Chapter 14
Role of Resource Users' Knowledge for Developing Realistic Strategies for a Circular Economy for Plastics from the Norwegian Fishing Sector

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Abstract The complexity of resource management often demands an integration of transdisciplinary methods to find sustainable solutions. The absence of aggregated scientific information threatens holistic and robust resource management. Contrary to traditional resource management studies, the involvement and engagement of resource users are prioritized here. As resource users and stakeholders are significant, yet unexplored sources of information, this study presents a stepwise approach that includes resource users' local ecological knowledge in gathering the information necessary for resource management. The framework's application is then demonstrated in the case of plastic fishing gear deployed by the commercial fishing fleet of Norway. The insights from stakeholders were used to ascertain potential barriers and opportunities in establishing circular and sustainable management strategies for Fishing gear resource management in Norway.

14.1 Sustainable Resource Management: Global Context

The science of resource management involves generating a systematic understanding of the processes that lead to improvements in, or the deterioration of natural or anthropogenic resources. The management of resources is relatively straightforward, especially when the resources and use of the resources by users can be monitored, and the information can be verified and understood in a non-complex way (Dietz et al. 2003). In the terminology of resource management, information refers to the real knowledge about stocks, flows, and processes within the resource system, as well as about the human–environment interactions affecting the system (Dietz et al. 2003). Highly aggregated information may ignore or average out local data, which is essential for identifying future problems and developing sustainable solutions (Dietz et al. 2003).

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Historically, local and regional governments have been deemed responsible for managing resources through political instruments, and resource users have been assumed incapable of reversing the tragedy of commons (Hardin 1968). Dietz et al. (2003) and Johannes (1984), however, provided strong arguments advocating the necessity of studying not only the resource itself but also the local methods, traditions, and knowledge associated with its use. As all humanly used resources are embedded in complex, social-ecological systems (SES) (Ostrom 2009), one needs to incorporate both ecological and socio-technical knowledge in describing the resource system. Accordingly, Ostrom (2009) proposed a multilevel, transdisciplinary framework for analyzing the sustainability of resource systems. The framework was designed to capture the complex interactions among the system and subsystems.

A system is ‘a combination of interacting elements organized to achieve one or more stated purposes’ (ISO 2008). Here, the SES framework proposed by Ostrom (2009) is adapted, the case system of fishing gear (FG) resources deployed by the commercial fishers in Norway. The system is studied for developing sustainable strategies in the life cycle management of FGs in the region. The interacting elements or *subsystems* are defined by adapting the SES framework proposed by Ostrom (2009), which is modified to represent the SES of FG resources in Norway. Figure 14.1 provides an overview of the framework, showing the relationships between the four core subsystems of an adapted SES that affect each other, as well as linked to social, economic, and political settings and related ecosystems. The central system and associated subsystems for management of the selected anthropogenic resource are:

14.1.1 Main Social Ecological/economic System: Fishing Gear Resources

A. **Resource system**: The Norwegian commercial fishing sector.
B. **Resource units**: Plastics from commercial fishing gears and ropes.
C. **Governance systems**: The regulatory framework and governing institutions.
D. **Resource users**: Fishers and other stakeholders.

The framework highlights the need for interaction and engagement between the four subsystems to gather holistic scientific information about the system. SD and the circular economy provide a global context to define and outline the improvement of FG resource management in the region. This chapter suggests outcomes in the form of strategies and mechanisms for achieving the overall goal of sustainable life cycle management of FG resources in Norway. Although the suggested outcomes are limited to the case of the commercial fishing sector of Norway, the knowledge can be adapted to similar ecosystems elsewhere.

