The Biological Potential for Sustainable Utilisation of Bycatch Species in Norwegian Fisheries

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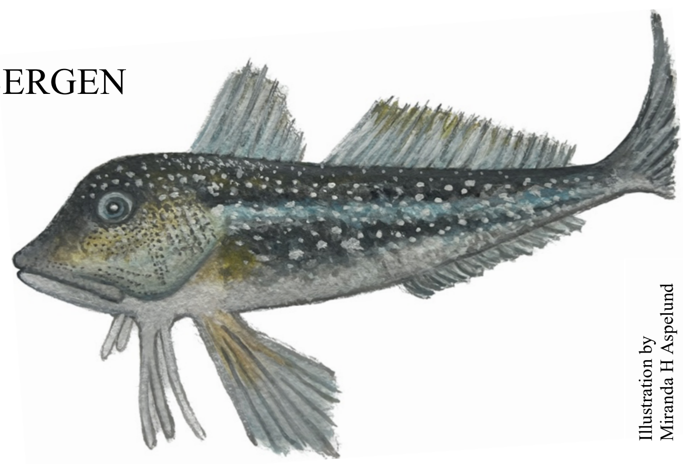

Illustration by
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ABSTRACT

With a growing global population and an increasing demand for food in the future, novel marine resources are needed. Some bycatch species may have little or no commercial value when there is not an established market for the particular species and no fishery targets them directly. As a result of this, bycatch are in many instances discarded at sea and not reported. Discarding of catches is considered unsustainable and a waste of natural resources as the organisms are not utilised. The four bycatch species grey gurnard (*Eutrigla gurnardus*), long rough dab (*Hippoglossoides platessoides*), megrim (*Lepidorhombus whiffiagonis*) and Norway redfish (*Sebastes viviparus*) were examined by investigating to what extent the four species were landed and utilised in Norwegian fisheries using data from the Norwegian Directorate of Fisheries. Further, the discarded and unreported catches of the species in a coastal gillnet fishery and in offshore trawl and longline fisheries were explored using data from the Norwegian Reference Fleet. The current study found that relatively small quantities were landed of the four focus species in Norway, and that much greater quantities of the catches were discarded and not reported. On average for the four focus species, 99.6% of the total annual catch weight comprised of discarded and unreported catches in the three fisheries examined. The findings of this study indicate that there are possibilities for improved and increased utilisation of the four focus species. Considering the indices currently available for the abundance of the species, increased, sustainable utilisation of the species could be possible, as long as a precautionary approach is followed. Increased utilisation of bycatch species can provide a valuable source of food for human consumption while also reducing waste in the fisheries sector, and should therefore be considered an important resource and be better utilised in the future.

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DEFINITIONS

Bycatch: The catch of non-target species that can either be landed or discarded.
Discards: The portion of animals in the total catch which is thrown away or dumped at sea before landing.
High-grading: The act of discarding individual fish with a lower commercial value to make room for catches with higher commercial value when space or quota is limited.
Landings: Catches that are retained onboard and landed upon returning to port.
Target species: One or more species which a fisher intends to capture.
Total catch: All biological material retained by the fishing gear and brought onboard the vessel. May also be used in the context of a single species.
Unreported catches: Catches that are not reported explicitly in official landing statistics. These include discarded catches, illegal catches and unmandated catches (catches for which there is no legal requirement to report upon landing).

1. INTRODUCTION

The global human population is projected to reach 9.6 billion by 2050, demanding a 60% increase in the global food production (FAO, 2011). Currently, fish provide approximately 20% of the world's animal protein and nearly 7% of all protein consumed by humans (FAO, 2016, 2018). However, many fish stocks have been heavily exploited in the past centuries and it is estimated that of the 600 marine fish stocks monitored by the Food and Agriculture Organization (FAO), 7% are depleted, 17% are overexploited and 52% are fully exploited (FAO, 2018). This highlights the need for novel marine food sources to meet the increasing demand for food and to relieve current fish stocks of the pressure they are experiencing today. Utilising marine species that are currently not being exploited or are underutilised, such as bycatch species, could provide potential solutions for addressing this issue.

In many commercial fisheries today, bycatch, the capture of non-target species, is commonly caught alongside the targeted species (Alverson et al., 1994; Clegg, 2022; Kelleher, 2005; Pascoe, 1997). Bycatch has for the past decades caught widespread attention in scientific communities, and a significant increase in the number of peer-reviewed publications with words associated to fisheries bycatch has been documented (Kelleher, 2005; Soykan et al., 2008). As a results of this, there has also been a growing interest and coverage of bycatch in the media. Many of the current studies on bycatch have focused their research on how the capture of non-target species may affect fish stocks, populations and ecosystems, and ways that gear technology and fishing practices can be improved to decrease bycatch in fisheries (Alverson et al., 1994; Crowder & Murawski, 1998; Davies et al., 2009; Komoroske & Lewison, 2015). However, few studies have until now investigated ways that bycatch species can be sustainably utilised and explored the biological potential that these species may hold, making it an area of research which requires further investigation.

Bycatch often represents a species diverse proportion of the total catch and can consist of fish or other animals that are of the same species or of different species than the target species (Alverson et al., 1994; Harrington et al., 2005; Pascoe, 1997). Fish of the same species may be considered bycatch if some of the individuals in the catch are for example below the minimum landing size or of the non-targeted sex (Pascoe, 1997). In fisheries where there are no defined or pre-determined target species, as for instance in mixed or small-scale artisanal fisheries, it can be challenging to determine which species constitute the bycatch (Davies et al., 2009; Pascoe, 1997). Bycatch happens as a result of no fishing gear being perfectly species or size selective, and because the targeted species tend to live in habitats that are occupied by a wide range of species, making it difficult for the fishers to only catch the target species (Clegg, 2022; Pascoe, 1997).

Some bycatch species may have little or no commercial value when there is not an established market for the particular species and no fishery targets them directly. In some cases, the costs related to landing the bycatch species (such as storage, icing and freight costs) may even exceed the potential profit that the fishers might receive for the bycatch (Clegg, 2022; Pascoe, 1997). As a result of this, it has been observed that species captured as bycatch are in many instances discarded at sea and not reported (Alverson et al., 1994; Crowder & Murawski, 1998; Davies et al., 2009). Discarding describes the process of throwing away or dumping fish or other animals overboard at sea, and therefore not landing the species (Clegg, 2022; Kelleher, 2005). Globally, it has been estimated that about 10% of the total annual catches of marine capture fisheries are discarded and not utilised (Madsen et al., 2022; Pérez Roda et al., 2019; Zeller et al., 2018). Discarding of organisms can also be a consequence of the catch containing protected species, species that the fisher does not hold quotas for, individuals that are below the minimum landing size, or due to high-grading, a process where individuals of lower value or quality are discarded to make space for catches with higher value when quotas or space onboard the fishing vessels are limited (Clegg, 2022; Pascoe, 1997).

Studies have found that the discarding of fish often results in the mortality of the organisms, even when the fish are returned to the ocean while assumed alive (Alverson et al., 1994). The mortality of discarded fish is commonly linked to the fish being injured while being in contact with the fishing gear, rapid pressure changes during fishing activities (barotrauma), suffocation as a result of the fish being above water for longer periods, prolonged soaking times when using passive gears, and the handling by fishers while the fish are on deck (Alverson et al., 1994; Davis, 2002; Wassenberg & Hill, 1989). Especially for species such as cod, whiting and redfishes (*Sebastes*) whose air bladders expand and trap them at the surface, survival rates are expected to be very low (Alverson et al., 1994; Cushing, 1984; Hill & Wassenberg, 1990). A study by Hill and Wassenberg (1990) examined the survival of discards in prawn trawlers in Australia and found that about half of the discarded fish floated (45%), and that the survival for some fin fish was as low as 2% (Hill & Wassenberg, 1990). For flatfishes caught as bycatch by shrimp vessels in the North Sea however, the survival was found to strongly depend on the species and the size of the individuals, as well as the catch processing conditions (Berghahn et al., 1992).

The discarding of fish and other animals in marine fisheries is considered a highly unsustainable practice and a waste of resources, both ecologically and economically, as the organisms are not utilised (Crowder & Murawski, 1998; Harrington et al., 2005; Stobutzki et al., 2001). This has made discarding an issue of global importance as it negatively affects the sustainable exploitation of marine resources and marine ecosystems and threatens the financial viability of fisheries (Madsen et al., 2022; Stobutzki et al., 2001). The discarding of marine organisms also affects fisheries management as it represents a significant source of uncertainty in stock assessments and in the estimation of fishing mortality (Clegg, 2022; Davis, 2002). In 1987, Norway implemented a discard ban on cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*) after it was discovered that the fisheries of these species were highly impacted by high-grading during the 1980s (Gullestad et al., 2015). In 2009 the discard ban was expanded to cover all species, stating that all species should be landed with the exception of a few species that were not covered by the ban (Anon, 2023b; Gullestad et al., 2015). Similarly, in 2015, a landing obligation was introduced by the European Union with an exemption for species for which scientific evidence demonstrated high survival rates (Madsen et al., 2022).

Due to the nature of fishing operations and the way catches are reported, information regarding bycatches and the discarding of marine species can be limited and include a high amount of uncertainty (Davis, 2002; Gilman et al., 2020). To improve the understanding of the Norwegian fisheries and their fishing activities, the Institute of Marine Research (IMR) established the Norwegian Reference Fleet in collaboration with the Norwegian fishing fleets in 2000 (Clegg & Williams, 2020). The fleet consists of both coastal and offshore fishing vessels that cover most of the Norwegian waters and includes vessels that use a wide range of gear types (Clegg & Williams, 2020). The Reference Fleet is a self-sampling programme where the fishers are paid to collect biological data such as length and weight measurements of catches, otoliths, scales and stomachs, and genetic and environmental samples (Nedreaas et al., 2006). The programme is aimed at collecting data to support stock assessments and to document fishing efforts and catch compositions. The fishers are tasked to keep a full record of their fishing activities and total catches, including bycatch, discards and the catches of non-commercial species, making it a valuable source of information regarding species that are frequently caught as bycatch and potentially often discarded in the Norwegian fisheries (Clegg, 2022; Clegg & Williams, 2020; Nedreaas et al., 2006).

The demersal species grey gurnard (*Eutrigla gurnardus*), long rough dab (*Hippoglossoides platessoides*), megrim (*Lepidorhombus whiffiagonis*) and Norway redfish (*Sebastes viviparus*) are examples of four species that are commonly captured as bycatch in Norwegian fisheries. Grey gurnard, *Eutrigla gurnardus,* belongs to the family Triglidae, consisting of gurnards and sea robins. The species is found in the eastern Atlantic from Morocco and the Mediterranean to Norway and Iceland and is widely distributed in the North Sea, being one of the ten most dominant species in the North Sea (Floeter et al., 2005; Heessen & Daan, 1994). Grey gurnard is usually found between 10 and 150 metres (Muus et al., 1999). Long rough dab, *Hippoglossoides platessoides*, is a flatfish common to the North Atlantic, belonging to the family Pleuronectidae. It is distributed on both sides of the North Atlantic and is recognised as one of the ten most abundant species in the Barents Sea (Walsh, 1996). Long rough dab lives on soft bottoms and is found at a depth range between 10 and 400 metres (Muus et al., 1999). Megrim, *Lepidorhombus whiffiagonis*, is a flatfish that is part of the Scophthalmidae family. It is distributed in the northeast Atlantic and can be found as far south as the west coast of Western Sahara (Sánchez et al., 1998). Megrim is commonly found on a sandy or muddy bottom and has a depth range of 100 to 700 metres (Sánchez et al., 1998). The Norway redfish, *Sebastes viviparus*, belongs to the family Scorpaenidae and is the smallest of the *Sebastes* species found in the North Atlantic (Barro, 2005; Johansen et al., 2002). It is commonly found shallower than the other redfish species, but may occur as deep as 600-700 metres (Barro, 2005; Johansen et al., 2002; Nedreaas et al., 1994). The Norway redfish is distributed along the coast of Norway from the south-western Barents Sea to the North Sea Trench, and is also found in the northern parts of the North Sea (Barro, 2005; Johansen et al., 2002).

The four bycatch species grey gurnard, long rough dab, megrim and Norway redfish are currently relatively unknown species for the normal consumer in Norway, as they are commonly not found in supermarkets or in restaurants. Because the species are not targeted directly by any fisheries and there is currently a limited market for the four bycatch species, it has been observed to be difficult at times for fishers to land these species when they have been captured. Bastille (2019) found there to be a great variation in which species that were landed or not depending on the geographical area. For the species that were caught in areas south of Bergen, 56% of the grey gurnard that had been captured were landed, 1% of long rough dab, 19% of megrim and 28% of Norway redfish in the period from 2012 to 2017 (Bastille, 2019). For the same species that had been caught on the Møre coast, 0.1% of the grey gurnard that had been caught were landed, 0.1% megrim, and 0% Norway redfish (Bastille, 2019). In a study by Berg and Nedreaas (2020) looking at discards in the coastal gillnet fishery, similar results were found; there were large regional differences in which species were landed and not landed (Berg & Nedreaas, 2020). Berg and Nedreaas (2020) concluded that the coastal gillnet fleet in Norway had access to greater resources than what was landed, and that several species had the potential to be better utilised as food sources in the future and the potential for greater value creation (Berg & Nedreaas, 2020).

It has been suggested in the FAO Code of Conduct for Responsible Fisheries that states should encourage those involved in the fish processing, distribution and marketing to improve the use of bycatch as long as it is done in agreement with responsible fisheries management practices (FAO, 1995). Similarly, in the 2016 National Bycatch Reduction Strategy by the National Oceanic and Atmospheric Administration (NOAA) in the United States, it was proposed that utilisation should be increased of fish that have been lawfully harvested but discarded due to the low market value (NOAA, 2016). NOAA suggested that finding ways to use legally caught bycatch could reduce the magnitude of bycatch and also provide economic benefits to the fishing industry (NOAA, 2016). Furthermore, studies have proposed that increased utilisation of bycatch could be an important approach to the reduction of discards (Kelleher, 2005). Even though the increased utilisation of bycatch has been suggested and proposed, it remains a relatively unexplored topic in Norwegian fisheries. The current study will try to investigate the biological potential of four bycatch species in Norway by comparing the landed and the discarded and unreported catches of these species, and discuss how the species could be sustainably utilised.

The main aim of the present thesis is to examine to what extent the four focus species, grey gurnard, long rough dab, megrim and Norway redfish, are landed and utilised in Norwegian fisheries, and to explore the biological potential for improved and increased utilisation by looking at the discarded and unreported catches of the focus species using data from the official landing statistics of the Norwegian Directorate of Fisheries and the Norwegian Reference Fleet.

To achieve this aim, specific objectives include:

1. To determine the quantity which was landed of the four focus species, and to describe the variations depending on year, season, geographical area and gear type.
2. To determine the quantity which was discarded and unreported of the four focus species in the gillnet, trawl and longline fisheries in two case study areas in coastal and offshore regions.
3. To determine the length distribution of the four focus species in catch group 23 (discarded individuals), catch group 26 (landed individuals) and catch group 29 (individuals processed for fish meal production), and to examine variations between catch group 23 and 26 depending on geographical area and gear type.
4. To discuss the potential for improved and increased utilisation of the four focus species in regards to sustainability and market potential.

2. MATERIALS & METHOD

2.1 Study Area and Fishery Characteristics

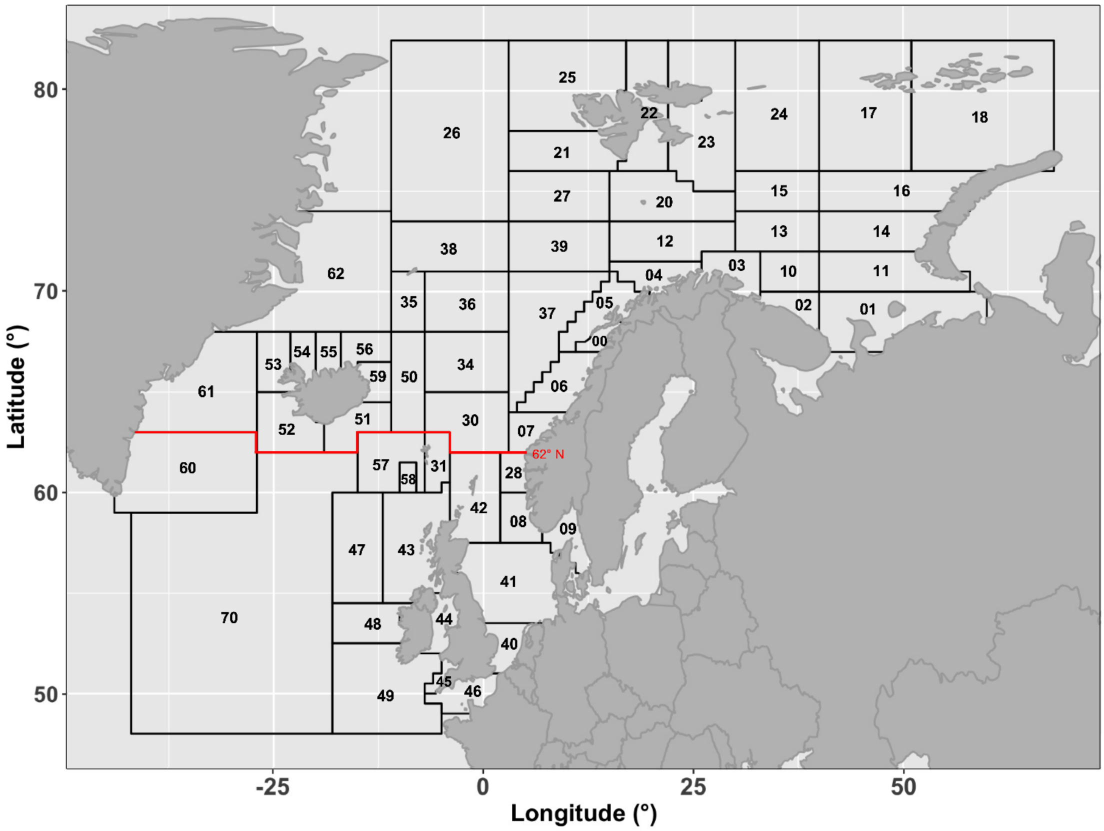

Figure 1: *Main statistical areas as defined by the Norwegian Directorate of Fisheries. Red line indicates the division between the areas north and south of 62° N.*

For the current thesis, the study area was defined as the main statistical areas of the Norwegian Directorate of Fisheries (Figure 1). These areas include the Norwegian Sea and the Norwegian territorial waters around Jan Mayen and Svalbard, as well as large parts of the Barents Sea, the Greenland Sea, the North Sea and the waters south of Iceland. To examine the differences in catches between areas in northern and southern locations, the statistical areas were divided at 62 degrees north latitude. The northern areas will be described as "north of 62° N" and southern areas as "south of 62° N" (Figure 1).

