Chapter 2
A Conceptual Framework for Assessing and Managing Abandoned, Lost and Discarded Fishing Gear

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Abstract Abandoned, lost or otherwise discarded fishing gear (ALDFG) is a complex problem that causes negative ecological, economic and social impacts. In order to understand cause-and-effect chains spanning socio-economic and ecological systems and identify and assess potential improvement measures, a holistic approach is necessary. In this chapter, we introduce a framework for assessing ALDFG and aquaculture gear from commercial fishing and fish farming activities in Norway. The proposed framework integrates the Drivers, Pressures, States, Impacts and Responses (DPSIR) framework with ecosystem accounting, to assess impacts and improvement measures more holistically and explicitly. The framework includes indicators for each aspect, derived from international and national frameworks and data sets. Drivers and pressures are related to existing data sets on fishing and aquaculture production and ALDFGs, whereas the ecosystem accounting framework is used as a lens for developing the state and impact aspects of the model. A leverage points view of circular economy solutions to the problem of ALDFG is taken for the Responses aspect of the model.

Keywords ALDFG · Circular economy · Leverage points · Ecosystem services · DPSIR framework

2.1 Introduction

Marine and coastal ecosystems are under increasing pressure from pollution and overexploitation of resources driven by industries such as fishing and aquaculture (IPBES 2019). These drivers and pressures are inhibiting the planet's ability to provide a safe operating space for humanity (Barbier 2017; Bratman et al. 2019; Orth et al. 2020). In Norway alone, coastal areas and oceans are estimated to provide between 12,000 and

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14,000 million Euros of ecosystem services per year (Skre 2017). However, these services are being impacted by pollution of ocean and coastal areas with plastic fishing and aquaculture gear. It is estimated that 380 tonnes of plastic waste from commercial fishing enter Norwegian waters each year (Deshpande et al. 2020).

Abandoned, lost or otherwise discarded fishing gear (ALDFG) are dispersed throughout marine habitat biomes and can impact a range of ecosystem services (ES). In the water column, ghost fishing by ALDFG can impact fish populations for several months before they become a feature of the sea floor where they are found to disturb important nursery areas for fish (Brown and Macfadyen 2007; Laist 1997). ALDFG on beaches and other coastal habitats are now a common feature across Norway. This can reduce the aesthetic value of coastal areas as well as having an impact on the biochemical flows within sediments.

There are currently several policies and measures in place to help manage ALDFGs. In this chapter, a framework to assess and manage ALDFG is presented, as a tool to link and trace drivers, activities, pressures, states, impacts and responses in a holistic manner. The framework includes aspects and indicators that help structure, monitor and manage key elements.

2.2 Background and Key Concepts

The proposed framework builds on several key concepts and frameworks briefly introduced in this section.

2.2.1 DPSIR

Drivers, Pressures, State, Impact, Response (DPSIR) is an internationally recognised, holistic framework, to provide an understanding of the cause-and-effect associations between human activities and the natural environment. The origins of DPSIR can be found in the OECD's (Organisation of Economic Co-Operation and Development) PSR (Pressure, State, Response) framework (OECD 1994). PSR was designed to provide structure for the OECD's environmental policies and reporting. The flexibility of PSR has meant that other international institutions have been able to adapt the framework to their own requirements, such as the Driver-Pressure-State-Impact-Response (DPSIR) developed by the European Environmental Agency (EEA 1999). DPSIR is now used at multiple levels of governance from the EU and OECD to small communities. Table 2.1 provides a description of the constituent parts of the DPSIR framework and the more recent DAPSIR-ALDFG framework (Drivers-Activities-Pressures-State-Impact-Response.