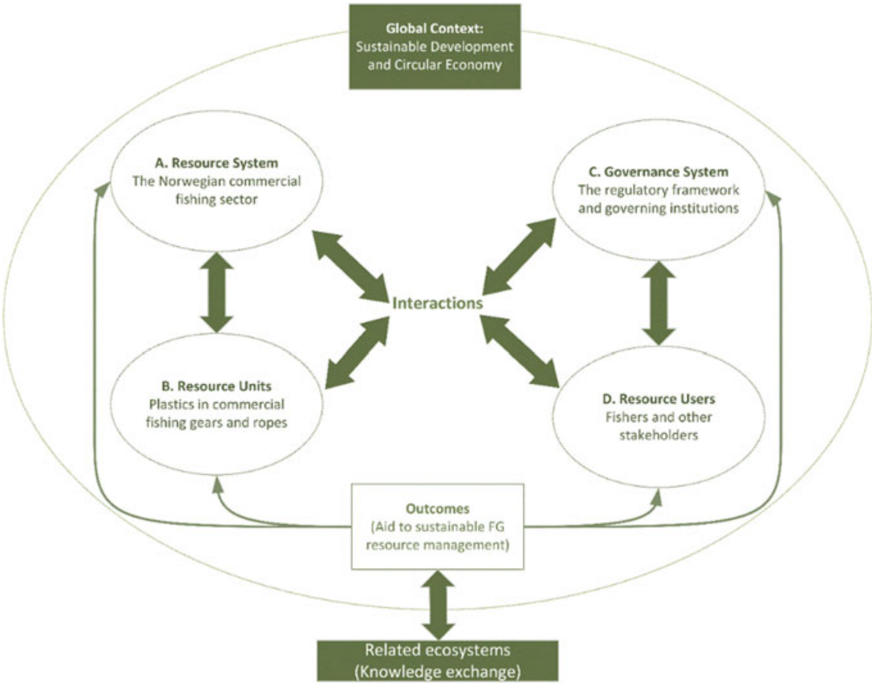

Fig. 14.1 The core subsystems in a framework for analyzing the social-economic system of FG resources. Modified from Ostrom (2009)

14.2 Description of Case Study

Norway is a Northern European country surrounded by water to the south (Skagerrak), the west (the North Sea and the Norwegian Sea), the north, and north-east (the Barents Sea). With a marine resource-rich coastline of more than 25,000 km, Norway is the European leader regarding both commercial fishery and aquaculture (Lawson 2015). The commercial fishery has always played a critical social and economic role, nationally and regionally, and has been the basis for settlement and employment along the entire Norwegian coast (FAO 2013). The commercial capture fishery sector is segmented into the coastal and ocean fishing fleet. The coastal fishing fleet comprises smaller vessels operated by 1–5 fishers and size ranges from 10 to 20 m. On the other hand, the ocean fleet is known for its deep-water and sophisticated fishing practices, where fishing vessels are generally more than 28 m in size, and crew members can vary from 20 persons or more (FAO 2013; Fiskeridirektoratet 2017). The primary capture species include herring, cod, capelin, mackerel, saithe, blue whiting, and haddock. A few additional species are caught in smaller quantities, but have a high commercial value such as prawns, Greenland halibut, and ling.

Six major Fishing Gear (FG) types, namely trawls, purse seines, Danish seines, gillnets, longlines, traps/pots, and their associated ropes, are most commonly deployed by the fishers and hence considered for this study. FG is defined as:

> Any physical device or part thereof or combination of items that may be placed on or in the water or on the seabed with the intended purpose of capturing or controlling for subsequent capture or harvesting, marine or freshwater organisms whether or not it is used in association with a vessel (FAO 2016).

The design and material of FGs vary based on the type and purpose of that gear. Plastic polymers (PP, PE, and Nylon) remain the primary building blocks of any FGs, constituting approximately 60–90% of FG material (Deshpande et al. 2019b). Therefore, plastic polymers from FGs are termed as resources in developing management strategies throughout this chapter. Among the total plastic waste entering the oceans, ALDFG is considered as a particularly troublesome waste fraction that may continue to trap marine animals for decades upon release (Laist 1997; Macfadyen et al. 2009). The amount, distribution, and effects of ALDFG have risen substantially over the past decades, with the rapid expansion of fishing efforts and fishing grounds, and the transition to synthetic, more durable, and more buoyant materials used for FG (Derraik 2002; Gilman 2015). In addition to the threat to marine ecology, the loss of fish stocks due to ghost fishing and the expanded cost of valuable resources on lost or abandoned FGs also possess significant economic setbacks (Deshpande and Aspen 2018).