The fishing vessels operating within the main statistical areas consist of both offshore and coastal vessels, with the coastal vessels defined as vessels fishing inside of the 12 nautical mile boundary along the coast of Norway. As of 2022, a total of 5 611 fishing vessels were registered in Norway, of which 4 745 were classified as active vessels, meaning that these vessels generated income from their catches (Fiskeridirektoratet, 2022). The Norwegian fishing fleet operates year-round, but the vessels fishing in the northernmost areas may be restricted in the winter months by the sea ice cover (Clegg et al., 2023).

Coastal vessels are commonly smaller in size, the majority being less than 15 metres in overall length, and are often operated by a single person or a few crew members (Årland & Bjørndal, 2002; Bye & Lamvik, 2007). Of the total number of fishing vessels in Norway in 2022, 91.8% were vessels smaller than 15 metres in overall length (Fiskeridirektoratet, 2022). The smaller vessels are restricted in their operational range and tend to stay closer to shore and harbours as they have limited space and facilities onboard for processing and storing of the catches. The coastal fishing vessels are generally multi-gear vessels, where the gear type can change with the seasonal features of the fishery. The choice of fishing gear will also be determined by the size of the vessel and the number of crew members onboard (Fangel et al., 2015). Some of the most common gear types for coastal vessels include gillnets, longlines, shrimp trawls, seines and pots.

The offshore fishing vessels, on the other hand, are usually larger vessels that use gear types such as trawls, automatic longlines, nets and different types of seines. These vessels have the capacity to stay at sea for longer periods as they commonly have onboard processing facilities and large freezer units for storing of the catch (Clegg et al., 2021a). Offshore vessels are also better equipped to operate in areas further from shore and in rougher conditions, and usually have onboard accommodation for crew which allow them to stay at sea for several weeks (Fangel et al., 2015).

2.2 Data Sources

The data used in this study were acquired from the Norwegian Directorate of Fisheries and the Reference Fleet of the Norwegian Institute of Marine Research (IMR), which will be described in the following section.

2.2.1 *Official Landing Statistics of the Norwegian Directorate of Fisheries*

The official landing statistics of the Norwegian Directorate of Fisheries provide information about all catches that are landed and sold in Norway, including the quantity of the landed catches and the first-hand value of the products. The Norwegian Directorate of Fisheries is responsible for the mandatory logging of the landed catches which is done through a sales note-system (Anon, 2022; Fiskeridirektoratet, n.d.). The sales notes contain information about the catch and the fishing trip, including fish species, weight of the catch, size-composition in rough weight categories, vessel, fishing gear, area and location of fishing, and is reported to the directorate via one of the five Norwegian Sales Organisation (Anon, 2015; Fangel et al., 2015). The sales notes are signed by both the buyer and the seller to reduce the chances of false reporting, and must be sent to the sales organisations for the fisher to receive the payment from the sales organisations (Clegg et al., 2023).

For this study, the landing statistics for a period of 10 years, from 2012 to 2021, were explored. Landings that contained species of invertebrates were excluded from the data set. Landed catches that contained species of fish that had been caught in other statistical areas than those defined as the study area were also excluded. A complete overview of the catches landed of all species of fish in Norway for the period 2012 to 2021 can be found in Appendix 1. The landing statistics included information regarding the month when the catches were landed. These were organised into seasons where spring was defined as: March, April, May; summer as: June, July, August; autumn as: September, October, November; and winter as: December, January, February (Appendix 2). For some species, the landing statistics contained several accounts of the same species, often in regards to the geographical locality of the species; Atlantic herring was for example recorded as Skagerrak herring, Norwegian spring-spawning herring, North Sea herring etc. These groups were combined to find the total landed quantity for each individual species.

The landing statistics were used to quantify and visualise the different species of fish that had been landed in Norway from 2012 to 2021. Next, the four focus species, grey gurnard, long rough dab, megrim and Norway redfish, were examined further by quantifying and visualising the landings of these species by year, season, area and gear type. An overview of the landed quantities of the four focus species by season, statistical area and gear type can be found in Appendix 2, 3 and 4, respectively.

2.2.2 *Norwegian Reference Fleet*

The fishing vessels participating in the Norwegian Reference Fleet collect and report their catches and fishing activities to the Norwegian Institute of Marine Research (IMR). The crew are contracted and paid to report detailed information about everything they catch, including information regarding bycatch, discards and the catches of non-commercial species (Clegg & Williams, 2020; Nedreaas et al., 2006).

As of 2022, 22 coastal fishing vessels and 14 offshore vessels participated in the Norwegian Reference Fleet (Havforskningsinstituttet, 2023). Of the coastal vessels, all vessels were between 10.0 and 15.0 metres in overall length, while for the offshore vessels, the largest vessel was 75.5 metres in overall length, and the smallest was 34.0 metres. Norwegian fishing vessels can apply to be part of the Reference Fleet programme and will be randomly selected if several vessels apply and fulfil the selection criteria (Clegg & Williams, 2020). The contracts last for a period of four years, but the contracts may be renewed if the vessels are still eligible to apply. The vessels are selected based on their gear, target species and home port, with the aim of choosing vessels that are representative of the Norwegian fishing fleet and their fishing activity (Bjørge et al., 2013; Fangel et al., 2015). In addition, the crew of the selected vessels should be supportive of sustainable management and have a good reputation (Fangel et al., 2015). A complete list of the target species for each fishing gear used by the Norwegian Reference Fleet can be found in Table 5 in Clegg and Williams (2020).

Once a vessel has been selected and contracted to take part in the Reference Fleet, the vessel is assigned a research technician from the Norwegian Institute of Marine Research who is responsible for training the crew in the sampling techniques and data collection protocols of the programme (Moan et al., 2020; Nedreaas et al., 2006) The technician visits the vessel regularly to ensure that the sampling methods and data quality are maintained, and to assist the crew if they are experiencing any problems with the equipment or have other queries. The crew are also given literature to assist in species identification and are encouraged to send photographs and samples to the IMR if they are unsure and need verification by taxonomists (Clegg & Williams, 2020). The data reported by the Reference Fleet is frequently checked for anomalies and errors by the IMR, and if there are reasons to believe that the sampling from a vessel is inconsistent and that the crew has not followed the sampling protocol, the contract may be terminated (Bjørge et al., 2013). To ensure that the catches are accurately and truthfully reported by the crew, an agreement between the IMR, the participating fishers and enforcement and surveillance authorities were established. This ensures that the vessel can not be prosecuted, and that the data will not be requested for inspection or enforcement purposes (Clegg et al., 2021b; Clegg & Williams, 2020).

The sampling procedures and equipment used by the Reference Fleet are similar to those used by the IMR onboard their research vessels and during their research cruises (Nedreaas et al., 2006). The Coastal Reference Fleet and the Offshore Reference Fleet are both required to report their total catches and fishing activities, including bycatch and discards of all species, but follow slightly different protocols. The sampling design also differs depending on the gear used by the vessel. The Coastal Fleet record discarded and landed portions of the catch separately. In the Offshore Fleet however, discards have only been registered separately from landed catches since 2019. Prior to 2019, vessels only recorded their total catches with discards and landed catches combined.

In the Coastal Fleet, vessels report their catches daily, and take length measurements of their catches once a week. Up to 20 randomly selected individuals are length measured per species, including individuals caught as bycatch and individuals which are later discarded. The Offshore Fleet, however, reports their total catches every other day, and also takes length measurements of their catches every other day. Similarly to the Coastal Fleet, a maximum of 20 randomly selected individuals of each species are length measured.

All length measurements are measured as total length (TL), where the individual is measured from the tip of the snout to the end of the caudal fin (Mjanger et al., 2019). The length measurements are recorded in centimetres and are rounded down to the closest 0.5 cm for measurements below 50 cm, and rounded down to the closest 1 cm for measurements above 50 cm when using electronic fish sampling boards (Mjanger et al., 2019). For the vessels using conventional fish length measuring boards, length measurements are rounded down to the closest 1 cm. The weight of each species in the catch is measured as round weight in kilograms (the total weight of the fish prior to the removal of any parts). Data such as gear type and number, soak time, fishing depth (maximum and minimum), fishing time and location are also recorded. A complete overview of the sampling procedures of the Coastal and Offshore Reference Fleet can be found in Appendix B in Clegg and Williams (2020).

The Reference Fleet vessels are equipped with electronic fish sampling boards (Scantrol), electronic scales and computers with specialised software to report their catch data (Havforskningsinstituttet, 2023; Nedreaas et al., 2006). They are also provided with waterproof iPads with the Sea2Data software for registering their catches. Some of the smaller vessels in the Coastal Fleet prefer to use conventional fish length measuring boards and paper forms, but the use of electronic sampling boards and iPads are being implemented and tested by the vessels that wish to do so. The participating vessels in the Reference Fleet are required to keep electronic logbooks with their collected catch data, which are transmitted to the IMR using a satellite link and continuously added to the database (Havforskningsinstituttet, 2023; Nedreaas et al., 2006).

Data from the Norwegian Reference Fleet were used to examine the quantity discarded of the four focus species, grey gurnard, long rough dab, megrim and Norway redfish, in the coastal gillnet fishery, and the unreported quantity of the species in the trawl and longline fisheries in the Barents Sea. This was done using data from the studies Berg and Nedreaas (2020) and Clegg (2022) respectively, which will be described in the following sections.

2.2.2.1 Discarded Catches in the Coastal Gillnet Fishery

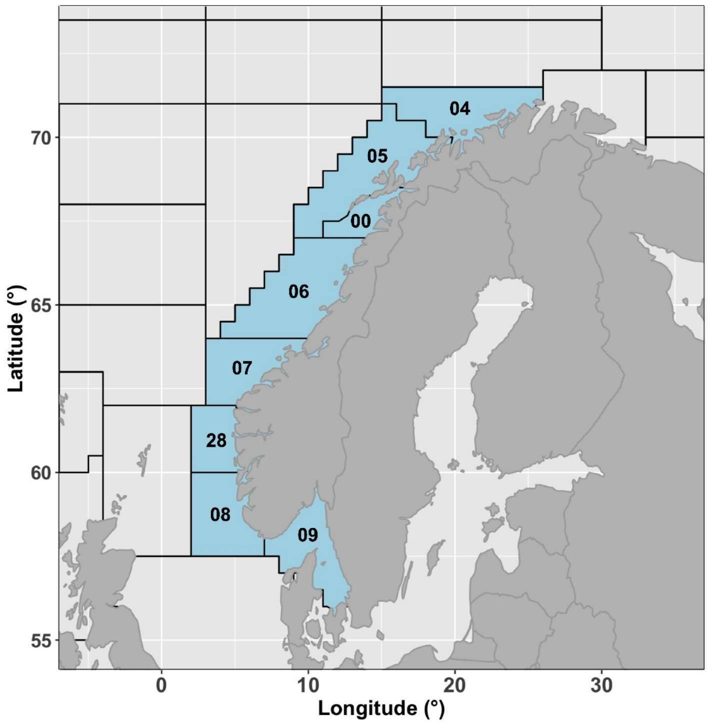

Figure 2: *Statistical areas in the coastal gillnet fishery used by Berg and Nedreaas (2020).*

The discarding of species caught by the Coastal Reference Fleet using gillnets in 2018 were estimated by Berg and Nedreaas (2020). The study looked at discards in the coastal gillnet fishery and used an upscaling method to apply this estimate to the entire fleet of coastal gillnetters in Norway. Their data were limited to the year 2018 and the study area included the statistical areas 04, 05, 00, 06, 07, 28, 08 and 09, covering the coast of Norway from the north to the south (Figure 2). Coastal vessels were defined as vessels smaller than 15 metres in overall length and operating inside of the 12 nautical mile boundary around the coast of Norway. A complete description of the methodology and estimation process can be found in Berg and Nedreaas (2020).

The estimated weight discarded of the four focus species, grey gurnard, long rough dab, megrim and Norway redfish, were retrieved from Berg and Nedreaas (2020) and used in the current thesis to describe the quantity that was discarded of these species in each statistical area in 2018. The estimation process and methodology used by Berg and Nedreaas (2020) are described in the following section. The calculations were done for each of the statistical areas included in the study.

The total number of individuals discarded of each species was calculated for each statistical area using data from the Coastal Reference Fleet (CRF). The number of sales notes containing catches with gillnets for each statistical area with vessels participating in the Coastal Reference Fleet was found in the official landing statistics. The mean number of individuals discarded per sales note of each species and area was then estimated using the following equation:

$$Number\ of\ individuals\ discarded\ per\ sales\ note = \frac{total\ number\ of individuals\ \ discarded\ from\ \ CRF}{total\ number\ of\ sales\ notes\ from\ CRF} \tag{1}$$

The mean number of individuals discarded per sales note per species was then multiplied by the total number of sales notes from vessels smaller than 15 metres in overall length and fishing with gillnets in each of the statistical areas to find the total number of individuals discarded of each species per area, using the following equation:

$$Total\ number\ of\ individuals\ discarded\ = \\ number\ of\ individuals\ discarded\ per\ sales\ note * \ total\ number\ of\ sales\ notes \tag{2}$$

In order to estimate the biomass discarded of each species in each statistical area, the estimated number of individuals discarded needed to be transformed to weight. First the mean weight of each species and area was calculated using the following equation:

$$W = a * L^b \tag{3}$$

where W is the weight of the individual (g), L is the length (mm), a is the species scaling coefficient, and b is the shape parameter based on the body form of the species (Brodziak, 2012).

The mean length of each species in each area was found by using the length measurements of discarded individuals collected by the Coastal Reference Fleet. Species specific a and b values for the length-weight relationship of each species were retrieved from the database of the Norwegian Institute of Marine Research. The database was based on length and weight data from IMR research cruises and the Norwegian Reference Fleet for the period 2010 to 2019.

The mean individual weight of each species for each area was multiplied with the total number of individuals discarded to find the total weight discarded of each species and for each statistical area using the following equation:

$$Total\ weight\ discarded\ of\ species\ X\ = \\ total\ number\ discarded\ of\ species\ X * mean\ weight\ of\ species\ X \tag{4}$$

In order to use this estimation process and methodology, it was assumed that the participating vessels in the Coastal Reference Fleet were representative of the rest of the coastal fleet fishing with gillnets in Norway. Additionally, it was assumed that all of the catches were reported accurately and sampled according to the methods and protocols of the Reference Fleet. For further details, see discussion of the methodology in section 4.2.

The estimated discarded weight of the four focus species in the coastal gillnet fishery for each statistical area for 2018 can be found in Appendix 5, in combination with the landed weight of the same species and the same areas for 2018 (Appendix 5).

2.2.2.2 Unreported Catches in the Trawl and Longline Fishery in the Barents Sea

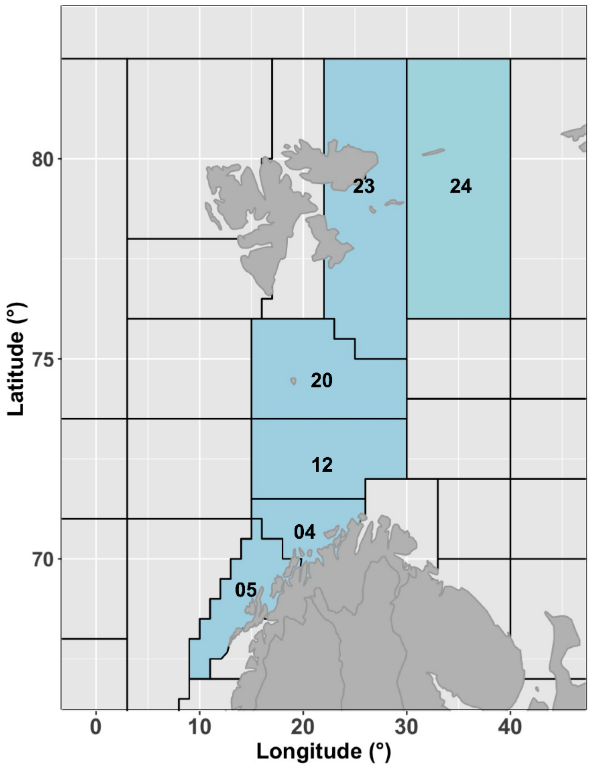

Figure 3: *Statistical areas in the trawl and longline fishery in the Barents Sea used by Clegg (2022). Area 24 was excluded from the longline fishery due to negligible fishing activity.*

The unreported catches of species caught by Offshore Reference Fleet vessels using trawl and longline in the Barents Sea was estimated by Clegg (2022; see Paper II, III and Appendix A). The study used data collected by the Norwegian Reference Fleet, daily electronic logbooks of fishing vessels and the sales notes from the Norwegian Directorate of Fisheries to estimate the unreported catches using unit- and ratio-based estimators. The data were collected from the period 2012 to 2018 by vessels above 28 metres in overall length, and the study area was defined as the statistical areas 04, 05, 12, 20, 23 and 24 (Figure 3). Area 24 was excluded from the longline fishery due to negligible fishing activity (Clegg, 2022).

The estimation process was based on the same approach used by Berg and Nedreaas (2020), but the methodology was adapted to the data that was available from offshore fisheries. While the Coastal Reference Fleet reported their discarded catches directly, the Offshore Fleet did not during the 2012 to 2018 period, and therefore total catches were used instead (Clegg *et al.*, 2023). The average total catch of the Reference Fleet vessels was first estimated. The estimated total catches were then extrapolated to the entire fishery using information regarding the fishing activity of trawl and longline vessels in the study area using the daily electronic logbooks. The total catch estimates were then compared to the official landing statistics based on the sales notes to estimate the unreported catches. The complete methodology for estimating unreported catches using the unit- and ratio-based estimators is described in Clegg *et al*. (2023).

In the longline fishery in the Barents Sea during the 2012 to 2018 period, there were no unreported catches of megrim. For the trawl fishery in the Barents Sea, the estimation of unreported catches was done on a limited number of 30 species due to data inaccuracies (Clegg, 2022: Appendix A). The study only used species that were recorded by the Norwegian Reference Fleet but did not appear in the sales notes for any given year. Therefore, the total catches that were estimated for the species were entirely unreported. As a result of this, there were no estimated unreported catches of long rough dab in the trawl fishery in the Barents Sea.