DPSIR has proved to be a powerful tool for understanding causal relationships between human developments and the natural environment. However, certain conceptual changes to the framework have been required to operationalise the framework at

Table 2.1 Responses and leverage points for managing ALDFG in fisheries and aquaculture

Leverage points, listed in increasing level of effectiveness (Meadows 1999)	Example of response measure	Increased stocks and flows	Reduced stocks and flows
12. Constants, parameters, numbers (such as subsidies, taxes, standards)	Beach and ocean clean-ups	F4	S2
11. The sizes of buffers and other stabilising stocks, relative to their flows	Support for increased gear repair and reuse	F1	F3
10. The structure of material stocks and flows (such as transport networks, population age structures)	Port reception facilities	F2, S3	F3
9. The lengths of delays, relative to the rate of system change Gear redesign: biodegradeable		S3?	S3?
8. The strength of negative feedback loops, relative to the impacts they are trying to correct against	Gear retrieval regulation/practices (time spent retrieving lost gear reduces time for commercial fishing)	F2, S3	F3, S2
7. The gain around driving positive feedback loops	Reward schemes, such as, e.g. gear payback systems	F2, S3	F3, S2
	Reward schemes (or raw material prices) to incentivise products with recycled content from fisheries and aquaculture	F7, S6	F3–F6
6. The structure of information flows (who does and does not have access to information)	Public records of gear material balance	F2	F3
	Ecolabels of new products with recycled content	F5, S4	F3–F6
5. The rules of the system (such as incentives, punishments, constraints)	Extended producer responsibility	F1, F2, F4–F7, S3–S6	F3, S2
4. The power to add, change, evolve, or self-organise, system structure	Circular economy and business models	All	All
3. The goals of the system			
2. The mindset or paradigm out of which the system arises (goals, structures, rules)			
1. The power to transcend paradigms			

lower levels of governance. The initial improvement to the framework was suggested by Cooper (2013), who aimed to link the different aspects of the DPSIR framework by providing slight elaborations on their definitions. Cooper finds that the original DPSIR framework does not allow for direct relationships between the five aspects of the framework. For example, the Drivers aspect, initially conceived as "social, demographic or economic developments in societies" (Cooper 2013), is too broad to allow for a direct coupling with the Pressures aspect of the framework. He further suggests that the Drivers category should be defined as "an activity or process intended to enhance human welfare" and can be broken down into two categories: distinct Drivers, "activities proximal to at least one Pressure"; and Underlying Drivers, social or economic developments, identical to the Drivers in the original framework. This elaboration allows each distinct driver to be linked to at least one pressure, allowing for the highlighting of causal relationships between these two aspects of the framework.

Elliott et al. (2017) furthermore make a clearer distinction between the two types of Drivers by adding the Activities aspect, which replaces the Distinct Drivers from Cooper's (2013) framework. The Pressures aspect of the framework is coupled to both the Activity and the State (change) by the two authors (Cooper 2013; Elliott et al. 2017). Pressures are defined as those aspects which are caused by at least one Activity that contribute to a change in the State. The next part of the framework is State (change) (Atkins et al. 2011). Cooper (2013) defines State as "an attribute or set of attributes of the natural environment that reflect its integrity regarding a specified issue". Elliott et al. (2017) suggest using a framework similar to Natural Capital Accounting here, whereby changes to ecosystems and the ecosystem services they produce should be used as proxies for the state. This leaves the benefits from the ecosystem services as the logical measure for the Impacts (Welfare) in the Elliott et al. (2017) framework. Responses (Measures) are the final part of the framework and relate to actions that can be taken to positively change the system. Elliott et al. (2017, p. 38) recommend that each measure should address one or more of the 10 tenets for successful environmental management, which state that measures should be: ecologically sustainable, technologically feasible, economically viable, socially desirable, legally permissible, administratively achievable, politically expedient, ethically defensible, culturally inclusive and effectively communicable.