Although ALDFG is the proven most dangerous fraction of marine litter (Brown and Macfadyen 2007), little or no information is available on the regional flows, sources, and fate of plastics from the fishing sector. Jambeck et al. (2015) identify this knowledge deficiency about plastic flows from fishing activities in the quantification of total plastic in marine debris. Lack of scientific evidence resulted in strong dependence on precautionary principles or conservative methods to manage FG resources in coastal countries. The risk of ALDFG accumulation is ever pertinent to countries characterized by a long and productive coastline. The geographic location and a strong dependence on fishing activity make Norway among the most vulnerable countries in the EU-EEA region from the detrimental effects of ALDFG pollution. Consequently, there is a pressing need to build a holistic and systemic understanding of fate, transport, sources, sinks, and end-of-life (EOL) management alternatives of the regional plastic flow from the fishing sector. Additionally, the lack of scientific data on FG resources necessitates the need to incorporate alternative information sources into assessment models.

Therefore, this study aims to showcase how multi-stakeholder inputs can be used to facilitate problem-driven research and generate valuable evidence for managing a system of FG resources in Norway.

14.3 Theoretical Background

Aligning the SES framework presented in Fig. 14.1, the knowledge from stakeholders is deemed essential in obtaining the information for resource management. In the case of the data-less sector, scientists often need to rely on resource users' knowledge to work with the resources under study.

Two theoretical developments explain the need and mean to obtain the missing information from *resource users*, namely *Local Ecological Knowledge* (LEK) (Mackinson 2001) and *Fishers' Knowledge* (FK) (Johannes et al. 2000) relevant to fisheries-related research. These theoretical frameworks are elaborated upon here.

14.3.1 Local Ecological Knowledge and Fishers Knowledge

Resource users develop a comprehensive knowledge of their resources and their environments, and is rarely collected systematically. Scientific attempts to collect such knowledge in highly structured formats can elicit large amounts of information on the ecosystem and its elements (Neis et al. 1999). This type of knowledge is often referred to as *Local Ecological Knowledge* (LEK), where a group of individuals holds a cumulative body of knowledge, often site-specific, about an ecological system (Zukowski et al. 2011). LEK includes the knowledge local people have of nature: their perceptions, classifications, and understanding of ecological dynamics and functions (ethnoecology), as well as their beliefs (Berkes et al. 2000). It is often based on long-term observations of the local ecosystem considering local variations and behavioral patterns, and focusing on essential resources/species of the concerned ecosystem (Ruddle 2000). Practical applications of LEK range from a variety of systems, including but not limited to, small-scale agriculture, horticulture, forestry, and fisheries (Fischer et al. 2015). In applying LEK on fisheries management, Johannes (1982) and colleagues played a crucial role in establishing and documenting the use of LEK in the sector of fishery management through their work between 1980 and 2000 and coined a new term as *Fishers Knowledge* (FK).

In his first documented study on applying FK, Johannes (1984) emphasized the variety and depth of information local fishers possess on marine ecology and conservation, fish behavior/habitats, fishing practices, FG types, and other ecosystem concepts. Further, Johannes et al. (2000) argued that by ignoring such readily available and inexpensive source of knowledge while studying the local system, humanity runs the danger of 'missing the boat' on fisheries sustainability. The information captured through LEK is proven critical for resource management studies, especially in the data-less or data-poor systems.

Although fishers possess a valuable source of information, integrating and translating that information to the science of resource management demands creativity in applying suitable scientific methods (Fischer et al. 2015; Hind 2015). So far, the application of LEK was demonstrated to manage biodiversity and marine protected areas (Johannes 1984; Silva and Lopes 2015), studying fish species, habitats, and catch patterns (Granek et al. 2008; Martins et al. 2018), fishery resource management (Fischer et al. 2015; Ruddle 2000; Silva et al. 2018) and to understand the impacts of fishing methods and equipment (Ratana et al. 2003; Wallner-Hahn and de la Torre-Castro 2017).

In this case study, fishers are identified as key resource users, possessing valuable *information* on the system life cycle stages of commercial FG resources. Therefore, this study contributes to the science of capturing information from fishers' LEK or FK on fishing practices.

14.4 Methods

To develop sustainable management strategies in the case of fishing gear resources in Norway, a stepwise approach is proposed and executed. Figure 14.2 demonstrates the stepwise approach including the identification of information needs, relevant stakeholders, and further collection and validation of data before finally devising the evidence-based strategies for sustainable management of FG resources. The steps are elaborated below.

