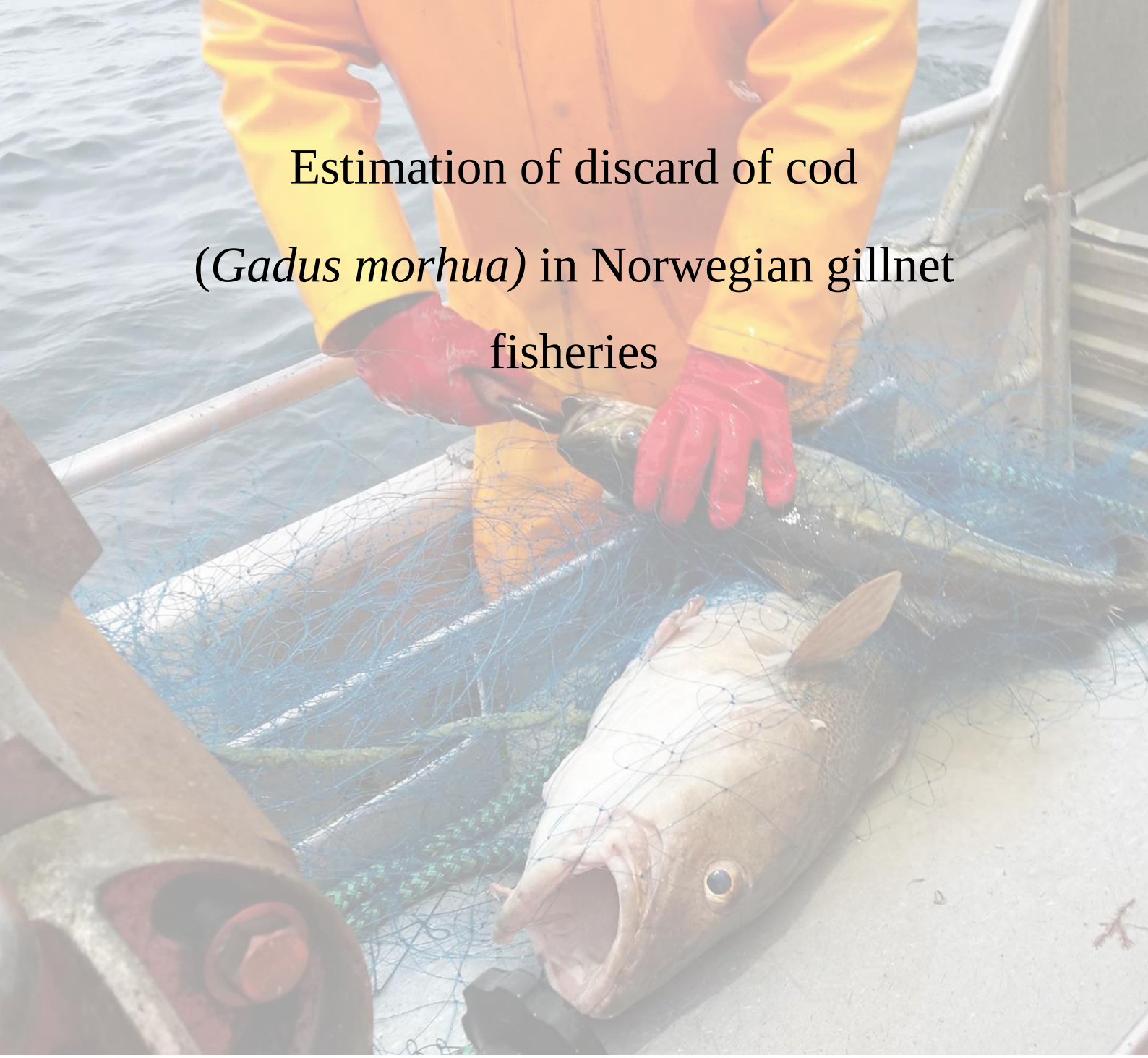

Estimation of discard of cod (*Gadus morhua)* in Norwegian gillnet fisheries

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ABSTRACT

Estimates have suggested that around 10 % of global marine fisheries-catches are discarded at sea, instead of landed and utilized. Since 1987, Norway has gradually implemented a Discard ban, which prohibits the act, but also makes it hard to obtain data from discarding. The unreported discarding adds to the total fishing mortality in the stock and might lead to uncertainties in stock assessments. Estimations of discard of cod in coastal cod-fisheries with gillnets, in three statistical areas in Northern Norway, were conducted using reported data from a selection of vessels working with the Institute of Marine Research, called the Coastal Reference Fleet. Data on landings and number of sales notes from the official landing statistics were used to upscale the estimated discards to the whole coastal fleet fishing with gillnets in the areas, with two different approaches. The mean annual discard rates of cod were less than or equal to 0.73 % of total catch in weight for vessels under 15 meters in the statistical areas 00, 05 and 06 combined, irrespective of calculation method. Estimated mean discard rates per annual quarter in each area were generally higher in quarters 3 and 4, than in quarters 1 and 2. Comparisons of length distributions for landed and discarded fish showed occasional signs of high grading in the fishery (discarding smaller legal-sized cod), especially in quarter 1 and 2. The study relies on the assumption that the data from the Coastal Reference Fleet are representative for the whole coastal fishing fleet. If this is true, the annual mean discard rates for cod in coastal fisheries with gillnets are relatively small. This indicates that the additional mortality from discarding in this coastal gillnet fishery will not have large impacts on the stock assessments. The generally higher mean discard rates from quarter 3 and 4 will be from catches mainly consisting of Norwegian coastal cod. Further studies concerning discarding in this part of the fishery is recommended.

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1 INTRODUCTION

DEFINITIONS:

