-1. The information is obtained through skype meetings and email communications with the relevant managers and project leaders responsible for clean-up operations at HNR and LAS facilities.

#### **General Observations from HNR and LAS beach clean-up operations**

- 1) Beach clean-up is conducted by volunteers and their knowledge on the classification of various types of FGs is limited that might lead to the bias in reporting.
- 2) Clean-up operations mostly find the parts of gillnets, trawls and Danish seines, hence using the average weight range of individual fishing Gear types does not give the correct reflection of the weight range from the clean-up operations.
- 3) Amount of heavy FGs are minimum and such bigger nets are seldom found on the beaches located on the Nor-Norge.
- 4) The fishery-related waste is historical, and it is almost impossible to estimate the year, date, and source of the retrieved fishing gears.

**Assumptions:**

1. The average weights per unit of FGs obtained from the Norwegian FG suppliers and expert opinion was used to estimate mass of plastic from the collected FGs from beach clean-up operations.
2. The weight of metal and other non-plastic parts of the FGs are excluded from the calculations.
3. Expert judgement was used to estimate the uncertainty in the calculated flow quantities.

**Validation:** The results and estimated uncertainties are reported to the stakeholders from HNR and LAS. The results are further modified and validated based on consultation with the experts from

**Table A1.3: Data collection template for beach clean-up surveys**

Type of Fishing Gears Collected from the beach clean-ups	Total FGs Collected (HNR+LAS) <sup>a</sup>	Weight range of FGs per unit		Avg. weight retrieved from the beach clean-ups and associated Uncertainty			
		Min (Kg)	Max (Kg)	Min. Weight (kg)	Max. Weight (kg)	Avg. (tons)	% Uncertainty
Large rope (m)							
Small rope (m)							
Trawl nets, Danish-/Scottish seine, less than 1 m <sup>2</sup>							
Trawl nets, Danish-/Scottish seine, larger than 1 m <sup>2</sup>							

Pots/traps							
Gillnets							
Longlines							
buoys/floats							
<b>Average MoP in collected waste FGs from beach clean-ups and avg. uncertainty</b>							

## 5) Data from Waste management facilities (WMFs) in Norway.

In total, 18 WMFs located all across Norway was shortlisted and contacted based on their likelihood for receiving the FG related waste. The likelihood was determined based on their near harbor or coastal location. In the primary data collection round, telephonic interviews were used to confirm the capacity of selected WMF to handle waste FGs. In the second round of data collection, structured questionnaire was circulated to 18 WMFs to retrieve the information on:

- a) Total capacity of WMF
- b) Typical annual load of FGs related waste received by WMFs (tons/yr)
- c) Typical criteria and segregation pattern of WMFs to handle waste FGs? (i.e. fraction sent for landfilling, incineration and segregated for recycling?



## **Appendix A2**

### **Description of Relevant Regulatory Framework (International, Regional and National) for Commercial Fishing Gears**

**Table A2.1:** Summary of relevant legislative instruments governing Fishing Gear Resource System at International, regional, and national levels.

Scope	Legislative Instrument and Governing body and Year	Brief Description	Compliance Level M: Mandatory O: Optional
International	UN Convention on the Law of the Sea (UNCLOS)	The UNCLOS is the international agreement that defines the rights and responsibilities of nations concerning their world's oceans. The agreement establishes guidelines for geopolitics, commercial activities, the environment, and the management of marine resources. The provisions do not specifically refer to marine litter, but they require that states protect and preserve the marine environment.	M
	MARPOL 73/78, Annex V	Annex V of MARPOL 73/78 is a primary international instrument that addresses explicitly ocean-based litter from ships. Annex V provides an updated framework for controlling garbage generated by ships. It imposes a general ban on all garbage dumping from ships at sea unless expressly noted. Also, it requires that ships provide a garbage record book and that port reception facilities handle waste from ships without delay.	M
	London Protocol	The London Protocol is an instrument that prohibits the dumping of industrial waste and other substances from human-made structures (ships, etc.). The participating parties also are required to implement measures that prevent, reduce and eliminate contamination by dumping (where possible).	M
	Sustainable Development Goals (SDGs) /UN/2015	SDG 14 of the 17 sustainable goals launched by the UN in 2015 focuses specifically on “Life below water.” Target 14.1 of the Sustainable Development Goals (SDG): “by 2025, prevent and significantly reduce marine pollution of all kinds. Other goals advocate the sustainable production and consumption of products, resource efficiency, and reduction of carbon footprints.	O