Step-1: Identify and map the system life cycle of the selected resource

Here, the typical system life cycle of six commercial FGs deployed in Norway is developed and demonstrated by Deshpande and Aspen (2018). The six FGs, namely Trawls, Purse seines, Danish seines, Gillnets, Longlines, and Traps, most commonly deployed FGs by the commercial fishers are selected, and their life cycle stages were identified. The system life cycle is mapped and presented in Fig. 14.3.

Step-2: Define *Information* needed for resource management

Scientific information is the backbone of any resource management strategy. In the terminology of resource management, *information* refers to the real knowledge about stocks, flows, and processes within the resource system, as well as human–environment interactions affecting the system. Information on three critical factors is considered essential in analyzing the performance of the FG resource system.

1. Composition of the commercial fishing fleet and stakeholders.
2. Sources, sinks, and flows of resources throughout the system lifecycle of commercial FGs.
3. End-of-life handling and management of FGs.

After finalizing the lifecycle processes for FGs, Material Flow Analysis (MFA) was considered an apt method for analyzing the system lifecycle sources, flows, and sinks of substance/materials (Brunner and Rechberger 2016). These information needs were identified and elaborated in Deshpande et al. (2020a).

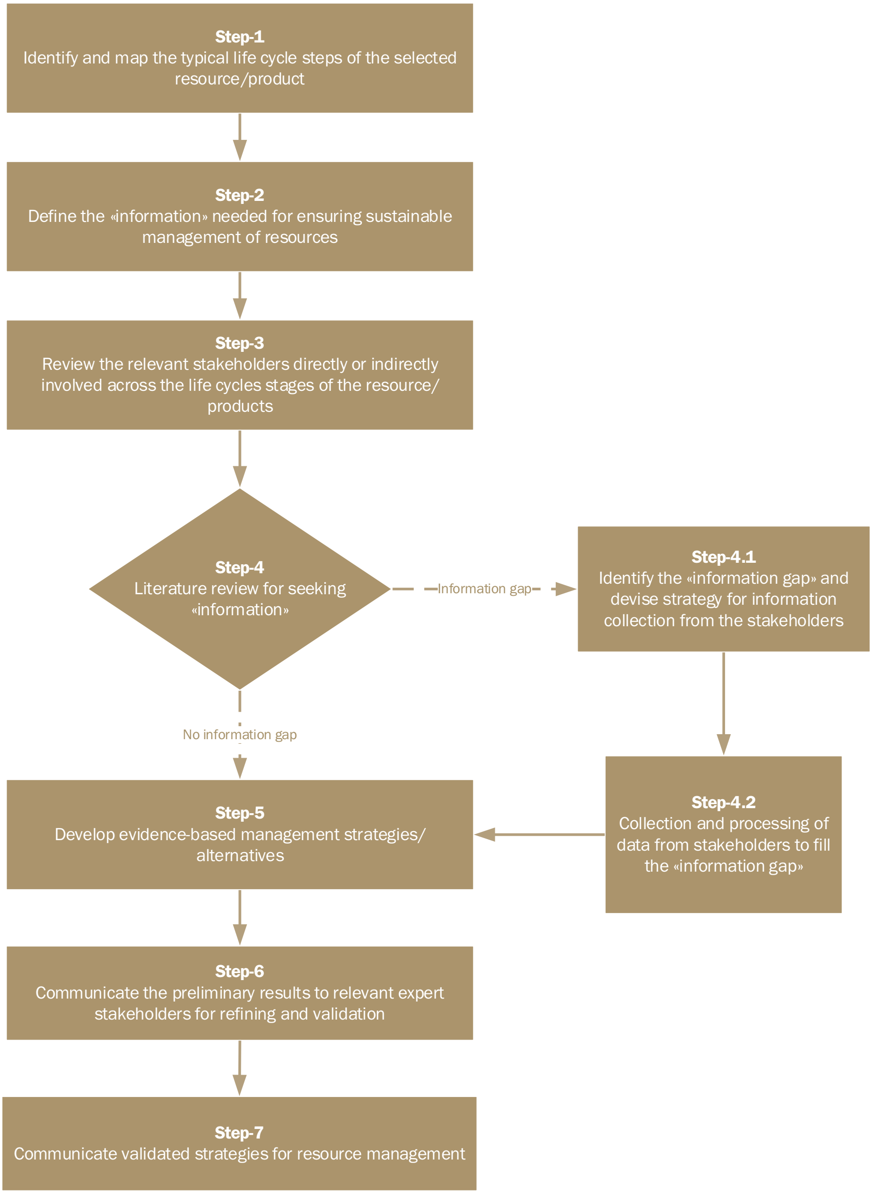

Fig. 14.2 Stepwise framework for evidence-based strategy development using multi-stakeholder perspective

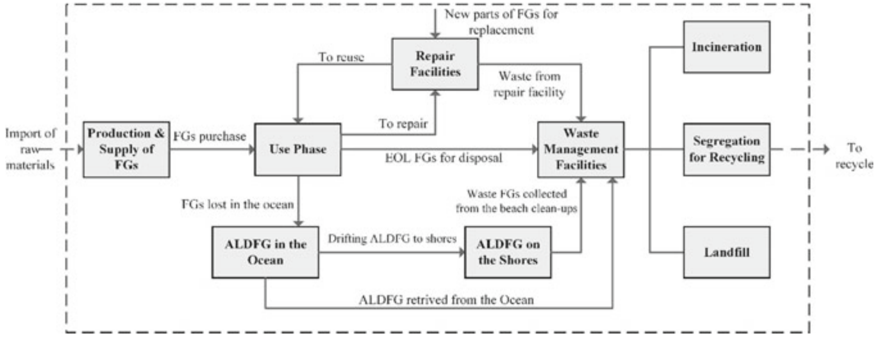

Fig. 14.3 Typical processes involved in the system life cycle of commercial FGs in Norway. (Modified from Deshpande 2020b: 2)

Step-3: Stakeholder mapping

This step involves identifying system stakeholders and mapping their needs. Users and other stakeholders are individuals or groups of individuals who use the resource system in diverse ways for sustenance, recreation, or commercial purposes (Ostrom 2009). The classification and mapping of stakeholders can be carried out in several different ways based on the applicability