The estimated unreported catches of the four focus species, grey gurnard, long rough dab, megrim and Norway redfish, were retrieved from Clegg (2022) and used in the current thesis to describe the quantity of these species which were unreported in the period 2012 to 2018. The quantities estimated using the unit-based estimator were chosen for this study, as the estimates were based on catches per unit (for example per day) and therefore were more comparable to the landing statistics of the Norwegian Directorate of Fisheries. The data retrieved from Clegg (2022) contained estimates for all of the focus species except for long rough dab in the trawl fishery, and for all of the focus species except for megrim in the longline fishery.

The estimated unreported catches of the four focus species in the trawl and longline fishery for the period 2012 to 2018 can be found in Appendix 6 and 7, in combination with the landed weight of the same species and the same areas for 2012 to 2018 (Appendix 6 and 7).

2.2.2.3 Length Distributions

Length measurements from the Norwegian Reference Fleet of the four focus species, grey gurnard, long rough dab, megrim and Norway redfish, collected between 2012 and 2021 were used to explore the length distributions of the species. These data were collected by both coastal and offshore Reference Fleet vessels operating within the defined study area consisting of the main statistical areas of the Norwegian Directorate of Fisheries, and included vessels fishing with all gear types.

Table 1: *Catch groups used by the Norwegian Reference Fleet when reporting their catches. Descriptions explain what the catch will be used for.*

Catch group	Description
23	Discarded or not landed individuals
26	Landed individuals
29	Individuals processed to make fish meal

The individual length measurements sampled by the Reference Fleet vessels are recorded with information about the catch groups, i.e. a description of what the catch will be used for. The length measurements used in the current study contained measurements of individuals in group 23, 26 and 29 where: group 23 contained discarded or not landed individuals, group 26 contained landed individuals, and group 29 contained individuals that were processed to make fish meal (Table 1).

The length distributions of the four focus species in the different catch groups (23, 26 and 29) were first examined, and the difference between the mean length of the individuals in each catch group was found. The length distribution and mean length of the four focus species in group 23 (discarded individuals) and group 26 (landed individuals) were then explored further by analysing the differences between individuals caught north and south of 62° N, between individuals caught by coastal and offshore vessels, and between individuals caught by different types of fishing gear. The number of individuals measured, the mean length and the standard deviation of each group can be found in Appendix 8.

The length of each individual was recorded in centimetres and in numbers of individuals per length group consisting of 0.5 cm intervals, following the same length measuring procedures as described in section 2.2.2 (Mjanger et al., 2019). The number of individuals were transformed into percentages to display the length distribution. When examining the length distribution and the differences in the mean length of individuals in each catch group, it could be observed that groups containing few individuals gave imprecise results due to the small sample size. Groups that contained less than 15 length measurements were therefore not included.

2.3 Comparative Analysis of Landed and Discarded and Unreported Catches

The landed catches from the official landing statistics of the Norwegian Directorate of Fisheries were compared to the discarded and unreported catches estimated by Berg and Nedreaas (2020) and Clegg (2022) for the four focus species, grey gurnard, long rough dab, megrim and Norway redfish, to analyse how the quantities of these catches compared.

In order to be able to compare the landed and the discarded and unreported catches of the focus species, the same fisheries, areas and time period were chosen. For the coastal gillnet fishery, the discarded catches were only estimated for 2018. The estimated discarded quantities for all of the statistical areas used by Berg and Nedreaas (2020) were therefore combined to find the total annual discarded quantity of the gillnet fishery for each of the species. For the trawl and longline fisheries in the Barents Sea, however, unreported catches were estimated for the period 2012 to 2018. The average unreported catch quantity per year was therefore used for the trawl and longline fisheries. The unreported quantities for all of the statistical areas used by Clegg (2022) were combined for each of the fisheries, and then divided by the number of years to find the average unreported catch quantity per year for each of the fisheries and for each of the four focus species.

For the landed catches of the focus species, data were available for the period 2012 to 2021. For comparing the landed catches to the discarded and unreported catches, the average landed weight for the period 2012 to 2018 was used for each of the fisheries and for each of the species. The landed catch quantity for the statistical areas of each of the three fisheries were combined for each of the fisheries, and then divided by the number of years to find the average landed catch quantity per year for each fishery and for each of the four species.

A full overview of the landed and the discarded and unreported catches of the focus species in the gillnet, trawl and longline fisheries can be found in Appendix 6 and 7.

2.4 Data Analyses

The processing and analyses of the data was conducted in RStudio version 1.4.1717 with R version 4.1.1 (R Core Team, 2017), and in Microsoft Excel for Office 365. R packages used included *tidyverse* (Wickham, 2019) for data manipulation (*dplyr*) and plotting (*ggplot2*). For visualisation of the statistical areas of the Norwegian Directorate of Fisheries, R packages *RstoxFDA* (Holmin & Fuglebakk, 2022) and *rworldmap* (South, 2011) were used.

Statistical analyses were run to test if there was a significant difference in the mean length of the four focus species between the individuals measured in the different catch groups (23, 26 and 29). An ANOVA was used to explore the differences in the mean length between the three catch groups (23, 26 and 29), and a t-test was run to examine the differences between discarded and landed individuals (group 23 and 26) for different areas and gear types. The significance probability was set to 0.05.

3. RESULTS

3.1 Landed Catches

3.1.1 Landed Quantity of All Species of Fish

Table 2: *Total weight (kilo tonnes) of all species of fish landed in Norway from 2012 to 2021.*

Year	Weight (kilo tonnes)
2012	2 044
2013	1 946
2014	2 132
2015	2 143
2016	1 869
2017	2 218
2018	2 286
2019	2 080
2020	2 211
2021	2 179
2012-2021	**21 108**

The total weight of all species of fish landed in Norway from 2012 to 2021 is described in Table 2, and the total landed weight per species can be found in Appendix 1. From 2012 to 2021, a total of 102 species of fish were landed in Norway with a total weight of 21 108 kilo tonnes (Table 2). The landed quantity was relatively stable during the 10-year period, with an average landed weight of 2 111 kilo tonnes per year.

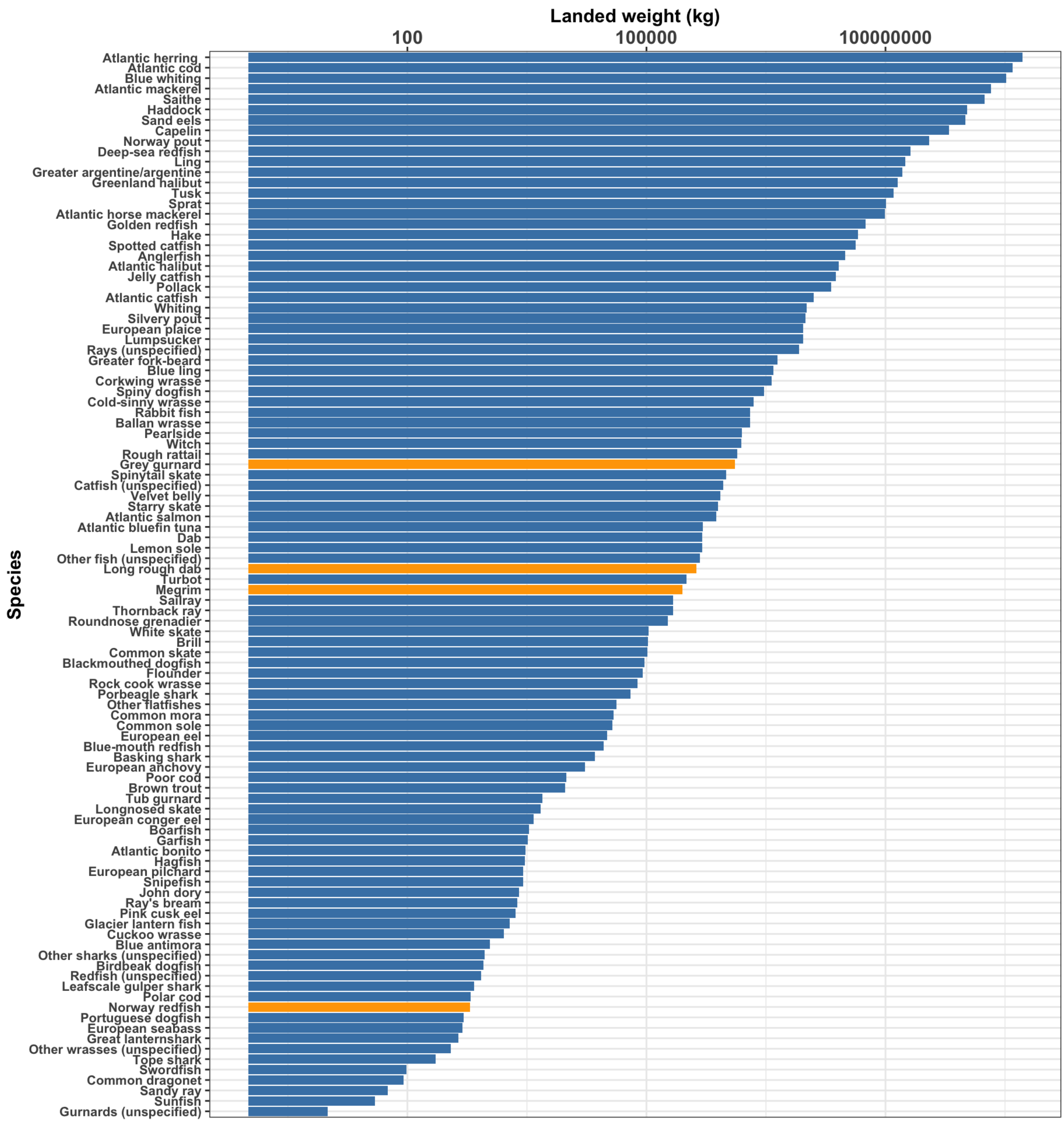

Figure 4: *Total weight (kg) of all species of fish landed in Norway from 2012 to 2021. Landed weight has been log transformed.*

Atlantic herring (*Clupea harengus*) was the species of which the greatest quantity was landed for the period 2012 to 2021 (Figure 4). In total, 5 250 kilo tonnes were landed in Norway during this period, constituting 25% of the total landed weight of all species of fish. Of the ten most landed species, half of the species were part of the family Gadidae and included Atlantic cod (*Gadus morhua*), blue whiting (*Micromesistius poutassou*), saithe (*Pollachius virens*), haddock (*Melanogrammus aeglefinus*) and Norway pout (*Trisopterus esmarkii*). Altogether, these species accounted for 10 413 kilo tonnes, making up almost half (49%) of the total quantity landed during this period. The other species that were also part of the ten most landed species, but not of the Gadidae family, included Atlantic mackerel (*Scomber scombrus*), sand eels (*Ammodytes*), capelin (*Mallotus villosus*) and deep-sea redfish (*Sebastes mentella*), in addition to Atlantic herring. These species made up a total of 3 960 kilo tonnes (not including Atlanitc herring), meaning that the ten most landed species constituted for 93% (19 623 kilo tonnes) of the total landed amount for 2012 to 2021.

3.1.2 Landed Quantity of Focus Species

Table 3: *Total weight (kg) of grey gurnard, long rough dab, megrim and Norway redfish landed in Norway per year in the period 2012 to 2021, and the total landed weight for 2012 to 2021.*

Year	Grey gurnard	Long rough dab	Megrim	Norway redfish
2012	1 928	4 840	647	0
2013	33 400	10 790	17 113	0
2014	56 076	12 014	12 727	0
2015	173 705	2 531	8 397	0
2016	82 889	58 709	22 110	0
2017	176 401	43 847	28 751	0
2018	150 913	179 415	36 081	0
2019	206 826	32 969	46 199	0
2020	276 701	35 592	54 297	0
2021	125 599	46 275	55 538	609
2012-2021	**1 284 438**	**426 982**	**281 859**	**609**

Of the four focus species, grey gurnard was the species of which the highest quantity was landed (Table 3). From 2012 to 2021, a total of 1 284 tonnes were landed of grey gurnard, constituting 0.006% of the total weight landed of all species of fish. About 427 tonnes were landed of long rough dab and 282 tonnes were landed of megrim, which accounted for 0.002% and 0.001% of the total landed weight of all species, respectively. Norway redfish was the species of which the smallest amount was landed of the four species. In total, only 609 kilos were landed during the ten-year period.

3.1.2.1 Grey Gurnard

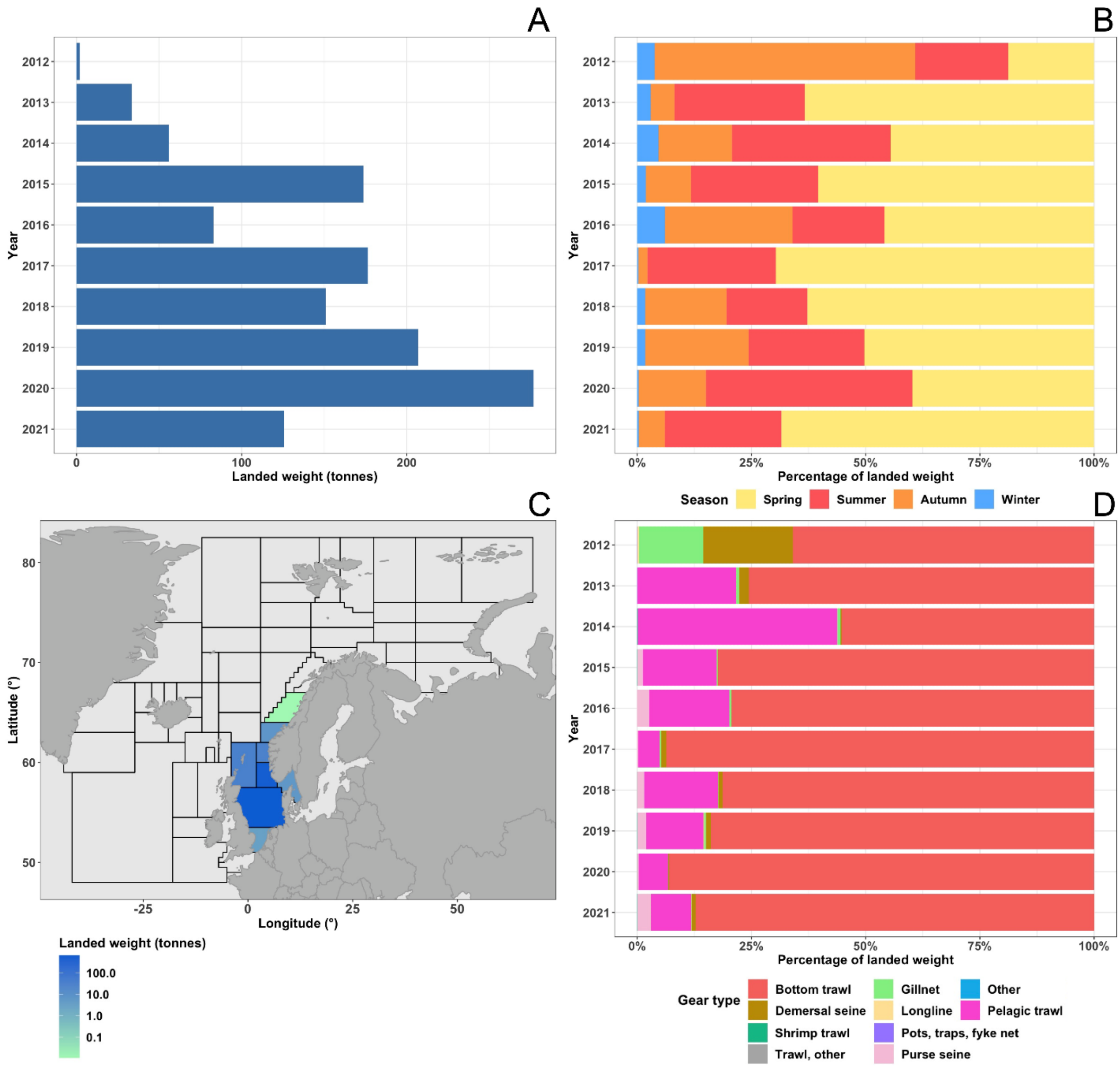

Figure 5: A: *Landed weight (tonnes) of grey gurnard per year from 2012 to 2021;* ***B:*** *Proportion (%) of the weight landed per year of grey gurnard during different seasons from 2012 to 2021;* ***C:*** *Landed weight (tonnes) of grey gurnard per statistical areas for the period 2012 to 2021. Landed weight has been log transformed;* ***D:*** *Proportion (%) of the weight landed per year of grey gurnard that was caught using different gear types.*

From 2012 to 2021, the landed weight of grey gurnard ranged from 1.9 to 276.7 tonnes per year, with an average weight of 128.4 tonnes per year (± 85.2; 1 SD) (Figure 5A). There was a steady increase per year from 2012 to 2020, with an overall increase of 274.8 tonnes in the landed quantity. From 2020 to 2021, however, the landed weight was more than halved (54.6% decrease).

For all years except for 2012 and 2020, spring was the season during which most of the catches of grey gurnard were landed (Figure 5B). In 2012, autumn was the season when most of the individuals were landed, and in 2020, it was summer. For all years, winter was the season during which the least of the catches were landed. Across all years, catches landed during spring accounted for 55.0% of the landed quantity, summer for 29.6%, autumn for 13.8%, and winter for 1.6%. The landed weight of grey gurnard for each month for the period 2012 to 2021 can be found in Appendix 2.

From 2012 to 2021, the statistical area which had the highest landed catches was area 41 with a landed weight of 642.5 tonnes, amounting for 50.0% of the total quantity landed of grey gurnard in all areas (Figure 5C). Area 08 had the second highest quantity, with a landed weight of 559.03 tonnes, constituting 43.5% of the total landed weight. This meant that the remaining six areas only accounted for 6.5% of the landed quantity. The area from which the least individuals were landed was area 06 with 11 kilos landed of grey gurnard. Across all year, 99.5% of the landed weight were from areas south of 62° N, and only 0.5% were from northern areas. Of the total quantity landed, 99.0% of the landed catches were caught outside of the 12 nautical mile boundary, while 1.0% were caught in coastal areas. The landed weight of grey gurnard for each statistical area during the period 2012 to 2021 can be found in Appendix 3.