2.2.2 Natural Capital Accounting

Natural capital is now recognised as integral to the World Economy (Barbier 2019) and attempts are being made to standardise and integrate natural capital accounting into the System of National Accounts (SNA) (UN 2021) and business decision-making frameworks (Natural Capital Coalition 2016). Natural capital is made up of three main components: subsoil assets, such as minerals and fossil fuels; abiotic flows, such as wind and solar energy; and ecosystem capital, made up of ecosystems and the services that flow to us and create value (Maes et al. 2013). Generally, economic activity has prevailed at the cost of natural capital. Nevertheless, economics is now viewed as a solution to natural capital loss by providing a frame for natural capital valuation (Polasky and Daily 2021). An important concept associated with natural capital is ecosystem services (ES). This concept details the flow of contributions from natural systems to humans, such as global and local climate regulation, coastal protection, water purification and air filtration. It is more than twenty years since Costanza et al. (1997) estimated that ES were worth an average of US$33 trillion per year globally. Researchers have since been trying to understand, and value, the multiple contributions that we receive from nature (IPBES 2016, 2019; Millennium Ecosystem Assessment 2005; TEEB 2010). More recently, ES assessments have moved towards the spatial distribution of both the flow of services and the ecosystem stocks, using accounting methodologies. The most significant development has been the publication of a full ecosystem accounting framework by the United Nations (2021). It is hoped that this framework will provide policy and decision makers with the data that they need to incorporate ecosystem stocks and service flows into their planning decisions. The process results in the development of accounts for a certain geographically bound system. The ecosystem extent account provides a tabular description of the hectares of each ecosystem type within the system. The ecosystem condition account describes the condition of each ecosystem within the ecosystem extent account. The condition can be measured by assessing the pressures, generally in terms of pollutants or land use change, on the ecosystems within the system. A full natural capital account, consisting of the ecosystem extent, ecosystem condition and ecosystem service flows can contribute to a range of aspects of the DAPSIR-ALDFG framework.

2.2.3 Circular Economy

The Circular Economy is described by Kirchherr et al. (2017) as

> An economic system that replaces the 'end-of-life' concept with reducing, alternatively reusing, recycling, and recovering materials, or energy, in production/distribution and consumption processes… with the aim to accomplish sustainable development… It is enabled by novel business models and responsible consumers.

The roots of the Circular Economy concept can be found in a range of academic disciplines, such as Ecological Economics and Industrial Ecology (Bruel et al. 2019). One of the first Ecological Economists, Kenneth Boulding, coined the phrase the *cowboy economy* to describe the current system of economics where supposed limitless resources can be exploited recklessly and success is measured on the throughput of resources through the system (Boulding 1966). Boulding proposes an alternative economy, the *spaceman economy*, as a more realistic view of our interaction with the environment. The *spaceman economy* is more similar to what we now call the Circular Economy: resources are limited and a cyclical reproduction of materials is necessary, albeit with the inevitable loss of energy from the system. The success criteria for the *spaceman economy* is based on the quality, and extent of capital stocks, rather than the throughput of resources. Recent conceptions of the Circular Economy are less radical than Boulding's proposal of changing our entire economic system. Rather, the Circular Economy has been designed to fit within our current economic system and to improve our use of resources and reduce externalities, in the form of pollution. The Circular Economy is thus more a set of principles that can be followed by individuals, organisations and institutions, in order to help them to reduce their environmental footprint (Kirchherr et al. 2017).

2.2.4 Leverage Points Analysis

Meadows (1999) developed the leverage points analysis to highlight "places to intervene in a system". The analysis interventions are divided in those which will have a deep system impact and those which will have a shallow impact. For example, changing the goals of a system is viewed as a deep leverage point, whereas changing the strength of feedback loops within a system is viewed as a shallow leverage point. Recent reviews assessing the use of leverage points have highlighted that mainly shallow leverage points are addressed, and therefore, we now have to focus on deeper leverage points in order to affect valuable changes. In this chapter, leverage points are used to categorise various responses within the DPSIR model to highlight the type of impact on the system they are likely to have.

2.2.5 Sustainability Indicators

Four of the main types of indicators used for Sustainability assessments are descriptive, performance, efficiency and welfare (EEA 1999). Descriptive indicators are used to describe the actual situation. For example, a descriptive indicator for the activity of the aquaculture industry could be the exported fish per year. A performance indicator is normally developed against a policy or a regional/national target and provides an indication of the distance of the current situation from the target. Efficiency indicators are those which assess the interaction between different aspect. This type of indicator would help to show how changes in technologies or policies effect different aspects of a system. Finally, welfare indicators are those which tell us whether we are better off. Typically, this would be gross domestic product (GDP), but this is limited to economic welfare; therefore, we may want to use an indicator which captures more of the natural environment, such as Gross Ecosystem Product (GEP) (Ouyang et al. 2020), the economic contribution of ecosystems to society.