Fleet: Commercial fishing vessels in a defined area, fishing with the same gear and targeting the same species (Pérez-Roda et al. 2019). In this thesis: smaller, coastal commercial fishing vessels less than 15 meters total length using gillnets (Williams 2016).

Catch: The total biomass that is removed from the sea and brought onto a commercial fishing vessel. The catch may be landed, discarded or utilized onboard.

Landing: The proportion of the catch of fish or other marine animals that is delivered to a landing site/processing plant or otherwise utilized on land.

Discard: The (dead or alive) proportion of the catch of fish or other marine animals that is not landed but thrown overboard/returned to the sea (Pérez-Roda et al. 2019).

Round weight: The weight of the fish when it comes directly from the sea, before removal of any parts. All fisheries statistics operate using this weight unit (Anon. 2018).

It has been estimated that around 10 % of global fish catches are not utilized due to discarding at sea (Zeller et al. 2018; Pérez-Roda et al. 2019). Discarding is the release of undesirable fish from a catch. The contact with fishing gear and/or handling and time on deck, will in many cases kill the fish even if it is released back to the ocean, unnecessarily contributing to the total mortality of the fish stock (Davis 2002; Pérez-Roda et al. 2019). It often remains unrecorded, as it for example is illegal in Norway, and may represent a significant source of uncertainty in fish stock assessments and estimations of fishing mortality. Discard is viewed as an important issue affecting today's fisheries management (Davis 2002). In addition, discarding of dead or dying fish is regarded as a wasteful utilization of the world's marine resources (Pascoe 1997; Davis 2002).

The mortality associated with discarding can be a result of prolonged soaking time for passive gears, rapid pressure changes (barotrauma), too long duration above water resulting in suffocation, and/or interactions between the fish and the fishing gear or the fishermen. When dead or dying fish are discarded, the resources are not utilized, and the fish cannot contribute to further production of the stock. The discarded fish will contribute as a source of food for scavenging animals, marine birds and mammals (Heath et al. 2014), but will not directly enter the global food market. Fish that are being discarded while assumed still alive are also counted as discards, because of uncertainties linked to their survival over time.