For all years, bottom trawl was the gear type used for the majority of the landed catches of grey gurnard (Figure 5D). Across the period 2012 to 2021, 85.2% of the total landed weight constituted of catches using bottom trawl. The second most common gear type was pelagic trawl, accounting for 12.6% of the total landed quantity across all years. The remaining 8 gear types made up 2.2% of the total landed weight. The landed weight of grey gurnard for each gear type during the period 2012 to 2021 can be found in Appendix 4.

3.1.2.2 Long Rough Dab

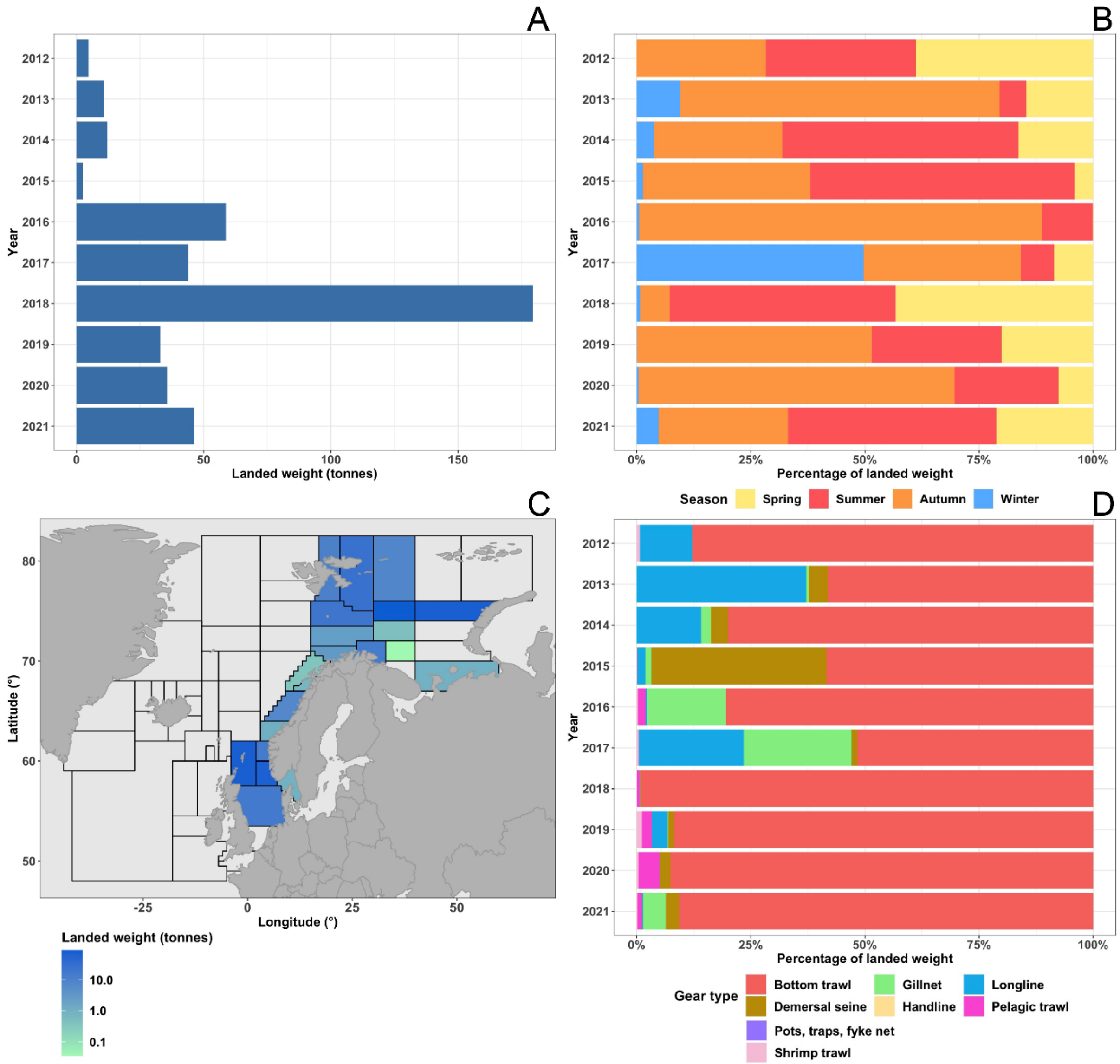

***Figure 6: A:** Landed weight (tonnes) of long rough dab per year from 2012 to 2021; **B:** Proportion (%) of the weight landed per year of log rough dab during different seasons from 2012 to 2021; **C:** Landed weight (tonnes) of long rough dab per statistical areas for the period 2012 to 2021. Landed weight has been log transformed; **D:** Proportion (%) of the weight landed per year of long rough dab that was caught using different gear types.*

For the period 2012 to 2021, the landed weight of long rough dab ranged from 2.5 to 179.4 tonnes per year, with an average weight of 42.7 tonnes per year (± 51.8; 1 SD) (Figure 6A). 2018 was the year with the highest landed quantity, which accounted for 42.0% of the total landed weight for 2012 to 2021. For all other years, the landed weight was less than 60.0 tonnes per year, with an average weight of 27.5 tonnes per year.

For the period 2012 to 2021, there was a great variation in the seasons during which most of the catches of long rough dab were landed (Figure 6B). For all years except 2012 and 2017, summer and autumn were the seasons when most of the catches were landed. In 2012, spring was the season during which most of the catches were landed, and in 2017, it was winter. Across all years, catches landed during summer accounted for 34.4% of the landed quantity, autumn for 34.3%, spring for 24.9%, and winter for 6.4%. The landed weight of long rough dab for each month for the period 2012 to 2021 can be found in Appendix 2.

From 2012 to 2021, the statistical area which had the highest landed catch was area 15 with a landed weight of 88.7 tonnes, amounting for 20.8% of the total quantity landed of long rough dab in all areas (Figure 6C). Area 10 was the area with the lowest landed catch, with a total landed weight of 35.2 kilos. The offshore areas in the Barents Sea such as 15, 16 and 22, and the areas on the north-eastern coast of the UK such as 41, 42 and 08, were some of the areas with the highest landed catches. Across all year, 59.8% of the landed weight were from areas north of 62° N, and 40.2% were from southern areas. Of the total quantity landed, 97.0% of the landed catches were caught outside of the 12 nautical mile boundary, while 3.0% were caught in coastal areas. The landed weight of long rough dab for each statistical area during the period 2012 to 2021 can be found in Appendix 3.

For all years, bottom trawl was the gear type used for the majority of the landed catches of long rough dab (Figure 6D). For the period 2012 to 2021, 87.7% of the total landed weight constituted of catches using bottom trawl. The second and third most common gear types were gillnet and longline, accounting for 5.4 and 4.2% of the total landed quantity, respectively, across all years. The landed weight of long rough dab for each gear type during the period 2012 to 2021 can be found in Appendix 4.

3.1.2.3 Megrim

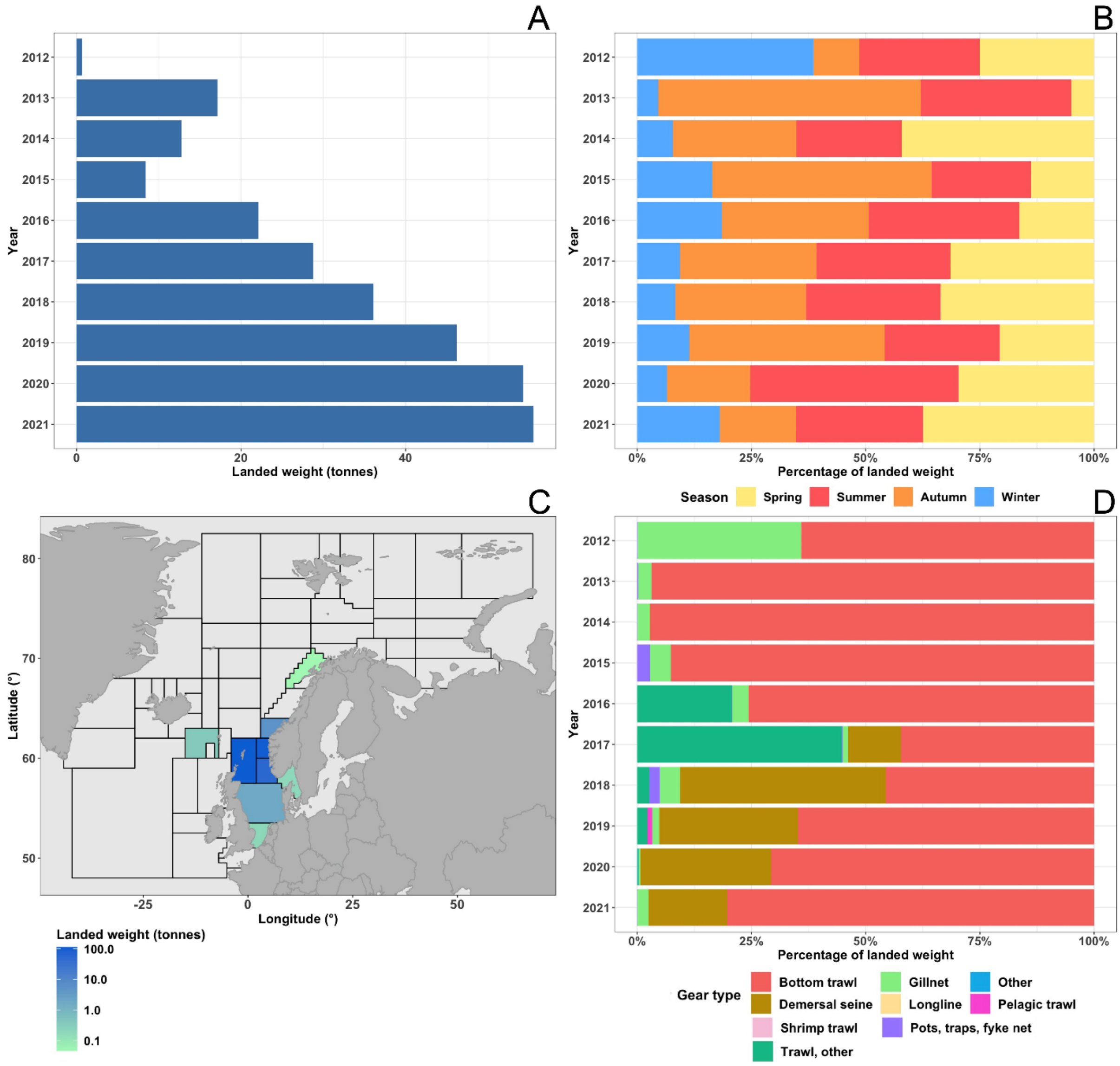

***Figure 7: A:** Landed weight (tonnes) of megrim per year from 2012 to 2021; **B:** Proportion (%) of the weight landed per year of megrim during different seasons from 2012 to 2021; **C:** Landed weight (tonnes) of megrim per statistical areas for the period 2012 to 2021. Landed weight has been log transformed; **D:** Proportion (%) of the weight landed per year of megrim that was caught using different gear types.*

From 2012 to 2021, the landed weight of megrim ranged from 0.6 to 55.5 tonnes per year, with an average weight of 28.2 tonnes per year (± 19.3; 1 SD) (Figure 7A). There was an overall linear increase in the landed weight per year from 2012 to 2021, except for a slight decrease in the landed weight from 2013 to 2014 and 2015.

For the period 2012 to 2021, catches landed during all four of the seasons were represented in all year (Figure 7B). For all years, spring, summer and autumn constituted similar quantities of the total landed weight, while winter was the season during which the least of the catches were landed. Across all years, catches landed during summer constituted for 31.5% of the landed quantity, autumn for 29.2%, spring for 27.9%, and winter for 11.4%. The landed weight of megrim for each month for the period 2012 to 2021 can be found in Appendix 2.

From 2012 to 2021, the statistical area which had the highest landed catch was area 42 with a landed weight of 113.3 tonnes, amounting for 40.2% of the total quantity landed of megrim in all areas (Figure 7C). The adjacent areas, area 28 and 08, had the second and third highest landed catches of 106.0 tonnes and 54.5 tonnes, respectively. Altogether, these three areas accounted for 97.2% of the total landed weight of megrim. The area from which the least individuals were landed was area 05 with 46.5 kilos landed. Across all year, 98.1% of the landed weight were from areas south of 62° N, and only 1.9% were from northern areas. Of the total quantity landed, 96.4% of the landed catches were caught outside of the 12 nautical mile boundary, while 3.6% were caught in coastal areas. The landed weight of megrim for each statistical area during the period 2012 to 2021 can be found in Appendix 3.

For all years, bottom trawl was the gear type used for the majority of the landed catches of megrim (Figure 7D). Across the period 2012 to 2021, 69.3% of the landed weight constituted of catches using bottom trawl. The second most common gear type was demersal seine, accounting for 20.9% of the total landed quantity across all years. The remaining 7 gear types made up 9.8% of the total landed weight. The landed weight of megrim for each gear type during the period 2012 to 2021 can be found in Appendix 4.

3.1.2.4 Norway Redfish

Table 4: *Year, month, area, gear type and weight (kg) of landed catches of Norway redfish in Norway.*

Year	Month	Area	Gear type	Landed weight (kg)
2021	June	08	Bottom trawl	61.0
2021	June	08	Bottom trawl	308.0
2021	July	08	Bottom trawl	240.0

The official landing statistics of the Norwegian Directorate of Fisheries only contained three records of Norway redfish being landed in the period 2012 to 2021. As a result of this, the available data on the landed quantity of Norway redfish is described in Table 4. The total quantity of Norway redfish was landed in 2021, and all individuals were landed during the summer (Table 4). The Norway redfish were all caught by fishing vessels using bottom trawl and in statistical area 08, south of 62° N and in offshore areas outside of the 12 nautical mile boundary.

3.2 Discarded and Unreported Catches of Focus Species

3.2.1 Coastal Gillnet Fishery

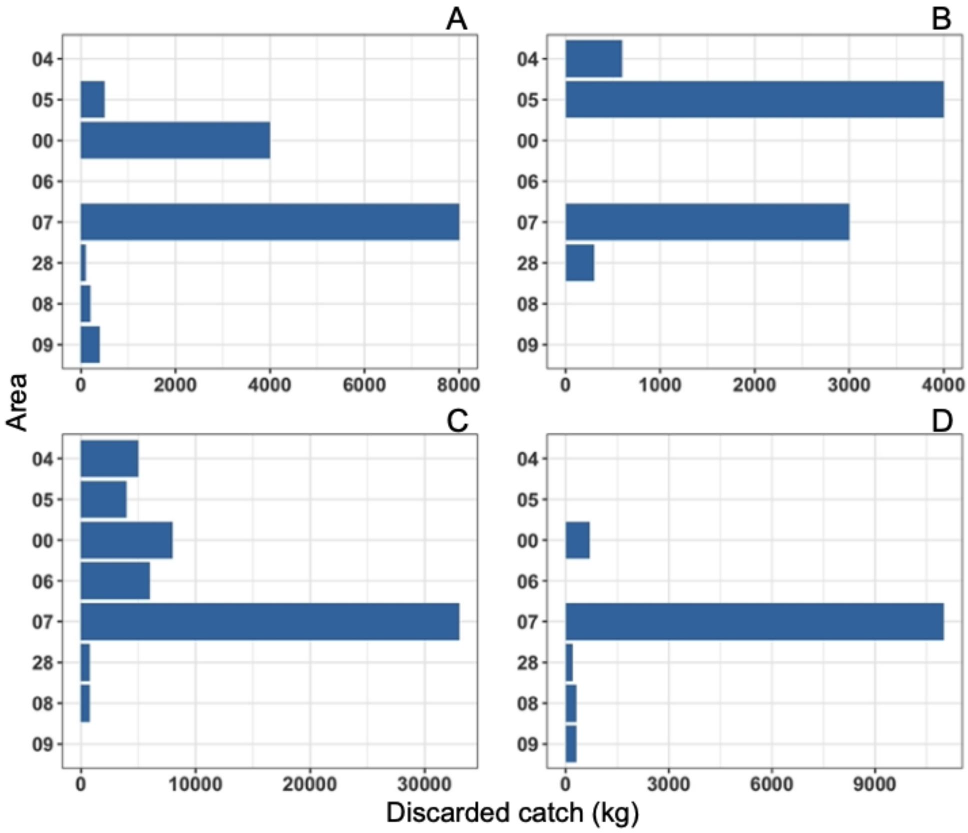

Figure 8: *Discarded catches (kg) of* ***A****: grey gurnard;* ***B****: long rough dab;* ***C****: megrim and* ***D****: Norway redfish per statistical area in the coastal gillnet fishery in 2018. Notice the difference in the scale of the x-axis.*

The weight of the discarded catches of grey gurnard in the gillnet fishery in 2018 ranged from 100 kilos in area 28 to 8 000 kilos in area 07 (Figure 8A). The average weight of the discarded catches was 2 200 kilos across all areas (± 3 207; 1 SD). The area with the second highest discarded weight was area 00 with discarded catches constituting 4 000 kilos. In total, area 28 and 00 accounted for 90.9% of the discarded weight in the coastal gillnet fishery. Across all areas, 94.7% of the discarded weight of grey gurnard were from areas north of 62° N, and 5.3% were from southern areas.

The weight of the discarded catches of long rough dab ranged from 300 kilos in area 28 to 4 000 kilos in area 05 (Figure 8B). The average weight of the discarded individuals was 1 975 kilos across all areas (± 1 812; 1 SD). The area with the second highest discarded weight was area 07 with discarded catches accounting for 3000 kilos. Area 28 and area 07 constituted in total for 88.6% of the discarded weight. Across all areas, 96.2% of the discarded weight of long rough dab were from areas north of 62° N, and 3.8% were from southern areas.

The weight of the discarded catches of megrim ranged from 800 kilos in area 28 and 08 to 33 000 kilos in area 07 (Figure 8C). The average weight of the discarded individuals was 8 229 kilos across all areas (± 11 235; 1 SD). The majority of the discarded catches were from areas north of 62° N. The areas north of 62° N had an average weight of 11 200 kilos constituting 97.2% of the total discarded weight of megrim, while the area south of 62° N had an average weight of 800 kilos, accounting for 2.8%.