2.3 The DAPSIR-ALDFG Framework

The DAPSIR-ALDFG framework combines the introduced concepts into a joint framework to assess and manage ALDFG. The framework builds on the DPSIR indicator system to accommodate a traceable and measurable linkage between drivers, activities, pressures, states, impacts and responses in the fisheries and aquaculture sector and associated production systems. Figure 2.1 shows an outline of the framework from a systems perspective. The framework encompasses both physical and non-physical elements within these systems, such as ecosystems (physical) and policy measures (non-physical). In the following sections, aspects and indicators of the framework will be elaborated.

2.3.1 Aspects

Several aspects are based upon the themes presented earlier in this chapter, such as natural capital accounting and circular economy.

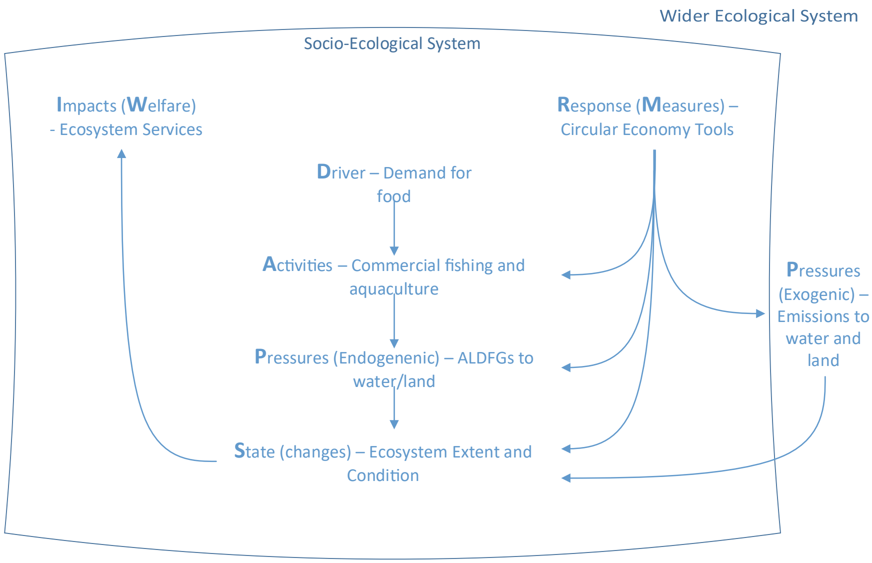

Fig. 2.1 DAPSIR-ALDFG framework. Modified from Cooper (2013), Elliott et al. (2017)

2.3.1.1 Drivers

A driver is a broad human activity that enhances human welfare (Cooper 2013) or our basic human needs (Elliott et al. 2017). In the case of ALDFG, the demand for fish is the main driver. In the study by Skirtun et al. (2022), they formulate the driver as "global seafood demand and a stable wild-capture production", they use statistics from a private company, Det Norske Veritas (DNV). In this study, we take global seafood demand as the main driver and suggest the OECD-FAO projections on the demand for aquaculture and fish products. OECD (Organisation for Economic Co-operation and Development) and FAO (Food and Agriculture Organisation of the United Nations) are international organisations which have been working internationally for over 60 years in the pursuit of prosperity and the defeat of hunger respectively. The OECD et al. (2022) outlook reports provide us with a projection of the demand for fish over the next 30 years. These reports can help us to understand the direction of travel of the commercial fishing and aquaculture. This may indicate whether the ALDFG and aquaculture gear issues will increase or decrease in the coming years.

2.3.1.2 Activities and Subactivities

Activities are broken down into aquaculture and capture fisheries in Norway. This links with the driver of food demand as we would expect a positive effect of demand for food globally on the production of fish from aquaculture and fisheries.