In a fishery, the catch may be divided into target and non-target species. A target species (can be one or several) for a fishery determine where and when the fishing takes place, and which gear is used, for example, the cod fishery in the Barents Sea. A non-target species in a fishery are any species that are

not intended to be caught (Pascoe 1997), which may be unwanted because of low or no economic value, or because it is a protected species. It may also be an unwanted species because the fishers do not have a quota or fishing rights for it (Gullestad et al., 2015). The terms target and non-target species may therefore be fishery-specific (Pascoe 1997).

Unintentional catch of non-target species is one reason for discarding. Sometimes, parts of the catch of a target species are not needed or wanted. This might be caused by minimum landing/fishing sizes for the species. If there are regulations against fishing below a certain size for a species, the fishers might discard the fish of these sizes to avoid penalties (Pascoe 1997). Also, the amount of one species in the catch, typically at the end of the fishing season, might exceed the amount of the boats/fleets total allowable catch (TAC) (Gullestad et al. 2015). Discarding of target species is sometimes motivated by "high grading" (i.e. selecting only the biggest and most valuable individuals in a catch to save storage room and quotas). In some cases there are larger and better paying markets for certain size-ranges of species, typically the largest (as with for example cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*)) (Pascoe 1997). The fishermen may be motivated to high grade by a desire to fill their quota with the most profitable fish (Gullestad et al. 2015). Discarding of smaller individuals may also be motivated by the idea of releasing the fish that are (assumedly) still alive and letting them grow to larger sizes before being harvested. In this practice there are uncertainties linked to the long-term survival of the fish, as they may have unnoticeable injuries such as nitrogen bubbles in the blood vessels and slime or scale loss resulting in lowered immune defence. Lastly, discarding occurs because of a low quality fish catch, caused by for example soak time or damage from gear, handling or scavengers (Gullestad et al. 2015).

In 1987 Norway introduced a discard ban on cod and haddock, and the ban was gradually expanded to new species. In 2009 an obligation to land all catches was introduced, but with some exemptions (Gullestad et al. 2015). The ban is implemented as a part of the Norwegian regulations on the practice of fishing in the sea. Presented in chapter 10, the discard ban starts with stating that all catch of fish shall be landed. The regulation goes on to present the exceptions to the rule, which includes discarding of viable fish or fish not included in the list of species covered by the ban (Anon. 2004).

The Norwegian discard ban is first and foremost enforced by presence and surveillance at sea by the Norwegian Coast Guard and the Directorate of Fisheries' (DoF) Surveillance Service. The Coast Guard dispose 15 operative vessels and also dispose aeroplanes and helicopters, and conduct around 2000 at sea inspections each year, checking the vessels' catches in relation to their log book reports (Gullestad et al. 2015; Anon. 2009). The presence and surveillance from the inspectors are very important and make it harder for large-scale discarding to go unnoticed. However, it is possible that small-scale discarding in for instance the coastal fisheries is more difficult to detect, and the mortality from many such smaller events may add up to have a significant effect.

There are several regulations that help with enforcement of the discard ban, apart from the surveillance by the Coast Guard. To "help" the fishers, making the discard ban easy and convenient to follow, the authorities have created different procedures. For example, it has become a practice that discarding of the occasional fish that is damaged from gear/soak time/scavengers to the extent that it is no longer suitable for human consumption, will not be prosecuted by the enforcers (Gullestad et al. 2015). The economic value of illegal landings is normally obtained by the state. An incentive regarding unintentional bycatches, is to pay fishers for the extra work they perform in handling and landing the fish instead of discarding it. As a compensation the fishermen retain 20 % of the economic value of the illegal bycatch, if it is believed to have been caught unintentionally (Anon. 2009; Gullestad et al. 2015).

When the discard ban was implemented, the technical regulations for different fisheries changed from having a "minimal landing size" to a "minimum fishing size" (Gullestad et al. 2015). This is a type of conceptual change in the regulations which might help to change the way fishers, managers and gear-producers consider fishing-activities. To not exceed the "minimum fishing size" in their fishing, the fishers have to use knowledge about distribution, behaviour and migration of the different fish species, and selective gear.