The weight of the discarded catches of Norway redfish ranged from 200 kilos in area 28 to 11 000 kilos in area 07 (Figure 8D). The average weight of the discarded individuals was 2 500 kilos across all areas (± 4 756; 1 SD). The discarded catches were relatively low for all areas except for area 07, which constituted for 88.0% of the discarded weight in the coastal gillnet fishery. Across all areas, 93.6% of the discarded weight of Norway redfish were from areas north of 62° N, and 6.4% were from southern areas.

3.2.2 Trawl Fishery in the Barents Sea

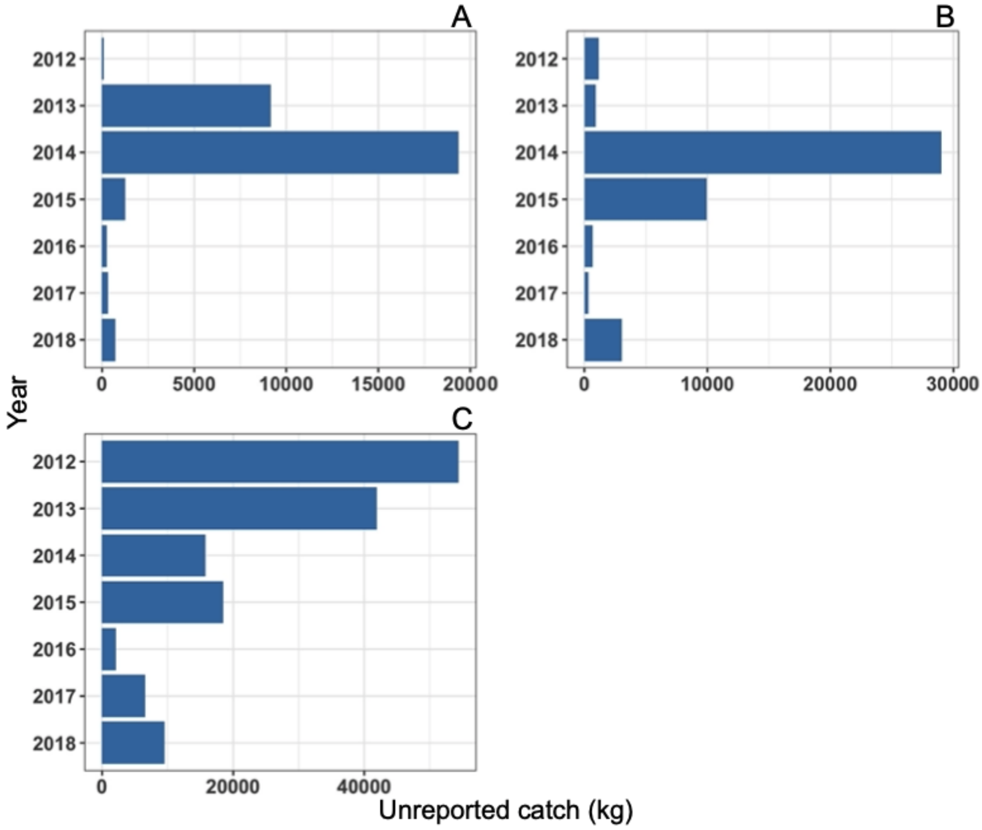

Figure 9: *Unreported catches (kg) of **A**: grey gurnard; **B**: megrim and **C**: Norway redfish per year in the trawl fishery in the Barents Sea for 2012 to 2018. Data for long rough dab was not available for this fishery. Notice the difference in the scale of the x-axis.*

The weight of the unreported catches of grey gurnard in the trawl fishery from 2012 to 2018 ranged from 97 kilos in 2012 to 19 363 kilos in 2014 (Figure 9A). The average weight of the unreported catches was 4 450 kilos across all years (± 7 329; 1 SD). 2013 was the year with the second highest unreported weight, with unreported catches constituting 9 151 kilos. In total, 2013 and 2014 accounted for 91.5% of the unreported weight in the trawl fishery of grey gurnard.

The weight of the unreported catches of megrim ranged from 303 kilos in 2017 to 29 010 kilos in 2014 (Figure 9B). The average weight of the unreported catches was 6 435 kilos across all years (± 10 509; 1 SD). The unreported catches were relatively low across all years, except for 2014 and 2015. 2015 had the second highest unreported weight of 9 946 kilos. Altogether, 2014 and 2015 constituted for 86.5% of the total unreported weight of megrim.

The weight of the unreported catches of Norway redfish ranged from 2 140 kilos in 2016 to 54 406 kilos in 2012 (Figure 9C). The average weight of the unreported catches was 21 274 kilos across all years (± 19 496; 1 SD). There was a steady decrease in the unreported weight per year from 2012 to 2016, followed by a slight increase from 2016 to 2018. 2012 and 2013 were the two years with the highest unreported catches, accounting for 64.7% of the total unreported catches of Norway redfish.

3.2.3 Longline Fishery in the Barents Sea

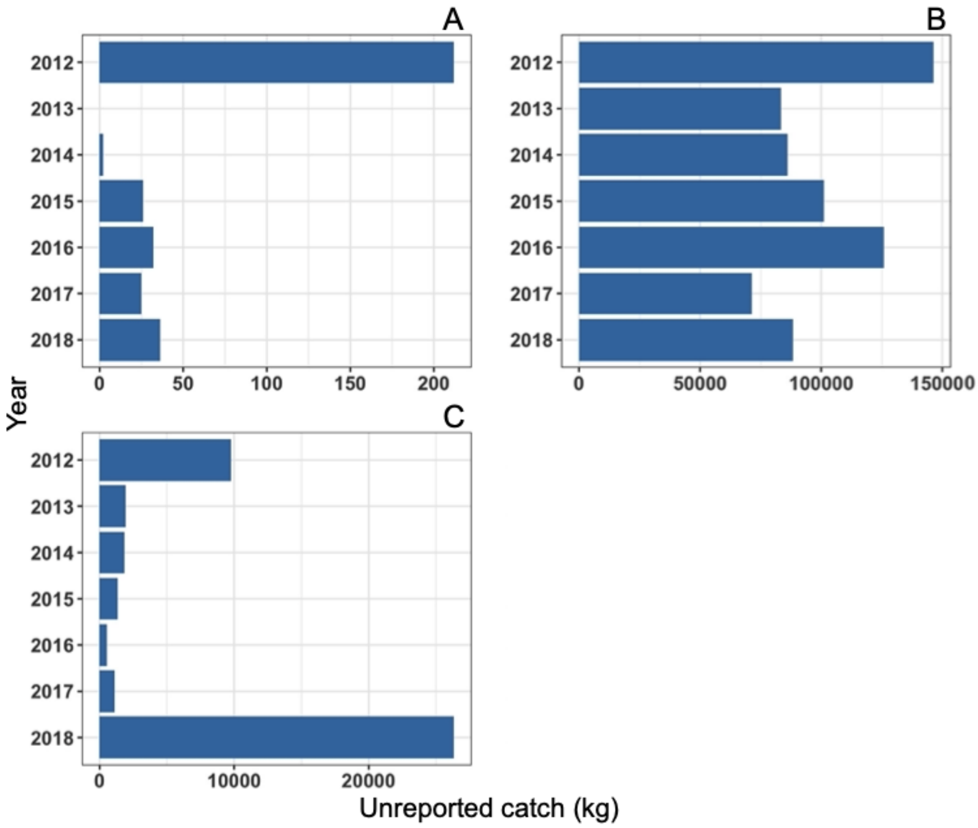

Figure 10: *Unreported catches (kg) of **A**: grey gurnard; **B**: long rough dab and **C**: Norway redfish per year in the longline fishery in the Barents Sea for 2012 to 2018. Data for megrim was not available for this fishery. Notice the difference in the scale of the x-axis.*

The weight of the unreported catches of grey gurnard in the longline from 2012 to 2018 ranged from 2 kilos in 2014 to 212 kilos in 2012 (Figure 10A). The average weight of the unreported catches was 48 kilos across all years (± 74; 1 SD). The unreported weight of grey gurnard was relatively low for all years except for 2012 which had the highest unreported catches. In total, 2012 accounted for 63.7% of the unreported weight in the longline fishery.

The weight of the unreported catches of long rough dab ranged from 71 313 kilos in 2017 to 146 232 kilos in 2012 (Figure 10B). The average weight of the unreported catches was 100 319 across all years (± 26 540; 1 SD). The unreported weight was relatively even for all years, except for 2012 and 2016, which were the years with the highest unreported catches. Altogether, these two years constituted 38.7% of the total unreported weight of grey gurnard.

The weight of the unreported catches of Norway redfish ranged from 512 kilos in 2016 to 26 334 kilos in 2018. The unreported catches were relatively low for all years, except 2018 and 2012, which had the highest and second highest unreported catches, respectively. Across all years, 2018 and 2012 accounted for 84.3% of the total unreported weight of Norway redfish.

3.3 Comparative Analysis of Landed and Discarded and Unreported Catches

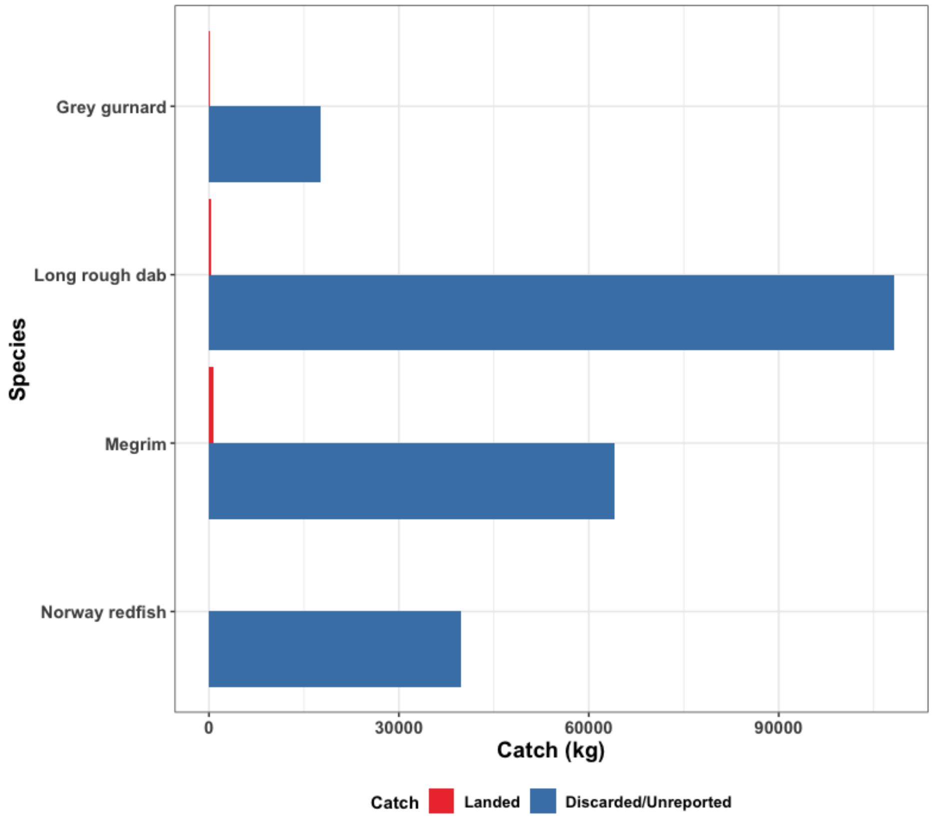

Figure 11: *Total annual landed and discarded/unreported catches (kg) of grey gurnard, long rough dab, megrim and Norway redfish in the gillnet, trawl and longline fisheries. Landed catches are retrieved from the official landing statistics of the Norwegian Directorate of Fisheries, and the discarded and unreported catches are estimated by Berg and Nedreaas (2020) and Clegg (2022).*

The total annual landed weight of the four focus species, grey gurnard, long rough dab, megrim and Norway redfish, in the gillnet, trawl and longline fisheries was compared to the total annual estimated discarded and unreported weight of the four species for the same fisheries, statistical areas and time period (further description in Materials and Method, 2.3) (Figure 11; Appendix 5, 6 and 7). Of the four species, megrim was the species of which the highest quantity was landed, with a total annual weight of 673 kilos for the three fisheries. Norway redfish was the species with the lowest quantity of landed catches, with no landed catches. Across the four focus species, the average annual landed weight was 281 kilos for the three fisheries.

Of the four focus species, long rough dab was the species with the highest discarded and unreported quantity, with a total annual weight of 108 219 kilos for the three fisheries. The species with the lowest discarded and unreported weight was grey gurnard with a total annual weight of 17 698 kilos. Across the four species, the average annual discarded and unreported catch weight was 57 460 kilos for the gillnet, trawl and longline fisheries.

For grey gurnard and long rough dab, the total annual discarded and unreported weight accounted for 99.7% and 99.6%, respectively, of the total annual catches (landed catches combined with discarded and unreported catches), while for megrim, the total annual discarded and unreported catches constituted 99.0 % of the total annual catches. As there were no landed catches of Norway redfish in the gillnet, trawl and longline fisheries during the time period studied, the total annual discarded and unreported catches accounted for 100% of the total annual catches.

3.4 Length Distributions of Focus Species

3.4.1 Differences Between Catch Groups

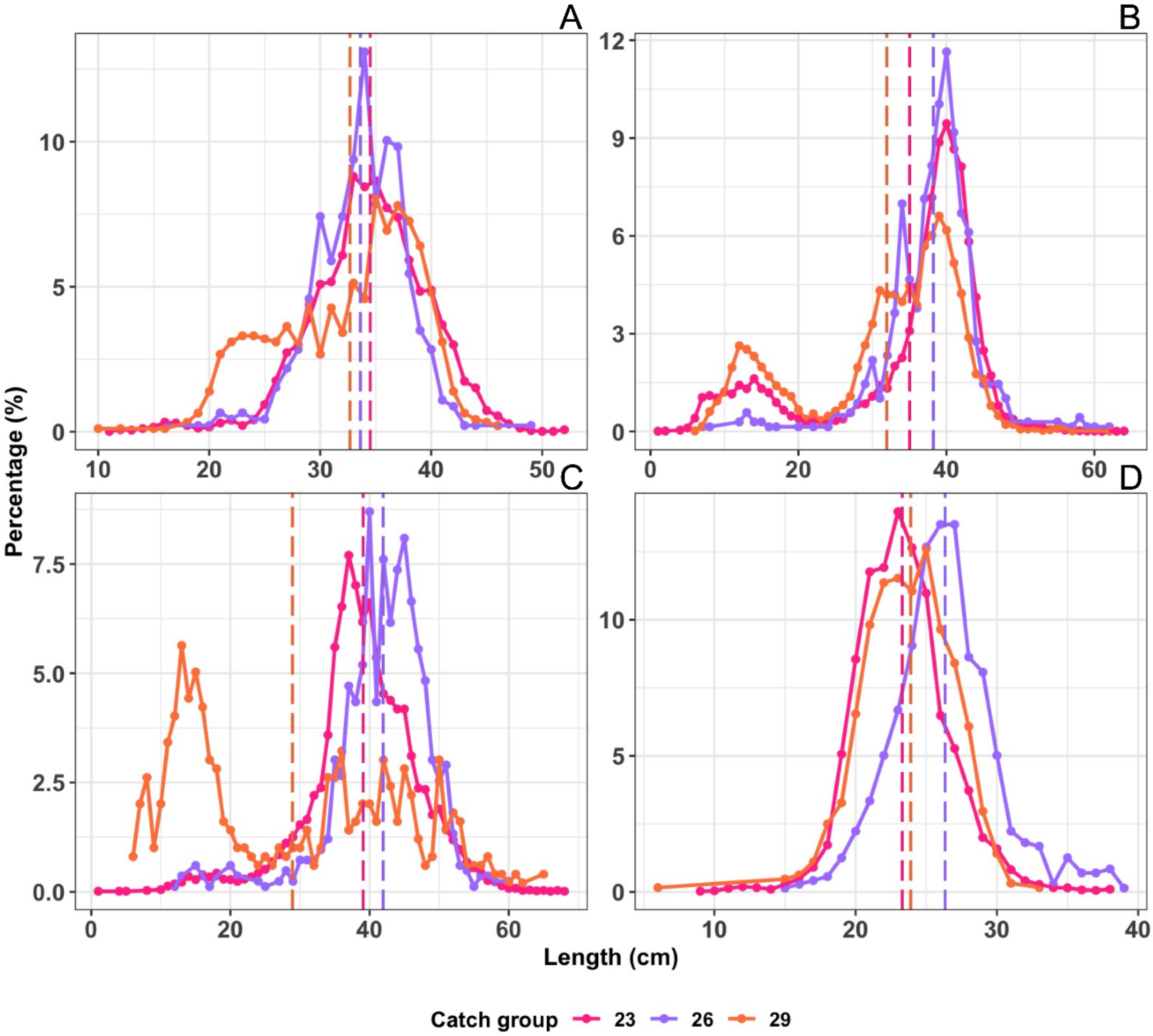

Figure 12: *Length distribution (%) of grey gurnard (**A**), long rough dab (**B**), megrim (**C**) and Norway redfish (**D**) in catch groups 23 (discarded individuals), 26 (landed individuals) and 29 (processed individuals). Vertical dashed lines indicate the mean length of individuals in each catch group. Notice the difference in the scale of the y- and x-axis.*

The length distribution of the four focus species, grey gurnard, long rough dab, megrim and Norway redfish, in the three catch groups, group 23 (discarded individuals), 26 (landed individuals) and 29 (processed individuals), are described in Figure 12.

A total of 8 722 individuals of grey gurnard were length measured by Reference Fleet vessels between 2012 and 2021. The mean length of the individuals in the three catch groups were: 34.5 cm (± 5.3; 1 SD) for group 23; 33.6 cm (± 4.2; 1 SD) for group 26; and 32.7 cm (± 3.6; 1 SD) for group 29 (Figure 12A; Appendix 8). The length distribution of the individuals in group 23 and 26 were relatively similar, while group 29 had a higher percentage of the smaller individuals, between 20 and 30 cm, compared to group 23 and 26. In addition, group 29 had the highest percentage of individuals between 35 and 40 cm, while group 23 and 26 had the majority of individuals between 30 and 40 cm. Performing a one-way ANOVA and a post hoc Tukey's test showed that there was a significant difference between the mean length of all three catch groups (catch group 23 and 26: P = 0.002; catch group 23 and 29: P = < 0.001; catch group 26 and 29: P = 0.006).