The subactivities associated with the activities are the large parts of the fisheries and aquaculture industry. For aquaculture, we consider salmon production and for fisheries, different types of fishing gear. The activities link to the pressures which are the abandonment, loss or discard of fishing or aquaculture gear in the marine environment. Subactivities include fishing/aquaculture in adverse weather conditions (Skirtun et al. 2022), fishing crew training (poor maintenance of fishing gear) and damage by wildlife, as described by Richardson et al. (2021).

2.3.1.3 Pressures

Each sub activity results in specific pressures on the biotic and abiotic environment resulting in a change in the state. The pressures are divided into the different fishing and aquaculture gear discarded into the marine environment. The pressures in this case are divided into the different OSPAR categories of marine waste (Lacroix et al. 2022) as these are used for data collection or beach cleans. This means that the pressures can be linked to on-going studies about the abundance of different types of fishing and aquaculture gear which is found on beaches, giving a long-term estimate of the pressure that such gear is putting on the environment.

One aspect missing from the pressures here is the limit or reference value for the type of gear: how much of the gear in the natural environment can be present before its state changes significantly? And what about the welfare that is derived from the natural environment?

2.3.1.4 State

The ecosystem accounting framework is used here to describe the state (change). Ecosystem accounting begins with the calculation of the extent, and then the condition, of each ecosystem type. In this case, we have used the IUCN framework to describe coastal and marine ecosystems (Keith et al. 2020). We suggest that the condition of each ecosystem can be calculated using the volume of ALDFG or aquaculture gear in each ecosystem. It will be important to decide on reference values for these condition variables in order to determine if an ecosystem is in optimal or suboptimal condition. Reference values can be calculated in a number of ways, using protected areas, expert elicitation, etc. In the case of plastics, these are now ubiquitous (Villarrubia-Gómez et al. 2018) and as such, it is difficult to find a perfectly intact marine or coastal environment unaffected by plastics.

The state of the biotic and abiotic marine and coastal environments are all affected by pressures from ALDFG. The condition of different ecosystem types is affected by the addition of ALDFG; therefore, we require data on both the extent and condition of each relevant ecosystem type. The abiotic environment, including the water column, subsea sediment and soil substrates are all affected by ALDFG.

2.3.1.5 Impact

Ecosystem services are used to describe the impact on welfare as a result in state changes. Ecosystems provide bundles of services to human beings (Klain et al. 2014). A change in the extent or condition of ecosystems, can thus have a multitude of effects on the services that they can provide (Grizzetti et al. 2019). An appropriate indicator here may be the Gross Ecosystem Production (in NOK) per hectare of ecosystem type (Ouyang et al. 2020).

Ecosystem services break down into three broad categories, provisioning, regulating and cultural services (Haines-Young and Potschin-Young 2018). These services provide different benefits to us such as, food provisioning, climate control, and recreational opportunities respectively.

The cascade model of ecosystem services (Haines-Young and Potschin-Young 2018) proposes that ecosystems in good condition, provide certain ecosystem services from which we benefit. Interference with the condition of ecosystems can result in changes to the ecosystem services and thus the benefits that we receive. There are multiple links between marine plastic and ecosystem condition/ecosystem services (Beaumont et al. 2019). Here we identify a number of the impacts from ALDFG or aquaculture gear.

Impact on Provisioning Services

ALDFG nets in the Marine and Marine/Terrestrial (coastal) environments can result in reductions in ecosystem services, and thus, our welfare. Once lost in the water column, nets can continue to catch fish for months reducing the potential catch for commercial fishermen (Macfadyen et al. 2009). Fishing gear is also associated with increased costs of commercial fishing due to entanglements, damage to gear and loss of operating time, these costs amounted to over 1 million pounds of losses for Scottish fishermen (Riddington et al. 2014).

Impacts on Cultural Services

Nature-based tourism around bird watching can bring large economic benefits to rural areas (Schwoerer and Dawson 2022). Debris from fishing and aquaculture activities can also impact on bird species: Ingestion of plastics can result in the reduction in fitness of individual birds and furthermore reduce their ability to rear young (Browne et al. 2015).

Culturally important animals, such as whales, are known to be particularly vulnerable to entanglement due to the their feeding behaviour and morphology (Saez et al. 2021).