and relevance to the problem. Here, stakeholders are classified based on their ability to provide information on the processes of the FG system lifecycle as presented in Fig. 14.3. Purchase, use, and EOL are the three main lifecycle phases of FGs. Stakeholders that are directly involved in one or more lifecycle phases are presented in Table 14.1.

Table 14.1 List of stakeholders and their relevance to the life cycle stages of the FG system

Stakeholders'	Pre-use (Purchase)	Use-phase	End-of-life phase	Other
Directorate of fishery			X	
Ports and harbors		X	X	X
Fishers and fishermen associations	X	X	X	X
FG producers/suppliers	X			
Relevant NGO's	X		X	X
Research and consultancy companies and academia			X	X
Waste management companies			X	
Waste collection and recycling companies			X	X

Step-4: Collection of relevant "information"

The information needs defined in Step-2 are met through a comprehensive review of available literature on the fishing sector, fishing patterns, FG waste management, and purchase patterns. However, the overall lack of systematic data on FGs resulted in aggregated or absence of data identified as *essential information*, for developing management strategies for FG resources.

Therefore, in this case, Step-4.1: identification of information gaps and targeting relevant stakeholders and further Step-4.2: devising strategies for data collection were deployed.

Step-4.1: Information gaps and key stakeholders

After the literature review, some of the key information gaps include overall understanding on the handling and management of FGs. Compared to Step-2, the missing information included:

(a) Mass flows of plastics across the life cycle stages of FGs
(b) Norwegian fishers and fishing vessels and organization of commercial fishing activities
(c) Selected FG types owned by a fishing company
(d) Annual purchase patterns for new FGs
(e) Annual repair pattern and frequency of FGs
(f) The typical lifespan of selected FGs
(g) The average annual rate of FG loss in the ocean
(h) Typical end-of-life alternatives for FGs
(i) Typical ocean and beach clean-up operations and mass of fishery-related plastic recovered annually.