A total of 35 355 individuals of long rough dab were length measured by Reference Fleet vessels between 2012 and 2021. The mean length of the individuals in the three catch groups were: 35.0 cm (± 10.7; 1 SD) for group 23; 38.2 cm (± 6.3; 1 SD) for group 26; and 31.9 cm (± 10.4; 1 SD) for group 29 (Figure 12B; Appendix 8). The length distribution of the individuals in the three catch groups followed a similar pattern; the highest percentage of individuals were between 30 and 50 cm in length, while a smaller proportion of the individuals were between 5 and 20 cm. The individuals in catch group 29 had a higher percentage of individuals between 5 and 20 cm compared to group 23 and 26, while for individuals between 30 and 50 cm, group 29 had a lower proportion of individuals than group 23 and 26. Performing a one-way ANOVA and a post hoc Tukey's test showed that there was a significant difference between the mean length of all three catch groups (catch group 23 and 26: P = < 0.001; catch group 23 and 29: P = < 0.001; catch group 26 and 29: P = < 0.001).

A total of 11 365 individuals of megrim were length measured by Reference Fleet vessels between 2012 and 2021. The mean length of the individuals in the three catch groups were: 39.1 cm (± 7.8; 1 SD) for group 23; 41.9 cm (± 6.9; 1 SD) for group 26; and 28.9 cm (± 15.4; 1 SD) for group 29 (Figure 12C; Appendix 8). Group 23 had the highest percentage of individuals between 35 and 45 cm, while group 26 had the highest proportion of individuals between 40 and 50 cm. Group 29, however, had the highest percentage of individuals between 10 and 20 cm, and a smaller proportion between 35 and 55 cm. Performing a one-way ANOVA and a post hoc Tukey's test showed that there was a significant difference between the mean length of all three catch groups (catch group 23 and 26: P = < 0.001; catch group 23 and 29: P = < 0.001; catch group 26 and 29: P = < 0.001).

A total of 12 845 individuals of Norway redfish were length measured by Reference Fleet vessels between 2012 and 2021. The mean length of the individuals in the three catch groups were: 23.3 cm (± 3.2; 1 SD) for group 23; 26.3 cm (± 3.7; 1 SD) for group 26; and 23.9 cm (± 3.1; 1 SD) for group 29 (Figure 12D; Appendix 8). The length distribution of the individuals in the three catch groups were relatively similar, with most individuals being between 18 and 32 cm. The length distribution of group 26, however, was slightly shifted to the right compared to group 23 and 29, with the highest percentage of individuals between 25 and 32 cm. Performing a one-way ANOVA and a post hoc Tukey's test showed that there was a significant difference between the mean length of all three catch groups (catch group 23 and 26: P = < 0.001; catch group 23 and 29: P = < 0.001; catch group 26 and 29: P = < 0.001).

3.4.2 Differences Between Landed and Discarded Individuals

The length distribution of the four focus species, grey gurnard, long rough dab, megrim and Norway redfish, were explored further by looking at the difference in the mean length between group 23 (discarded individuals) and 26 (landed individuals) in combination with differences in area and gear type.

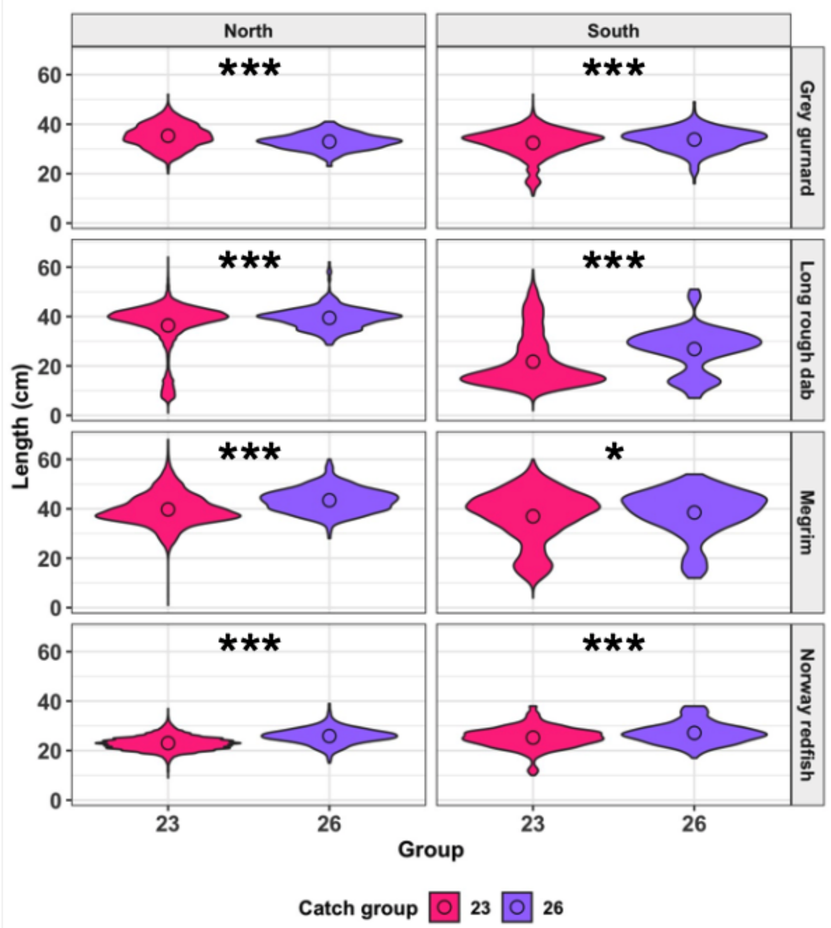

Figure 13: *Length distribution (cm) and mean length (open circle) of grey gurnard, long rough dab, megrim and Norway redfish in areas north and south of 62° N for individuals in catch group 23 (discarded individuals) and 26 (landed individuals). Asterisks indicate a significant difference between catch groups, and number of asterisks indicate level of significance: *** = <0.001; ** = 0.001; * = 0.05. No asterisk indicates that there was no significant difference.*

The length distribution and mean length of grey gurnard, long rough dab, megrim and Norway redfish caught in areas north and south of 62° N is described in Figure 13. There was a significant difference between the mean length of individuals from catch group 23 and catch group 26 for all species and all areas (Welch Two Sample t-test, $p = <0.05$; Figure 13).

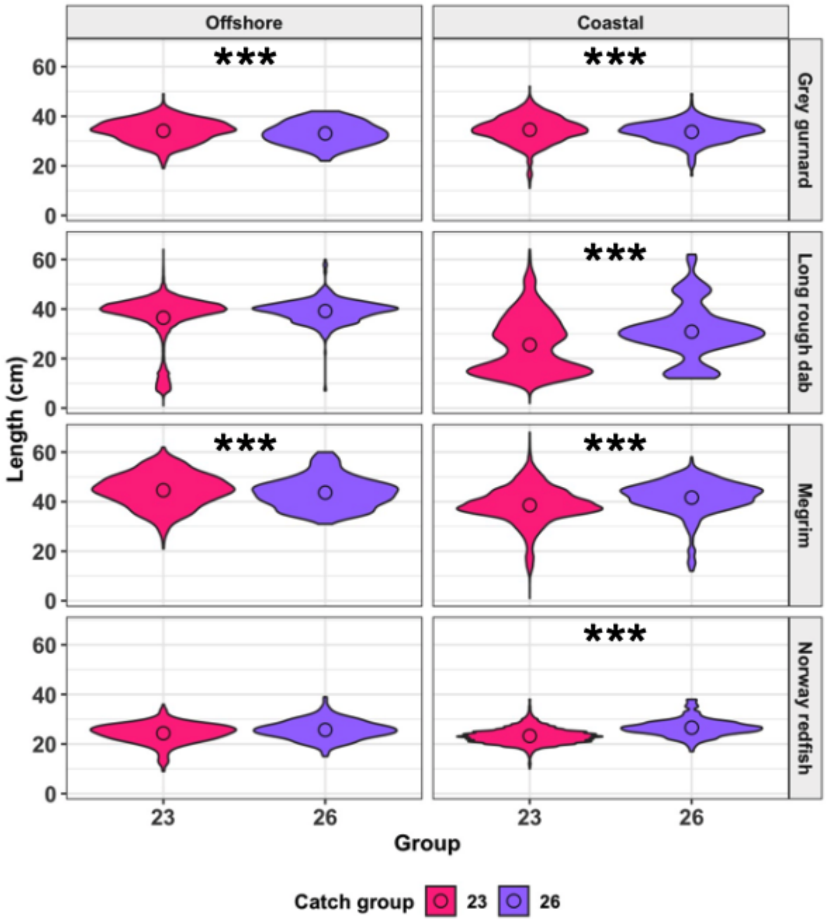

Figure 14: *Length distribution (cm) and mean length (open circle) of grey gurnard, long rough dab, megrim and Norway redfish in offshore and coastal areas for individuals in catch group 23 (discarded individuals) and 26 (landed individuals). Asterisks indicate a significant difference between catch groups, and number of asterisks indicate level of significance: *** = <0.001; ** = 0.001; * = 0.05. No asterisk indicates that there was no significant difference.*

The length distribution and mean length of grey gurnard, long rough dab, megrim and Norway redfish caught in offshore areas outside of the 12 nautical mile boundary and in coastal areas is described in Figure 14. There was a significant difference between the mean length of individuals from catch group 23 and catch group 26 for all species and all areas (Welch Two Sample t-test, p = <0.001), except for individuals of long rough dab and Norway redfish that had been caught in offshore areas (Figure 14).

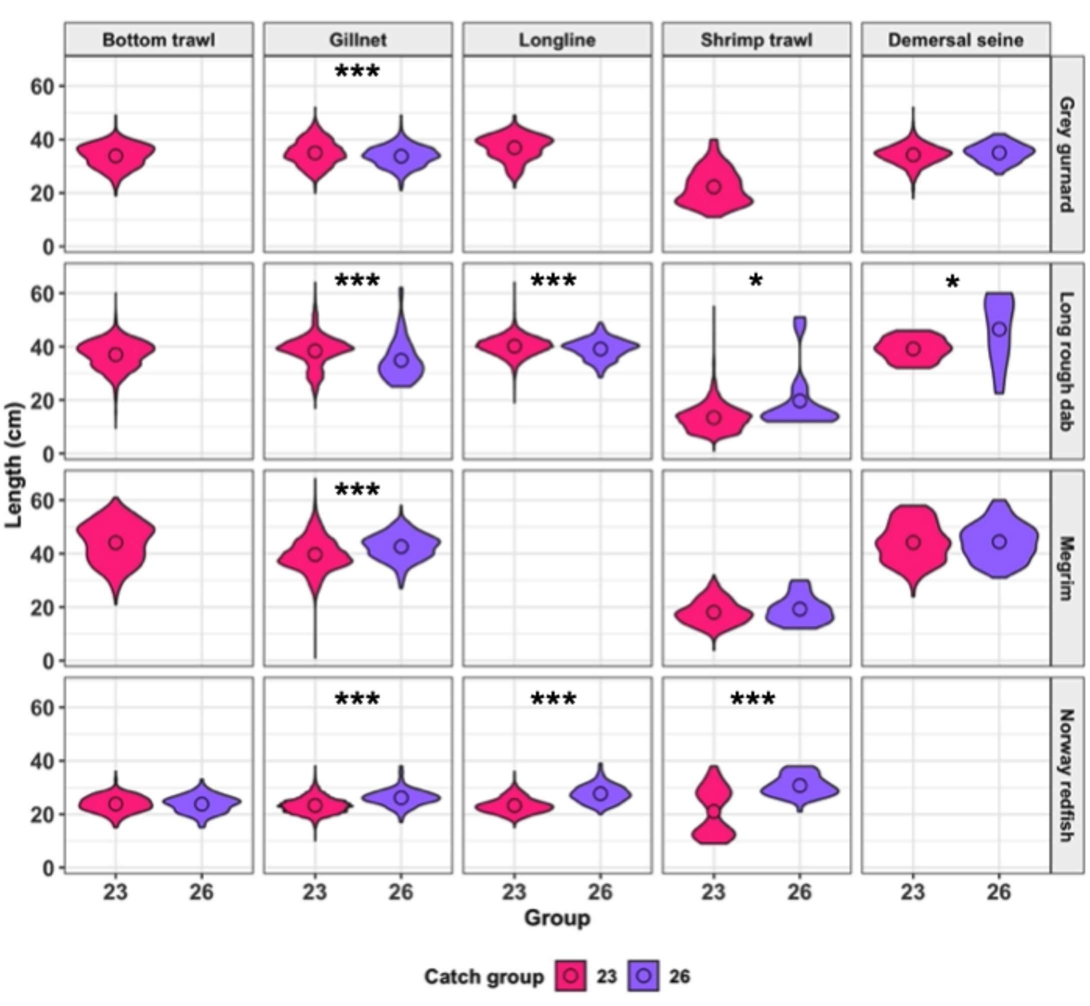

Figure 15: *Length distribution (cm) and mean length (open circle) of grey gurnard, long rough dab, megrim and Norway redfish caught by different gear types for individuals in catch group 23 (discarded individuals) and 26 (landed individuals). Asterisks indicate a significant difference between catch groups, and number of asterisks indicate level of significance: *** = <0.001; ** = 0.001; * = 0.05. No asterisk indicates that there was no significant difference.*

The length distribution and mean length of grey gurnard, long rough dab, megrim and Norway redfish caught by different gear types is described in Figure 15. There was a significant difference between the mean length of individuals from catch group 23 and catch group 26 for all species caught by gillnet, for long rough dab and Norway redfish caught using longline and shrimp trawl, and for long rough dab caught by demersal seine (Welch Two Sample t-test, $p = <0.05$; Figure 15). Not all species and gear types could be compared as some groups did not include length measurements of individuals in both catch groups 23 and 26.

4. DISCUSSION

4.1 Main Findings

The main aim of the current thesis was to examine to what extent the four focus species, grey gurnard, long rough dab, megrim and Norway redfish, were landed and utilised in Norwegian fisheries, and to explore the biological potential for improved and increased utilisation by looking at the discarded and unreported catches of the focus species using data from the official landing statistics of the Norwegian Directorate of Fisheries and the Norwegian Reference Fleet.

4.1.1 Landed and Discarded and Unreported Catches

In order to address the main aim, the quantities landed of the four focus species from 2012 to 2021 were explored, and the variations by year, season, geographical area and gear type were described. Of the four focus species, grey gurnard was the species of which the highest quantity was landed during the study period, while Norway redfish was the species with the lowest landed catches. The quantity landed per year of the focus species varied throughout the study period, but overall, there was an increase in the weight landed of grey gurnard, long rough dab and megrim from 2012 to 2021. All of the catches of Norway redfish were exclusively landed in 2021. For all of the focus species, similar trends could be observed when looking at variations in the landed weight by geographical area. The highest landed catches were from the statistical areas around the North Sea for all of the species but long rough dab, which had its highest landed catches caught in areas in the Barents Sea, in addition to some in the North Sea. All four of the species had the majority of their landed catches caught in offshore areas outside of the 12 nautical mile boundary and by using bottom trawl.

To explore the biological potential of the four focus species for better and increased utilisation, the estimated weight of the catches which were discarded or unreported in three fisheries were examined. In the coastal gillnet fishery, megrim was the species of which the highest quantity was discarded. In the trawl and longline fisheries in the Barents Sea, the greatest quantities of unreported catches were of Norway redfish and long rough dab, respectively. Comparing the weight of the landed catches and the discarded and unreported catches of the four focus species in the same fisheries, statistical areas and time period, showed that much greater quantities were discarded and not reported than landed for all of the species. For grey gurnard and long rough dab, the weight of the discarded and unreported catches were almost 300 times higher than the landed quantity when looking at the total annual quantity for the three fisheries. For megrim, the discarded and unreported catches were 95 times greater than the landed catches. On average for the four focus species, 99.6% of the weight of the total annual catches (discarded and unreported catches combined with landed catches) consisted of discarded and unreported catches.

The case studies used for comparing the landed catches to the discarded and unreported catches of the focus species were limited to certain statistical areas along the coast of Norway and in the Barents Sea, to the gillnet, trawl and longline fisheries, and to certain time periods. These are currently the only three fisheries where the discarded and unreported catches of bycatch species have been estimated using data from the Norwegian Reference Fleet. To increase the accuracy of the results, discarded and unreported catches could be estimated for additional fisheries, statistical areas and for longer time periods. For the trawl fishery in the Barents Sea, the estimated unreported catches of long rough dab were not available due to data inaccuracies (Clegg, 2022). It has, however, been observed that long rough dab is commonly caught as bycatch in the northeast Atlantic and that, although the bycatch in industrial fisheries may be used in fish meal production, most of the catches are found to be discarded (Millner et al., 2005; Muus et al., 1999). Albert et al. (1994) estimated the bycatch of long rough dab in Norwegian fisheries to be about 1000 tonnes (Albert et al., 1994). This suggests that the total estimated discarded and unreported quantity of long rough dab could be even higher than what was found in the results of the current thesis.

4.1.2 Length Distributions

The length distribution of the four focus species in catch group 23 (discarded individuals), catch group 26 (landed individuals) and catch group 29 (individuals processed for fish meal) were compared to investigate if there was a difference in the mean length of the individuals in each catch group. Comparing the mean length of the individuals in each catch group showed that for long rough dab, megrim and Norway redfish, catch group 26 contained the individuals with the largest mean length. For grey gurnard, long rough dab and megrim, catch group 29 contained the individuals with the smallest mean length. It was only for Norway redfish that catch group 23 contained the individuals with the smallest mean length. These results suggest that for some of the species, the larger individuals were more likely to be landed and sold, while the smaller individuals were more likely to be processed and used for fish meal. This could be an indication of high-grading, as the larger individuals in the catches seemed to be retained and landed, while the smaller individuals were either discarded or processed for fish meal.

The statistical analyses comparing the mean length of the individuals in each catch group found that there was a significant difference between all three catch groups for all of the species. When comparing the mean length of each catch group for each species, it could be observed that the difference between the mean length of the three catch groups was on average 1.4 cm for grey gurnard, 4.8 cm for long rough dab, 7.9 cm for megrim and 2.7 cm for Norway redfish (Appendix 8). High-grading is typically motivated by the economic advantage for the fishers, and will often be determined by whether the fisher believe they will have an opportunity of receiving a more profitable catch at a later time or not (Pascoe, 1997; Batsleer et al., 2015). As the four focus species currently have a limited market and relatively small quantities are landed of the species in Norway, it is difficult to determine whether a size difference of a few centimetres would impact the price that the fishers get when landing the catches, and if this would be the motivation for landing the larger individuals and not the smaller individuals. For megrim, the difference in the mean length between the landed individuals and the individuals processed for fish meal was 13.0 cm, while for landed and discarded individuals, it was only 2.8 cm (Appendix 8). In this case it seemed like the size of the individuals was not the reason for whether the individuals were landed or discarded, but that the size of the individuals was more important in relation to whether an individual was to be processed for fish meal.