<b>Regional</b>	EU Port Reception Facility (PRF) Directive/EU/2002& 2018	The PRF Directive was created in response to MARPOL's requirement for member states' ports to provide incoming vessels with adequate waste reception facilities. This PRF Directive requires advance notification of a vessel's waste deposit. It also outlines guidelines for reporting systems, cost-recovery fee systems, and enforcement schemes. The new, updated PRF Directive was launched in 2018 where the EU mandates necessity of PRF at every port of EU-EEA states. (EC, 2018a)	M
	OSPAR	OSPAR fits into the UNEP Regional Sea Program and is a mechanism that legally requires cooperation among member states to protect the marine environment of the Northeast Atlantic region. OSPAR aims to harmonize PRFs and fee systems, implement “fishing for litter” projects, harmonize enforcement schemes, and identify essential waste items from the fishing industry and aquaculture.	M
	EU marine strategy framework directive	The Marine Directive aims to achieve Good Environmental Status (GES) of the EU's marine waters by 2020. Indicators that define GES include characteristics of litter and impacts of litter on marine life. It incorporates work by the Technical Subgroup on Marine Litter (TSG ML)	
	Bonn Agreement	In the convention's preamble, that they state that they aim "to ensure good order and conduct on the fishing grounds in the North Atlantic Area." The convention covers rules for gear marking.	M
	Global Partnership on Marine Litter (GPML)	The Bonn Agreement is a mechanism designed for the North Sea States and EU to work together in fighting marine litter in the North Sea Area. Its policies are focused mainly on preventing maritime disasters and chronic pollution from ships/offshore platforms.	O

	The Marine Group (HAV) within the Nordic Council of Ministers (NCM)	(builds on Honolulu Strategy) Voluntary multi-stakeholder coordination mechanism, which all agree to work together to reduce further and better manage marine litter. Mainly focused on land-based activities.	O
	Convention on Conduct and Fishing Operations in the North Atlantic	Since 2013, HAV has prioritized environmental aspects of marine litter in Nordic waters with projects including plastic loading in Northern Fulmars, marine litter, and its sources in Nordic waters.	
	UNEP's Regional Sea Programme (RSP)/ UNEP / 2003	The Regional Sea Programme developed a Global Initiative on Marine Litter to organize and implement regional activities for addressing marine litter in 12 regional seas. These activities include: assessing marine litter, preparing a regional management plan for marine litter, organizing beach clean-ups, and meeting/collaborating with national authorities to address marine litter.	O
	Honolulu Strategy	The Honolulu Strategy was formulated at the Fifth International Marine Debris Conference in 2011. The framework has three goals and 19 strategies that serve as a practical reference for national parties. The three goals include: 1. reduce land-based litter 2. Reduce sea-based litter including ALDFG and 3. Reduce the impact of marine debris	O
	EU Strategy for Plastics in Circular Economy	On 16th Jan 2018, the European Commission (EC) adopted the “ <i>European strategy for plastics in a circular economy</i> ,” which recognizes plastics as a significant source of marine litter (EC, 2018b). In the elaborated action plan, additional action on plastics from fishing gears (FGs) and aquaculture were stressed owing to the hazardous nature of abandoned, lost, or discarded fishing gears (ALDFG) and an increase in commercial fishing activity in the EU waters (EC, 2018c).	O
<b>National</b>	Norway's Marine Resources Act (6/6/2008)	Norway’s Pollution Control Act has been modified to enforce the regulations required by the PRF Directive into Norwegian Law. It outlines guidelines for the delivery and reception of waste and cargo residues from ships calling port	M

	Norway's Pollution Control Act	Discharge from ships are regulated nationally by environmental safety laws	M
	Norway's Maritime Safety Act	Prohibits dumping of gear, moorings, and other objects in the sea that may injure marine organisms, impede harvesting, or damage gear. Any person that loses a net must attempt to remove the object from the sea. If this is not possible, this loss must be reported to authorities. Any person that salvages gear is entitled to reward. It also addresses gear marking.	M
	Norway's Waste Regulation	Waste regulation provides the guidelines on handling and management of waste within the region. The regulation promotes recycling and energy recovery, and loads of waste to landfills are regulated.	M

EC 2018a. DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on port reception facilities for the delivery of waste from ships, repealing Directive 2000/59/EC and amending Directive 2009/16/EC and Directive 2010/65/EU. Strasbourg: European Commission, Directorate-General for Mobility and Transport.

EC 2018b. A European Strategy for Plastics in a Circular Economy.

EC 2018c. Impact Assessment Report on Reducing Marine Litter: action on single use plastics and fishing gear. European Commission