As shown in Table 14.1, fishers are identified as key resource users, capable to address the highlighted information gaps, and therefore, methods are used to extract fisher's knowledge (FK).

A systematic survey was designed using the Delphi method to extract fishers' knowledge on the handling and management of six different FGs, commonly deployed by commercial fishers in Norway. Further, the fishers' LEK was then analyzed to quantify the average rates of listed FGs to understand their repair and disposal patterns and to quantify the number of FGs contributing to the ALDFG problem from Norwegian capture fishery. The questionnaire used and collected information is presented in Deshpande et al. (2019a).

For developing circular management strategies, we need information from other stakeholders: FG producers, waste management companies, agencies responsible for beach and ocean clean-up operations in Norway, recyclers, incineration, landfill companies, regulatory agencies, etc. Figure 14.4 demonstrates the list of contacted stakeholders and various methods for collecting relevant information.

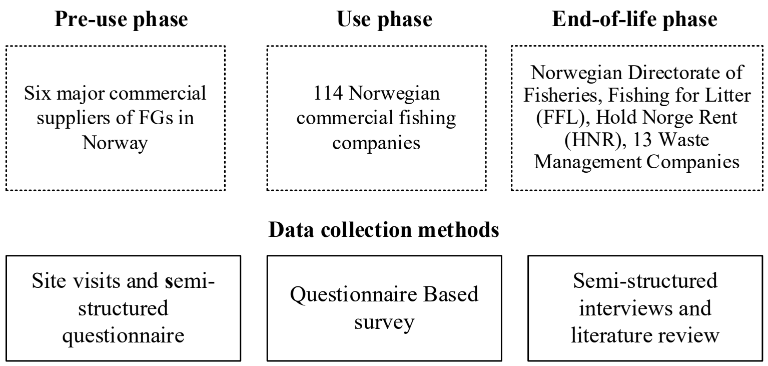

Fig. 14.4 Identification of relevant stakeholders and methods used for collection of relevant information for FG resources management. Modified from Deshpande (2020b)

Step-4.2: Methods for data collection from stakeholders

Survey and Questionnaire

A survey provides a quantitative or numeric description of trends, attitudes, or opinions of a population by studying a sample of that population. From sample results, the researcher generalizes or draws inferences to the population (Creswell and Creswell 2017). Most surveys involve the use of a questionnaire, and Robson (2011) stated three main ways applied for administrating questionnaires:

Self-completion: Respondents fill in the answers themselves.

Face-to-face interviews: An interviewer asks the questions to the respondent or the respondent fills in the questionnaire in the presence of an interviewer.

Telephone interview: The interviewer records the responses from the respondent via telephone conversation.

Here, a questionnaire-based survey was designed and face-to-face and telephone survey methods were used to obtain data from fishers. The details on survey design, administration, and analysis of responses are presented in Deshpande et al. (2019a). Apart from the structured questionnaire, site visits and semi-structured interviews were used to gather additional information from FG producers and waste management companies (Fig. 14.4). The collected data from 114 fishers and other stakeholders were processed using statistical tools and further presented as annual flows of plastic from the Norwegian commercial fishing practices using Material Flow Analysis (MFA) as elaborated in Deshpande (2020b).

Step-5: Develop evidence-based management strategies

In resource management, strategies backed by scientific evidence and stakeholder inclusion are considered robust. Therefore, based on the collected *information*, a set of strategies can be developed. This phase includes mapping of opportunities and barriers of realizing circular management of plastics from the fishing sector of Norway. The preliminary strategy development was conducted and potential strategies are presented in Deshpande and Haskins (2021).

Step-6 and Step-7: Validation and communication

Here, the suggested strategies and findings from the analysis are presented to the relevant expert stakeholders. The *expert judgment* is used to determine the sustainability of suggested management strategies for FG resources in Norway. Finally, the refined and validated strategies are communicated to the relevant stakeholders and regulatory actors for proposed improvement in the system. The suggested strategies, associated challenges, and opportunities are summarized in (Deshpande et al. 2020).