4.2 Representativeness and Reliability of the Norwegian Reference Fleet

In order to use the estimation process and methodology as described by Berg and Nedreaas (2020) and Clegg (2022) to estimate the discarded or unreported catches of the focus species, it was assumed that the participating vessels in the Norwegian Reference Fleet were representative of the rest of the Norwegian fishing fleet and that all of the catches were reported accurately and sampled according to the methods and protocols of the Reference Fleet (Berg & Nedreaas, 2020; Clegg, 2022). A study by Fangel et al. (2015) found that when comparing the bycatch estimates of seabirds using data from the Coastal Reference Fleet and independent data from an access point survey, results were similar (Fangel et al., 2015). Similarly, Moan et al. (2020) found that when comparing the fishing effort of Reference Fleet vessels in different regions, seasons and fisheries with the effort of the whole fishing fleet, similar patterns were observed overall suggesting that the fishing activity of the Reference Fleet vessels were representative of the rest of the vessels in the Norwegian fishing fleet (Moan et al., 2020). Clegg et al. (2023), however, observed that the Reference Fleet vessels participating in the longline fishery in the Barents Sea were some of the most active vessels in the fishery, and that the Reference Fleet vessels also used more hooks per fishing day than most other longline vessels in the fishery, proposing that this could lead to an overestimation when estimating the unreported catches of the fishery (Clegg et al., 2023). Clegg also noted that the Reference Fleet vessels often were some of the most modern and largest vessels in the Norwegian fleet, suggesting that their fishing activity and behaviour could differ from other vessels (Clegg, 2022).

As the Reference Fleet programme is based on self-sampling by the fishers, it can not be guaranteed that the sampling procedures are followed at all times and that the catches are recorded accurately and truthfully. Since the Norwegian Reference Fleet was established in 2000 and until 2021, 116 vessels have participated in the programme (Williams & Gundersen, 2021). This means that numerous vessels and fishers have taken part in the sampling, and that sampling errors are likely to have occurred. However, as the vessels have research technicians from the Norwegian Institute of Marine Research regularly visit the vessels and provide training for the crew, in addition to the collected data being frequently checked for anomalies and errors, it is believed that these incentives increase the accuracy and reliability of the data.

In a questionnaire survey to the fishers participating in the Norwegian Reference Fleet it was found that the majority of the fishers were motivated by a "social responsibility and a wish to strengthen fisheries management" and "the opportunity to contribute to marine research", suggesting that most of the participating fishers intend and wish to reliability report their catches (Williams et al., 2018). This could, on the other hand, also indicate that the Reference Fleet vessels might have a greater interest in the sustainability of marine resources than what other fishers in the Norwegian fishing fleet may have, and that their discarding behaviour might therefore differ from that of other vessels. In a study by Berg (2019) using catches from the Reference Fleet to estimate the discarding of cod in the coastal gillnet fishery, it was suggested that the participating vessels were more likely to follow regulations and that the estimated discards of cod should therefore be viewed as “minimum estimates”, as these estimates were likely to be higher for other vessels (Berg, 2019).

4.3 Data Limitations in Regards to Norway Redfish

For several of the statistical areas and years during the ten-year period studied, data were limited for the landed catches of some of the species, as for example for Norway redfish. This could be a result of there actually being very few or no landings of the species in certain areas or during certain years, but it could also be due to sampling errors such as misidentification of species. During the study period of 2012 to 2021, only three catches of Norwegian redfish were landed in Norway, and all catches were landed in 2021. The different redfish species found in Norwegian waters include species that are morphologically similar and that can be difficult to differentiate (Bruvold, 2021; Nedreaas & Nævdal, 1991). Individuals of Norway redfish that were caught during the study period could therefore have been landed as one of the other redfish species such as the deep-sea redfish (*Sebastes mentella*) or the golden redfish (*Sebastes norwegicus*), which were landed in large quantities. In the official landing statistics of the Norwegian Directorate of Fisheries, there were also catches landed as “Redfish (unspecified)” which could also contain individuals of Norway redfish.

Another possible reason for there being limited quantities landed and reported of Norway redfish during the study period could be due to the way the species is managed in Norway today. There is currently no individual minimum landing size (MLS) specifically for Norway redfish, instead, there is a common minimum landing size for all of the species of redfish in Norwegian waters. For individuals of redfish caught outside of the 12 nautical mile boundary, the MLS is 30 cm, while for individuals caught inside the 12 nautical mile boundary, the MLS is 32 cm (Anon, 2023a). However, Norway redfish have a common length of around 25.0 cm and a length at first maturity of 12.5 cm (Hureau & Litvinenko, 1986). This means that the majority of the individuals of Norway redfish will be below the MLS for redfish in Norway, making it difficult for fishers to land the species and increasing the chances of the species being discarded. When looking at the length distribution of Norway redfish in the three catch groups, it could be observed that the mean length for all catch groups were below the MLS for redfish in Norway, indicating that some individuals below the MLS for redfish in Norway were still landed. According to § 49 in Høstingsforskriften, it is allowed to have up to 10% of a single species below the MLS in a catch, and for redfish caught north of 62° N, 15% of the catch can contain individuals below the MLS, which could be the reason for this (Anon, 2023a).

4.4 Market Potential of the Focus Species

In the gillnet, trawl and longline fisheries in coastal and offshore areas in Norway, relatively small quantities were landed of the four focus species compared to the estimated weight of the discarded and unreported catches. A possible reason for the majority of the catches being discarded or not reported instead of landed, could be a result of there being a limited market for the species in Norway. There are currently few sales organisations in Norway offering a minimum landing price for the focus species, making it less likely for the fishers to land the catches of these species. For species of redfish, most of the sales organisations offer a minimum landing price for individuals above 0.7 kilos which is commonly heavier than the average weight of Norway redfish (Nedreaas, pers. com.) There are, however, currently two sales organisations offering a minimum landing price of 10.9 NOK per kilo for all sizes of redfish and 15.0 NOK per kilo for individuals of redfish below 0.7 kilos (Fiskehav, 2023; Vest-Norges Fiskesalslag, 2023). For species of gurnard, there is one sales organisation offering 14.0 NOK per kilo for individuals above 0.7 kilos, however, this is commonly heavier than the average weight of grey gurnard (McCarthy et al., 2018; Norges Råfisklag, 2023).

Comparing the landed catches of the four focus species in Norway to the landed catches of other countries in Europe showed that substantially higher quantities were landed by other European countries (Appendix 9). For the period 2012 to 2020, a total quantity of 17 202 tonnes were landed and reported of grey gurnard by the European countries that report their catches to ICES (not including Norway), with an average landed weight per country of 1 434 tonnes (ICES, 2022; Appendix 9). This was about the same amount that was landed in Norway from 2012 to 2021, however, when only looking at the top three countries landing their catches of grey gurnard (Denmark, UK and the Netherlands), the average landed weight per country was 4 322 tonnes. For long rough dab, 35 598 tonnes were landed by the European countries, with an average landed weight of 2 373 tonnes per country. This was more than 5 times the quantity that was landed in Norway from 2012 to 2021. When looking at the top three countries (Russia, Estonia and Iceland), the average landed weight per country was 10 742 tonnes for the period 2012 to 2020. For megrim 14 542 tonnes were landed by the countries reporting their catches to ICES, with an average landed weight of 1 454 per country, and an average landed weight for the top three countries (France, Iceland and Portugal) of 4 948 tonnes. Catches of Norway redfish were only landed and reported by two countries in Europe, Iceland and the Netherlands, with a total of 2 634 tonnes landed from 2012 to 2020, and with an average of 1 317 tonnes landed per country.

The quantities landed of the four focus species in other European countries indicated that there are possibilities and potential for improved and increased utilisation of the four species if a market was developed in Norway. The current study was limited to the four bycatch species grey gurnard, long rough dab, megrim and Norway redfish. There are, however, several other bycatch species found in Norwegian fisheries for which there currently is a limited market, and improved utilisation could be possible. Increased utilisation of the focus species and other bycatch species in Norway could benefit Norwegian fishers by providing an additional revenue, as well as an important source of income if other target species were to decline in abundance in the future (Crowder & Murawski, 1998; Pascoe, 1997).

4.5 Potential for Sustainable Utilisation and Considerations

In order to sustainably harvest and utilise the four focus species and other bycatch species, information regarding the abundance of the species should be assessed. Some bycatch species may belong to small and vulnerable populations and should therefore not be harvested beyond current bycatch levels, while other species may constitute larger populations or stocks that may sustain heavier exploitation. As bycatch species are commonly not directly targeted by a fishery, information regarding the population size of the species and how vulnerable the species might be to increased fishing pressure, may be limited (Baum et al., 2003).

4.5.1 Indices of Abundance of the Focus Species

To evaluate the future sustainable catch potential of the four focus species, indices of their abundance from different sources were assessed and compared to the findings of the current study. Assessments by the International Council for the Exploration of the Sea (ICES) were available for grey gurnard in the North Sea and Skagerrak, and for megrim in the northern North Sea and west of Scotland (ICES, 2022a, 2022b). Although the results from the current study showed that some of the Norwegian catches were from areas further north, the majority of the catches were from these assessment areas. The ICES report for grey gurnard recommended a harvest of 5 846 tonnes per year for the years 2023 and 2024, however, taking discards into consideration, it was recommended that landings should not exceed 1 120 tonnes (ICES, 2022a). This was approximately the same quantity that was landed on average per year during the period 2012 to 2021 for all of Norway. This suggests that the landed catches of grey gurnard should not be increased with the current discard level. Instead, the discarded catches of grey gurnard could be landed and utilised in order to sustainably utilise grey gurnard better. For megrim, it was recommended that the catches should not exceed 7 200 tonnes in 2023, which was substantially less than what was landed of megrim in Norway per year during the period 2012 to 2021 (ICES, 2022b). This indicated that megrim could be sustainably harvested in larger quantities than what it is today.

In the current study, landed catches of long rough dab were mainly from areas in the Barents Sea and in the North Sea. Long rough dab is currently not assessed by ICES, but an abundance index from a joint Norwegian-Russian ecosystem survey in the Barents Sea was available. During the survey, swept area estimates gave an estimated biomass of between 400-500 000 tonnes per year for the period 2004 to 2020 (Prozorkevich & van der Meeren, 2022). Similar biomass estimates were not currently available for the North Sea. The landed catches of long rough dab in Norway per year during the period 2012 to 2021 were much lower than the estimated biomass in the Barents Sea, indicating that the catches of long rough dab in Norwegian fisheries constitute considerable potential for improved and increased utilisation. The discarded and unreported catches of long rough dab should, however, be considered. The current study found that 108 tonnes were estimated to be discarded and not reported per year of long rough dab in the coastal gillnet fishery and in the longline fishery in the Barents Sea, and could possibly be higher if estimates for the trawl fishery were also available.

Norway redfish is abundant from the south-western Barents Sea in the north and to the northern part of the North Sea Trench, and is also found in many of the Norwegian fjords (Nedreaas, pers. com.). The Norwegian Institute of Marine Research has estimated a time series of the abundance of Norway redfish from the winter survey in the Barents Sea and the coastal ecosystem survey covering the coastal areas from Varanger to Møre (Fall et al., 2023; Höffle pers. com.). The total biomass of Norway redfish in these areas has in recent years been on average about 35 000 tonnes. The landed catches of Norway redfish were found to be very low in Norway during the period of 2012 to 2021, and limited to 2021. The estimated discarded and unreported catches in the coastal gillnet fishery and in the trawl and longline fisheries in the Barents Sea accounted for around 40 tonnes, suggesting that the current catches of Norway redfish are sustainable and that further utilisation could be possible. However, it needs to be taken into consideration that the precision of the abundance estimates are low, and that the estimated discarded or unreported catches from the trawl and longline fisheries were not available for areas south of the Barents Sea.

4.5.2 Considerations for Utilisation of the Focus Species and Other Bycatch Species

When considering the potential for increased utilisation of the four focus species and other bycatch species, the role of the species in the ecosystem needs to be evaluated. Increased utilisation and fishing pressure on the focus species will have a direct effect on the population of the focus species, but may also affect other species in the ecosystem indirectly such as prey species and species that rely on the focus species as a food source (Bellido et al., 2011). This is especially important in in the context of the multispecies and ecosystem-based approaches to fisheries management (Borges et al., 2001).

Further, the biology and life-history traits of the focus species need to be considered in order to utilise the species sustainably. Species with a slow growth rate and that are long-lived may be especially vulnerable to increase fishing pressure (Rochet, 1998). Similarly, the reproductive strategy of the species and the age of maturity should also be evaluated to ensure that the population of the species can be maintained and growth overfishing is avoided. Norway redfish is an example of a species which is slow-growing, long-lived and that have a viviparous reproductive strategy, meaning precaution should be executed when considering the increased utilisation of the species.

4.6 Potential of Bycatch Species for the Future

With an increasing global population and a higher demand for food in the future, food from the ocean should be considered a valuable resource. The findings of this study showed that larger quantities of the catches of the four focus species, grey gurnard, long rough dab, megrim and Norway redfish, were discarded and unreported than landed in the coastal gillnet fishery and in the trawl and longline fishery in the Barents Sea. This indicated that a substantial amount of these resources are wasted, and that there is a potential for better and increased utilisation of the species. The four species examined in the current thesis could provide a valuable source for human consumption if utilised in a sustainable manner. Kjellevold et al. (2022) emphasised that fish will be especially important for food security in the future, and suggested that shifting from terrestrial animal-based diets toward aquatic foods could improve the overall diet, and at the same time contribute to climate change mitigation (Kjellevold et al., 2022).

Utilising the four focus species and other bycatch species instead of discarding the catches of these species would promote sustainable practices in fisheries management and reduce waste in the fisheries sector. Reducing discards and consequently increasing the number of fish that are landed, would also have a positive effect on fisheries management, as more accurate information would be provided for stock assessments and more knowledge would be available about the impact that fisheries have on the marine ecosystem (Bellido et al., 2011; Clegg, 2022). Developing a market for the focus species and other bycatch species in Norwegian fisheries would benefit fishers by providing new resources and income sources, and the increased utilisation of bycatch species could also have a positive impact on commercially important species that have already been heavily exploited, by helping to relieve some of the pressure that they are experiencing (Clegg et al., 2021b).

5. CONCLUSIONS

The four bycatch species grey gurnard, long rough dab, megrim and Norway redfish were examined to investigate to what extent the species were landed and utilised in Norwegian fisheries. Further, the discarded and unreported catches of the species were explored, in addition to the length distribution of the species in different catch groups, to examine the biological potential for improved and increased utilisation of the species.

The current study found that relatively small quantities were landed of the four focus species compared to other commercial species in Norway during the period of 2012 to 2021. When comparing the annual quantity landed of the focus species to the estimated annual quantity discarded and unreported in the coastal gillnet fishery and in the trawl and longline fisheries in the Barents Sea, it was found that much greater quantities were discarded and not reported than landed. On average for the four focus species, 99.6% of the total annual catch weight (discarded and unreported combined with landed catches) comprised of discarded and unreported catches.

The current study compared the landed and the discarded and unreported catches of the four focus species in three fisheries consisting of limited areas and time periods. To increase the accuracy of the findings and to extend the results to additional fisheries, more statistical areas and longer time periods could be explored. Examining the landed and the discarded and unreported catches of other bycatch species and other fisheries would also be beneficial to improve our understanding and knowledge of the biological potential of bycatch species in Norwegian fisheries.

The findings of the current study indicate that there are possibilities for improved and increased utilisation of the four focus species. Considering the indices currently available for the abundance of the species, increased, sustainable utilisation of the species could be possible, as long as a precautionary approach is followed. The landed quantities of the four species in Norway were substantially lower than what was landed of the species in other countries in Europe, indicating that there is potential for improved utilisation of the species if a market was developed in Norway.

Bycatch is an inevitable part of fishing operations as no fishing gear is perfectly size and species selective. Species caught as bycatch are often discarded and not reported as a result of the species having little or no commercial value and a limited market, wasting great quantities of resources. The increased utilisation of bycatch species could promote sustainable practices and provide a valuable source of food for human consumption if utilised sustainably. By developing new markets for these species, fishers can potentially increase their incomes and at the same time reduces waste in the fisheries sector. Considering the findings of the current study, I argue that bycatch species should be seen as valuable resources in the future, especially with a growing global population and an increasing demand for food.