In the Marine/Terrestrial environment ALDFG impact on the aesthetic value of coastal areas, reducing associated cultural ecosystem services (Leggett et al. 2018). Moreover, it is often volunteer groups responsible for cleaning beaches (Cyvin et al. 2021) resulting in hours of unpaid labour and exposure of vulnerable groups to potentially contaminated and hazardous debris (Campbell et al. 2016).

Impacts on Regulating Services

Coral reefs are important nurseries for young fish, which will be the source of fish catch in the future. Derelict nets often accumulate on reefs (Chiappone et al. 2002) and can result in physical damage to coral reefs (Al-Jufaili et al. 1999). Paradoxically, the removal of nets from coral reefs is also associated with considerably damage to the reef structure (Donohue et al. 2001) Moreover, fishing gear can also act as reefs in themselves, providing additional complexity to the habitat (Erzini et al. 1997).

2.3.1.6 Response

Responses (Measures) are those attempts by individuals, groups, municipalities or governments to "prevent, compensate, ameliorate or adapt to changes in the state of the environment" (EEA 1999). To illustrate this, we use the leverage points framework by Meadows (1999) to describe various responses or measures that could help impact different aspects of the DAPSIR-ALDFG model. As the leverage point analysis follows a systems perspective, Fig. 2.2 is presented to provide a reference for which elements within the fisheries and aquaculture system and end-of-life treatment responses target. Although a more detailed systems perspective could have offered

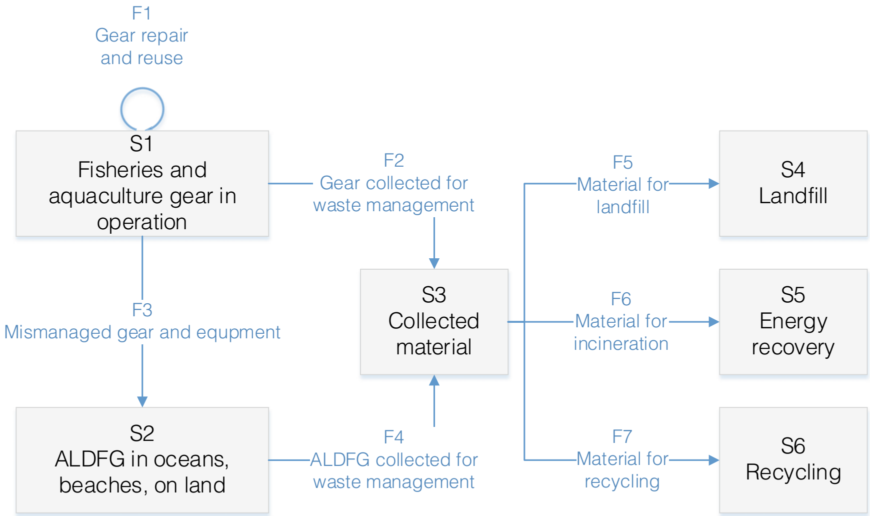

Fig. 2.2 Fisheries and aquaculture system with respect to ALDFG and gear management. F = flows, S = stocks

a more elaborate discussion of responses, a reduced model is used to illustrate the main points.

Figure 2.2 shows stocks and flows of fisheries and aquaculture gear and equipment. Activities and subactivities in fisheries and aquaculture involve gear in use (S1). Gear is frequently repaired and reused directly (F1), extending their time in operation. Gear is delivered for further waste management (F2) at ports and other collection points (S3). Gear loss due to for example weather conditions or gear conflicts, as well as gear dumping generates a flow (F3) of ALDFG in nature (S2). Ocean and beach cleanup activities may retrieve parts of this gear (F4) for storage, sorting and waste management (S4). Collected gear and ALDFG will be sorted and further processed depending on their condition, value and available technology and infrastructure. Possible end-of-life options involve landfill (F5, S4), incineration and energy recovery (F6, S5) and ideally recycling (F7, S6).

To consider responses for managing gear from fisheries and aquaculture more efficiently, we will analyze them according to which type of leverage points they target in the described system. Table 2.1 shows the 12 leverage points introduced by Meadows (1999), listed in increasing order of effectiveness.