14.5 Lessons Learnt from a Multi-stakeholder Perspective

In designing strategies for circular economy for sustainable FG management, necessary scientific information was either segregated, outdated, or absent. This lack of information on FG system lifecycle processes and flows demanded the use of methods like MFA to help generate key evidence on mass flows of plastics from FGs. However, conducting MFA on FGs was challenging owing to significant variation in all of the six selected FGs. All the quantitative and qualitative information was obtained through several rounds of face-to-face or telephone interactions with stakeholders in the region. The data collection lasted for about 20 months, followed by verification of results through the stakeholders. Verification proved to be a critical step as converting all of the information to a uniform quantitative form resulted in uncertainties. Through verification, the uncertainties were minimized, and robust results were communicated. The results from MFA, where the data were collected from stakeholders ranging from producers, recyclers, fishers, waste managers, waste collectors, beach cleaning agencies, and regulatory actors, are compiled and presented in Deshpande (2020b).

Dealing with multiple stakeholders, and especially fishers, was a distinctive experience. As a primary resource user, fishers possess an abundant source of information, but extracting that information for scientific purposes was challenging. While designing the questionnaire, an emphasis was given on constructing lucid, concise, and apt questions in the local language (Norwegian) with the help of the *Fishers Association in Trondheim* and the *Institute of Marine Research in Bergen* to avoid ambiguity in the questions. The face-to-face survey method was used to minimize confusion in the survey responses. However, uncertainty in survey responses can be attributed to responders speculating while answering specific questions where they lack knowledge. For designing management strategies for FGs, it was important to capture the annual purchase, repair, loss, disposal patterns, and typical life span of FGs. Therefore, survey questions required fishers to summarize the past 10–20 years of fishing practices, which could lead to memory bias and unavoidable subjectivity. Additionally, statistical variations in responses from fishers are due to differences in fishing practices, target species, fishing grounds (coastal or deep-water), fishing quotas, and experience, among other things. The detailed method of data collection and formulas used in estimating the patterns in FG use are discussed in Deshpande et al. (2019a).

Interaction with regional and local waste managers, collectors, and recyclers established that waste FGs could be recycled at the industrial scale using mechanical recycling technology. The mechanical recycling of plastics from EOL FGs results in the production of HDPE and LDPE polymers, the effective use of which has been demonstrated in injection-molding technology by various plastic industries in the Nordic region. Site visits and interviews with industrial stakeholders made clear the possibility of replacing virgin polymers in the production of fish farming brackets and walkways used in the aquaculture sector with recycled polymers from the fishing sector. Currently, plastic producers in the region are exploring these opportunities through pilot projects and physical tests on recycled polymers to establish the industrial symbiotic models, as presented in the study by Deshpande et al. (2020a). The interaction with waste recyclers and collectors also highlighted the barriers in establishing circular strategies for plastics from FGs. Few of the challenges mentioned by the stakeholders are quality of waste FGs, absence of segregation facilities, lack of strong policy drivers allowing landfilling over recycling, and mixed waste resulting in non-uniform quality of recycled plastics. The barriers and opportunities for circular and sustainable waste management of FGs are discussed in the study (Deshpande and Haskins 2021).

14.6 Conclusion

Stakeholders are vital in generating information essential for sound decision-making. This chapter highlights the need for stakeholder and resource user knowledge and its relevance for developing sustainable strategies for resource management using a case of the commercial fishing sector of Norway. The stepwise framework is presented here to identify an overall goal, information gaps, map relevant stakeholders, and propose methods to extract information from them. The developed strategies can then be validated through expert stakeholders to ensure robust decision-making.

The multi-stakeholder perspective was applied using the case of FG resource management in Norway. The successful application of a framework for the case was possible due to the engagement and support of various regional stakeholders. Hence, although subjective and uncertain, the knowledge of resource users (fishers) and other stakeholders was key to generating valuable evidence on the circular management of a resource system previously considered subject to mismanagement due to a lack of scientific knowledge.

In conclusion, involving the resource users, ‘fishers’, through the framework was proven to be an effective strategy for building evidence on FG parameters that are otherwise not measurable. These parameters can be used to estimate regional flows of plastic and other FG materials through material flow analysis (MFA) models. Furthermore, the simplicity of the stepwise method makes it practical and easily reproducible elsewhere to obtain the relevant scientific estimates on studied parameters for respective countries/regions, which is the critical necessity for good science.

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