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7. APPENDICES

Appendix 1*: Total weight (kg) landed of all species of fish landed in Norway from 2012 to 2021. Data were retrieved from the official landing statistics of the Norwegian Directorate of Fisheries.*

English name	**Norwegian name**	**Latin name**	**Family**	**Landed weight (kg)**
Atlantic herring	Sild	*Clupea harengus*	Clupeidae	5 249 930 690.2
Atlantic cod	Torsk	*Gadus morhua*	Gadidae	3 962 752 710.2
Blue whiting	Kolmule	*Micromesistius poutassou*	Gadidae	3 290 534 415.4
Atlantic mackerel	Makrell	*Scomber scombrus*	Scombridae	2 121 918 626.8
Saithe	Sei	*Pollachius virens*	Gadidae	1 743 540 779.5
Haddock	Hyse	*Melanogrammus aeglefinus*	Gadidae	1 064 320 185.7
Sand eels	Tobis	*Ammodytes*	Ammodytidae	1 002 495 305.5
Capelin	Lodde	*Mallotus villosus*	Osmeridae	629 249 994.3
Norway pout	Øyepål	*Trisopterus esmarkii*	Gadidae	351 586 800.5
Deep-sea redfish	Snabeluer	*Sebastes mentella*	Scorpaenidae	206 220 527.1
Ling	Lange	*Molva molva*	Lotidae	176 951 167.6
Greater argentine/argentine	Vassild/strømsild	*Argentina silus/sphyraena*	Argentinidae	163 364 638.3
Greenland halibut	Blåkveite	*Reinhardtius hippoglossoides*	Pleuronectidae	141 399 245.5
Tusk	Brosme	*Brosme brosme*	Lotidae	127 260 826.7
Sprat	Brisling	*Sprattus sprattus*	Clupeidae	101 196 733.7
Atlantic horse mackerel	Hestmakrell	*Trachurus trachurus*	Carangidae	97 534 011.9
Golden redfish	Vanlig uer	*Sebastes norvegicus*	Scorpaenidae	56 334 425.1
Hake	Lysing	*Merluccius merluccius*	Merlucciidae	45 105 629.2
Spotted catfish	Flekksteinbit	*Anarhichas minor*	Anarhichadidae	41 909 251.6
Anglerfish	Breiflabb	*Lophius piscatorius*	Lophiidae	31 138 114.0
Atlantic halibut	Kveite	*Hippoglossus hippoglossus*	Pleuronectidae	25 716 995.7
Jelly catfish	Blåsteinbit	*Anarhichas denticulatus*	Anarhichadidae	23 854 955.8

English name	Norwegian name	Latin name	Family	Landed weight (kg)
Pollack	Lyr	*Pollachius pollachius*	Gadidae	20 836 343.5
Atlantic catfish	Gråsteinbit	*Anarhichas lupus*	Anarhichadidae	12 552 313.1
Whiting	Hvitting	*Merlangius merlangus*	Gadidae	10 173 498.1
Silvery pout	Sølvtorsk	*Gadiculus argenteus*	Gadidae	9 840 202.0
European plaice	Rødspette	*Pleuronectes platessa*	Pleuronectidae	9 324 156.6
Lumpsucker	Rognkjeks/Rognkall	*Cyclopterus lumpus*	Cyclopteridae	9 288 089.3
Rays (unspecified)	Skater/Rokker (uspesifisert)	*Raja*	Rajidae	8 212 957.2
Greater fork-beard	Skjellbrosme	*Phycis blennoides*	Phycinae	4 404 506.1
Blue ling	Blålange	*Molva dipterygia*	Lotidae	3 946 502.8
Corkwing wrasse	Grønngylt	*Symphodus melops*	Labridae	3 759 229.0
Spiny dogfish	Pigghå	*Squalus acanthias*	Squalidae	2 973 733.9
Cold-sinny wrasse	Bergnebb	*Ctenolabrus rupestris*	Labridae	2 196 345.0
Rabbit fish	Havmus	*Chimaera monstrosa*	Chimaeridae	2 009 877.1
Ballan wrasse	Berggylt	*Labrus bergylta*	Labridae	1 991 871.5
Pearlside	Laksesild	*Maurolicus muelleri*	Sternoptychidae	1 565 289.0
Witch	Smørflyndre	*Glyptocephalus cynoglossus*	Pleuronectidae	1 550 613.8
Rough rattail	Isgalt	*Macrourus berglax*	Macrouridae	1 374 576.0
Grey gurnard	Knurr	*Eutrigla gurnardus*	Triglidae	1 284 437.5
Spinytail skate	Gråskate	*Bathyraja spinicauda*	Arhynchobatidae	994 845.9
Catfish (unspecified)	Steinbit (uspesifisert)	*Anarhichas*	Anarhichadidae	913 729.6
Velvet belly	Svarthå	*Etmopterus spinax*	Etmopteridae	850 342.5
Starry skate	Kloskate	*Raja radiata*	Rajidae	796 500.0
Atlantic salmon	Laks	*Salmo salar*	Salmonidae	755 984.9
Atlantic bluefin tuna	Makrellstørje	*Thunnus thynnus*	Scombridae	506 653.8
Dab	Sandflyndre	*Limanda limanda*	Pleuronectidae	502 897.9

English name	Norwegian name	Latin name	Family	Landed weight (kg)
Lemon sole	Lomre	*Microstomus kitt*	Pleuronectidae	499 411.3
Other fish (unspecified)	Annen fisk (uspesifisert)			468 136.0
Long rough dab	Gapeflyndre	*Hippoglossoides platessoides*	Pleuronectidae	426 981.6
Turbot	Piggvar	*Scophthalmus maximus*	Scophthalmidae	315 404.4
Megrim	Glassvar	*Lepidorhombus whiffiagonis*	Scophthalmidae	281 859.1
Sailray	Hvitskate	*Raja lintea*	Rajidae	217 467.5
Thornback ray	Piggskate	*Raja clavata*	Rajidae	217 131.5
Roundnose grenadier	Skolest	*Coryphaenoides rupestris*	Macrouridae	186 924.6
White skate	Burton-skate	*Raja alba*	Rajidae	105 488.6
Brill	Slettvar	*Scophthalmus rhombus*	Scophthalmidae	103 776.3
Common skate	Storskate	*Dipturus batis*	Rajidae	102 135.8
Blackmouthed dogfish	Hågjel	*Galeus melastomus*	Scyliorhinidae	95 125.0
Flounder	Skrubbe	*Platichthys flesus*	Pleuronectidae	90 283.2
Rock cook wrasse	Gressgylt	*Centrolabrus exoletus*	Labridae	77 454.4
Porbeagle shark	Håbrann	*Lamna nasus*	Lamnidae	62 991.0
Other flatfishes	Andre flyndre	*Pleuronectiformes*	Pleuronectidae	41 806.6
Common mora	Mora	*Mora moro*	Moridae	38 522.9
Common sole	Tunge	*Solea solea*	Soleidae	37 571.3
European eel	Ål	*Anguilla anguilla*	Anguillidae	32 227.6
Blue-mouth redfish	Blåkjeft	*Helicolenus dactylopterus*	Scorpaenidae	29 108.6
Basking shark	Brugde	*Cetorhinus maximus*	Cetorhinidae	22 384.0
European anchovy	Ansjos	*Engraulis encrasicolus*	Engraulidae	16 913.0
Poor cod	Sypike	*Trisopterus minutus*	Gadidae	9 829.4
Brown trout	Ørret	*Salmo trutta*	Salmonidae	9 584.5
Tub gurnard	Rødknurr	*Trigla lucerna*	Triglidae	4 944.0

English name	Norwegian name	Latin name	Family	Landed weight (kg)
Longnosed skate	Spisskate	*Dipturus oxyrinchus*	Rajidae	4 725.9
European conger eel	Havål	*Conger conger*	Congridae	3 856.5
Boarfish	Villsvinfisk	*Capros aper*	Caproidae	3 347.0
Garfish	Horngjel	*Belone belone*	Belonidae	3 246.6
Atlantic bonito	Stripet pelamide	*Sarda sarda*	Scombridae	3 034.0
Hagfish	Slimål	*Myxine glutinosa*	Myxinidae	2 981.0
European pilchard	Sardin	*Sardina pilchardus*	Clupeidae	2 842.0
Snipefish	Trompetfisk	*Macroramphosus scolopax*	Macroramphosidae	2 836.0
John dory	Sanktpetersfisk	*Zeus faber*	Zeidae	2 502.7
Ray's bream	Havbrasme	*Brama brama*	Bramidae	2 396.7
Pink cusk eel	Pink cusk eel	*Genypterus blacodes*	Ophidiidae	2 276.0
Glacier lantern fish	Nordlig lysprikkfisk	*Benthosema glaciale*	Myctophidae	1 938.0
Cuckoo wrasse	Blåstål/Rødnebb	*Labrus bimaculatus*	Labridae	1 612.1
Blue antimora	Blå antimora	*Antimora rostrata*	Moridae	1 092.3
Other sharks (unspecified)	Annen hai (uspesifisert)	*Selachimorpha*	Selachimorpha	928.7
Birdbeak dogfish	Gråhå	*Deania calcea*	Centrophoridae	907.1
Redfish (unspecified)	Uer (uspesifisert)	*Sebastes*	Scorpaenidae	841.8
Leafscale gulper shark	Brunhå	*Centrophorus squamosus*	Centrophoridae	683.0
Polar cod	Polartorsk	*Boreogadus saida*	Gadidae	620.0
Norway redfish	Lusuer	*Sebastes viviparus*	Scorpaenidae	609.0
Portuguese dogfish	Dypvannshå	*Centroscymnus coelolepis*	Somniosidae	510.0
European seabass	Havabbor	*Dicentrarchus labrax*	Moronidae	494.2
Great lanternshark	Stor svarthå	*Etmopterus princeps*	Etmopteridae	434.0
Other wrasses (unspecified)	Annen leppefisk (uspesifisert)	*Labridae*	Labridae	350.5
Tope shark	Gråhai	*Galeorhinus galeus*	Triakidae	224.3

English name	Norwegian name	Latin name	Family	Landed weight (kg)
Swordfish	Sverdfisk	*Xiphias gladius*	Xiphiidae	96.6
Common dragonet	Vanlig fløyfisk	*Callionymus lyra*	Callionymidae	89.0
Sandy ray	Sandskate	*Raja circularis*	Rajidae	56.3
Sunfish	Månefisk	*Mola mola*	Molidae	39.0
Gurnards (unspecified)	Knurr (uspesifisert)	*Triglidae*	Triglidae	10.0

Appendix 2: *Landed weight (kg) of grey gurnard, long rough dab, megrim and Norway redfish per month for the period 2012 to 2021.*

Season	Month	Species			
		Grey gurnard	Long rough dab	Megrim	Norway redfish
Winter	January	10 962.5	589.8	10 326.3	0.0
Winter	February	3 771.6	1 697.1	11 637.4	0.0
Spring	March	2 948.0	1 731.7	22 115.2	0.0
Spring	April	208 639.0	84 984.4	32 723.4	0.0
Spring	May	495 433.0	19 440.2	23 911.4	0.0
Summer	June	268 487.8	15 178.6	32 389.7	396.0
Summer	July	53 956.8	47 669.4	28 128.4	240.0
Summer	August	57 740.6	84 187.9	28 254.1	0.0
Autumn	September	99 300.1	83 060.5	36 187.0	0.0
Autumn	October	57 272.1	30 370.0	24 926.0	0.0
Autumn	November	20 602.6	32 940.9	21 194.1	0.0
Winter	December	5 323.4	25 131.1	10 076.1	0.0

Appendix 3: *Landed weight (kg) of grey gurnard, long rough dab, megrim and Norway redfish per statistical area as defined by the Norwegian Directorate of Fisheries for the period 2012 to 2021.*

Area	**Species**			
	Grey gurnard	**Long rough dab**	**Megrim**	**Norway redfish**
00	0.0	698.5	0.0	0.0
01	0.0	949.2	0.0	0.0
03	0.0	13 782.2	0.0	0.0
04	0.0	2 828.9	0.0	0.0
05	0.0	359.4	46.5	0.0
06	11.0	7 000.8	0.0	0.0
07	7004.0	1 048.7	5 277.0	0.0
08	559 037.6	66 880.1	54 583.7	609.0
09	5 989.2	936.7	193.6	0.0
10	0.0	35.2	0.0	0.0
12	0.0	2 395.9	0.0	0.0
13	0.0	451.1	0.0	0.0
15	0.0	88 743.6	0.0	0.0
16	0.0	73 111.0	0.0	0.0
20	0.0	19 433.4	0.0	0.0
22	0.0	10 620.0	0.0	0.0
23	0.0	25 772.2	0.0	0.0
24	0.0	7 966.0	0.0	0.0
28	31 866.8	15 240.1	106 030.4	0.0
40	3 237.0	0.0	192.5	0.0
41	642 503.2	15 990.0	1 849.1	0.0
42	34 788.7	72 738.6	113 301.3	0.0
57	0.0	0.0	385.0	0.0

Appendix 4: *Landed weight (kg) of grey gurnard, long rough dab, megrim and Norway redfish per gear type for the period 2012 to 2021.*

Gear type	**Species**			
	Grey gurnard	**Long rough dab**	**Megrim**	**Norway redfish**
Bottom trawl	1 094 428.5	374 579.6	195 399.2	609.0
Pelagic trawl	161 618.7	5 087.0	463.0	0.0
Shrimp trawl	311.9	950.6	4.4	0.0
Trawl, other	299.0	0.0	19 561.5	0.0
Gillnet	3 251.8	23 253.5	6 358.7	0.0
Longline	373.0	17 848.2	17.6	0.0
Demersal seine	8 964.6	5 260.1	58 773.7	0.0
Purse seine	15 180.0	0.0	0.0	0.0
Handline	0.0	2.2	0.0	0.0
Pots, traps, fyke net	5.0	0.4	1 188.6	0.0
Other	5.0	0.0	92.4	0.0

Appendix 5: *Estimated discarded catches (kg) in the coastal gillnet fishery (2018) based on Berg and Nedreaas, 2020. Landed weight (kg) was retrieved from the official landing statistics of the Norwegian Directorate of Fisheries for the same fishery, areas and time period.*

Area	**Species**				
	Weight (kg)	**Grey gurnard**	**Long rough dab**	**Megrim**	**Norway redfish**
04	Landed	0.0	46.5	0.0	0.0
04	Discarded	0.0	600.0	5 000.0	0.0
05	Landed	0.0	0.0	0.0	0.0
05	Discarded	500.0	4 000.0	4 000.0	0.0
00	Landed	0.0	11.0	0.0	0.0
00	Discarded	4 000.0	0.0	8 000.0	700.0
06	Landed	0.0	0.0	0.0	0.0
06	Discarded	0.0	0.0	6 000.0	0.0
07	Landed	32.0	0.0	0.0	0.0
07	Discarded	8 000.0	3 000.0	33 000.0	11 000.0
28	Landed	10.9	0.0	166.8	0.0
28	Discarded	100.0	300.0	800.0	200.0
08	Landed	11.5	7.7	506.6	0.0
08	Discarded	200.0	0.0	800.0	300.0
09	Landed	6.0	1.1	0.0	0.0
09	Discarded	400.0	0.0	0.0	300.0
Total	**Landed**	**60.4**	**66.3**	**673.4**	**0.0**
Total	**Discarded**	**13 200.0**	**7 900.0**	**57 600.0**	**12 500.0**

Appendix 6: *Estimated unreported catches (kg) in the trawl fishery in the Barents Sea based on Clegg, 2022. Statistical area used: 04, 05, 12, 20, 23, 24. Unreported catches were not estimated for long rough dab due to data inaccuracies. Landed weight (kg) was retrieved from the official landing statistics of the Norwegian Directorate of Fisheries for the same fishery, areas and time period.*

Year	Species				
	Weight (kg)	**Grey gurnard**	**Long rough dab**	**Megrim**	**Norway redfish**
2012	Landed	0.0		0.0	0.0
2012	Discarded	97.0		1 180.0	54 406.0
2013	Landed	0.0		0.0	0.0
2013	Discarded	9 151.0		903.0	41 943.0
2014	Landed	0.0		0.0	0.0
2014	Discarded	19 363.0		29 010.0	15 751.0
2015	Landed	0.0		0.0	0.0
2015	Discarded	1 233.0		9 946.0	18 464.0
2016	Landed	0.0		0.0	0.0
2016	Discarded	266.0		667.0	2 140.0
2017	Landed	0.0		0.0	0.0
2017	Discarded	335.0		303.0	6 621.0
2018	Landed	0.0		0.0	0.0
2018	Discarded	707.0		3 033.0	9 593.0
2012-2018	Landed	0.0		0.0	0.0
2012-2018	Discarded	31 152.0		45 042.0	148 918.0
Average per year	**Landed**	**0.0**		**0.0**	**0.0**
Average per year	**Discarded**	**4 450.0**		**6 435.0**	**21 274.0**

Appendix 7: *Estimated unreported catches (kg) in the longline fishery in the Barents Sea based on Clegg, 2022. Statistical area used: 04, 05, 12, 20, 23. There were no catches of megrim. Landed weight (kg) was retrieved from the official landing statistics of the Norwegian Directorate of Fisheries for the same fishery, areas and time period.*

Year	**Species**				
	Weight (kg)	**Grey gurnard**	**Long rough dab**	**Megrim**	**Norway redfish**
2012	Landed	0.0	556.0		0.0
2012	Discarded	212.0	146 232.0		9 746.0
2013	Landed	0.0	0.0		0.0
2013	Discarded	0.0	83 309.0		1 917.0
2014	Landed	0.0	1 698.0		0.0
2014	Discarded	2.0	86 189.0		1 840.0
2015	Landed	0.0	0.0		0.0
2015	Discarded	26.0	101 036.0		1 316.0
2016	Landed	0.0	0.0		0.0
2016	Discarded	32.0	125 733.0		512.0
2017	Landed	0.0	0.0		0.0
2017	Discarded	25.0	71 313.0		1 128.0
2018	Landed	0.0	0.0		0.0
2018	Discarded	36.0	88 424.0		26 334.0
2012-2018	Landed	0.0	2 254.0		0.0
2012-2018	Discarded	333.0	702 236.0		42 793.0
Average per year	**Landed**	**0.0**	**322.0**		**0.0**
Average per year	**Discarded**	**48.0**	**100 319.0**		**6 113.0**

Appendix 8: *Number of individuals measured, mean length (cm) and standard deviation (SD) of individuals of grey gurnard, long rough dab, megrim and Norway redfish in catch group 23 (discarded individuals), 26 (landed individuals) and 29 (individuals processed for fish meal). Individuals were length measured by Reference Fleet vessels from 2012 to 2021.*

Catch group		Species			
		Grey gurnard	Long rough dab	Megrim	Norway redfish
23 + 26 + 29	Number of individuals measured	8 722	35 355	11 365	12 845
23	Number of individuals measured	7 328	29 115	10 040	11 485
26	Number of individuals measured	458	687	828	718
29	Number of individuals measured	936	5 553	497	642
23	Mean	34.5	35.0	39.1	23.3
26	Mean	33.6	38.2	41.9	26.3
29	Mean	32.7	31.9	28.9	23.9
23	SD	5.3	10.7	7.8	3.2
26	SD	4.2	6.3	6.9	3.7
29	SD	6.3	10.4	15.4	3.1

Appendix 9: *Landed catches (tonnes) by European countries reporting their catches to ICES of grey gurnard, long rough dab, megrim and Norway redfish from 2012 to 2020. Landed catches by Norway are excluded. Tope three countries are listed in descending order. Data were retrieved from the Official Nominal Catches (2006-2020) of ICES.*

	Species			
	Grey gurnard	**Long rough dab**	**Megrim**	**Norway redfish**
Total weight landed (tonnes)	17 202	35 598	14 542	2 634
Number of countries	12	15	10	2
Average landed weight per country (tonnes)	1 434	2 373	1 454	1 317
Top three countries	Denmark UK Netherlands	Russia Estonia Iceland	France Iceland Portugal	Iceland Netherlands
Average landed weight for top three countries (tonnes)	4 322	10 742	4 948	1 317