At the lowest level, we find responses that target constants, parameters and numbers. Although several examples could be listed here, ocean and beach cleanups are good examples of such measures. Although they are critical to mitigate problems arising from ALDFG, they are not effective at targeting the original problems, which is gear loss and dumping. Targeting buffers and other stocks, such as supporting increased repair and recycling (flow F1 in Fig. 2.2), may for instance discourage gear dumping activities. This could be done through a number of measures, e.g. training and education or introducing taxes and fees on gear.

Port reception facilities is another response that discourages gear dumping by introducing infrastructure that facilitates more efficient collection of gear. This would not only discourage dumping but also increase the incentive to retrieve lost gear in capture fisheries as it could minimise the time gear which is not in operation occupies space on board vessels.

Gear redesign to reduce the impact of gear once it is lost or dumped could delay the time between gear becoming mismanaged (ALDFG) and negatively affecting ecosystem services. If efficient, this measure would reduce stock S2 (ALDFG in nature) without necessarily affecting flows in and out of that stock. However, caution should be made with respect to these types of measures as they may quickly incentivise more gear dumping, thereby increasing both flow F3 and stock S2.

Extended producer responsibility is an important, systemic response that ultimately target all stocks and flows in the system. By making gear producers responsible for collecting and managing obsolete gear, the potential ALDFG stock may be minimised, while material for downstream solutions after collection would increase. Although this measure is systemic, it is still a regulatory measure, required from industry through government regulation.

The potential to change the system at a deeper level is found in intervention points that fundamentally alter how the system works, evolve and self-organise, and furthermore introduce new goals and paradigm mindsets, ultimately leading to transcending paradigms. These types of responses require inner system drive. Circular economy responses such as circular business models all represent possible deep and effective changes to tackle ALDFG, as they integrate economic and environmental goals and are driven by system actors rather than regulatory action. They also cover all stocks and flows in the system depicted in Fig. 2.2 as they could positively create a demand for raw material (originating from activities in and beyond stock S4), as well as facilitate business opportunities in other places of the system, e.g. collection infrastructure and transport services. This book covers several examples of circular business models in relation to fisheries and aquaculture. Regulatory action to incentivise circular business models may still be useful in reducing barriers to establishing new enterprises, products and services.

2.3.2 Indicators

The DAPSIR-ALDFG framework helps organise aspects in a causal and traceable manner. To trace interactions across the system and monitor and verify performance of responses, creating system trajectories is useful. Figure 2.3 shows a system tracing example from the Norwegian fisheries and aquaculture industries. Once trajectories are identified, assessment and management indicator inventories can be built to

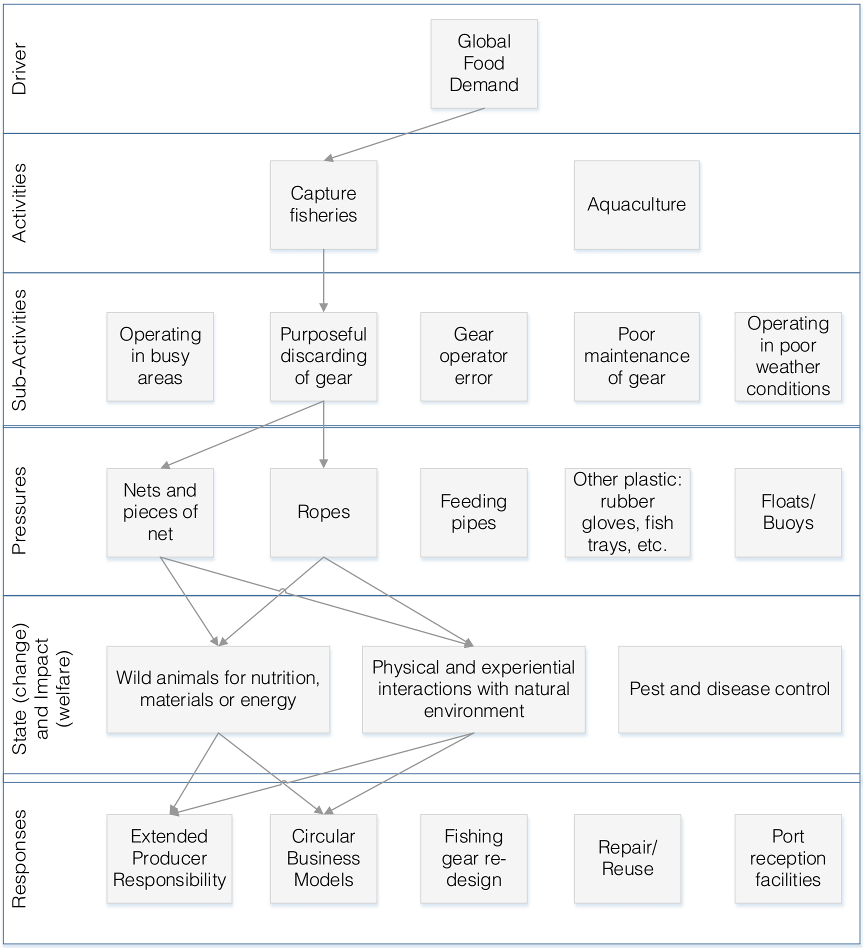

Fig. 2.3 Example of a trajectory in DAPSIR-ALDFG framework. Modified from Cooper (2013), Elliott et al. (2017), Smyth et al. (2015)

monitor system improvement. The indicator inventories would depend on trajectories to be considered, as well as data accessibility. A list of indicators for assessing and managing ALDFG in Norway is provided in Table 2.2.

2.4 Conclusions

In this chapter, we have presented the DAPSIR-ALDFG framework for assessing and managing ALDFG from commercial fishing and aquaculture in Norway. Several frameworks were used to build the model: ecosystem accounting for the states and

Table 2.2 Indicator inventory for ALDFG in Norway

Aspect	Indicator	Data sources
Driver	Global seafood demand: exports of fish for human consumption projections (descriptive indicator to indicate the direction of travel of the industries)	OECD/FAO (OECD et al. 2022)
Activities	Sea fishing. Fishermen, by contents and year	SSB
	Export of salmon, fresh and frozen, fish-farm bred	SSB
Subactivities	% fishers spend engaging in poor sub activities	No data source
	% aquaculture managers engage in poor sub activities	No data source
Pressures	PVC pipes (aquaculture)	OSPAR
	Ropes/cords (aquaculture/fishing)	OSPAR
	Buoys (aquaculture)	OSPAR
	Fish trays (aquaculture)	OSPAR
	Nets and pieces of nets (Fishing)	OSPAR
State	Ecosystem extent: hectares of each ecosystem type	Ecosystem extent accounts
	Ecosystem condition: ALDFG per ha of coastal ecosystems	Ecosystem condition accounts
	ALDFG per m3 of water column	
	ALDFG per m3 of soil substrate	
	ALDFG per m3 of subsea sediment	
Impact	Gross ecosystem production (NOK) per area of ecosystem type	Ecosystem extent and condition accounts
Response	Positive change in ecosystem condition accounts	Ecosystem extent and condition accounts
	Return on ecosystem based approach investment (change in ecosystem extent and condition per NOK spent)	Ecosystem extent and condition accounts

impacts, and the responses were framed around circular economy tools and categorised by the type of leverage point they may affect. The responses that have the potential to act at the deepest leverage points are the circular business models and the extended producer responsibility schemes. The practical responses, such as beach cleans and repairing of gear, can affect the stocks and flows of the fishing and aquaculture gear but may not provide the systematic change that is required to address the problem. All the indicators within the model were connected to suggested data sources to enable future modelling once ecosystem accounts are created for Norway's marine and coastal environments. This DAPSIR-ALDFG model can provide policy makers with a clear insight into how aquaculture and commercial fishing industries impact our welfare while at the same time provide some practical circular economy tools for addressing issues within these industries at multiple levels. Further iterations of the framework could include attempting a nested approach as proposed by

Elliott et al. (2017), whereby the framework is applied to socio-ecological systems in the same geographical area to assess how they interact, and react to, changes in the Norwegian system.

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