There are also different bycatch allocations in some fisheries**.** For example, parts of the Norwegian quota for saithe (*Pollachius virens*) are given to fishers with a quota to fish cod, as some bycatch of saithe in the catches in the same areas are almost inevitable (Anon. 2017). There are cases where fish under the minimum fishing size mix with larger fish in the fishing grounds. If the fishermen register too many of the smaller individuals in their catch, they are obliged to move fishing ground to a different area (Gullestad et al. 2015).

One of the original factors motivating the implementation of the Norwegian discard ban was events of high grading of cod in the 1980s. Cod has been a highly important fish species in Norway for hundreds of years, and it still is today with annual catch-values of around 6-7 billion NOK (Statistics Norway 2019). Records of landing of cod exists back to at least 1815 and quantitative information about the cod fishery dates back to the 1300s (Øiestad 1994). Cod is believed to have been an important source of food (and later income through sales and export) for people in Norwegian coastal areas for as long as they have been inhabited.

Cod fisheries in northern Norway is based on Northeast Arctic cod (NEA cod), and coastal cod. The migrating, mature NEA cod is commonly called "skrei", which means "the wanderer". The name originates from the fish's annual spawning-migration from the Barents sea to the Lofoten-area (Aglen 2009; Sundby & Nakken 2008). The coastal fishery for NEA cod peaks in late winter and early spring, in the main spawning-season. The coastal cod spends its whole life in coastal areas, in fjords and normally no more than 12 nautical miles from the coast. Typically, the catch of cod in coastal fisheries in northern Norway will be dominated by NEA cod in the first half of the year, and later dominated by

coastal cod in the second half (Aglen 2009). The minimum fishing size for cod north of 62° N is 44 cm (Anon. 2004). As fish below this threshold is by law not allowed to catch, the fishers are obligated to release alive and viable individuals in this category. Again, the intention is to let the fish grow to larger sizes and possibly reproduce before being harvested. Parts of the discard of cod in the coastal gillnet fisheries will belong to this category and are therefore not illegal discards.

High grading describes the process of discarding smaller individuals in a catch, for personal economic gain. Because of the commercial, cultural and ecological importance of both NEA cod and coastal cod, the observed practice of high grading from the 1980s was recognized as "economic madness and morally wrong", as said by the then present Minister of Fisheries, Bjarne Mørk-Eidem (Gullestad et al. 2015). However, it is unrealistic to believe that a discard ban will abolish all this practice. Gathering of data on discard and/or bycatch is associated with challenges in all fisheries. These challenges will in many cases be increased by landing obligations or discard bans as the fishers are then either not willing to report numbers on discards, or they are not asked. This is the case in the Norwegian fisheries, including the coastal fishery for cod. The lack of knowledge on the amounts of discards in the fishery may cause inaccurate stock assessments. By underestimating the fishing mortality in a stock, the basis for the TACs are also underestimated, potentially resulting in too large quotas (Anon. 2009).

When trying to estimate discards from Norwegian fisheries, the Norwegian Reference Fleet-programme provide valuable data. The High-Seas Reference Fleet was established by the Norwegian Institute of Marine Research (IMR) in the year 2000, as a way for the scientists to achieve better and more consistent samples from fisheries, as well as data on effort and the behaviour of the fleet (Nedreaas et al. 2006). At that time, it only included larger high-sea vessels. In 2005, the Coastal Reference Fleet (CRF) (Anon. 2011) was established as an expansion of the programme. This fleet consists of smaller, coastal fishing vessels mainly using gillnets and pots (Williams 2016). In 2015 the CRF consisted of 24 fishing vessels (Williams 2016). Figure 1.1 shows the geographical coverage from the Coastal Reference Fleet along the Norwegian coast (in 2015).

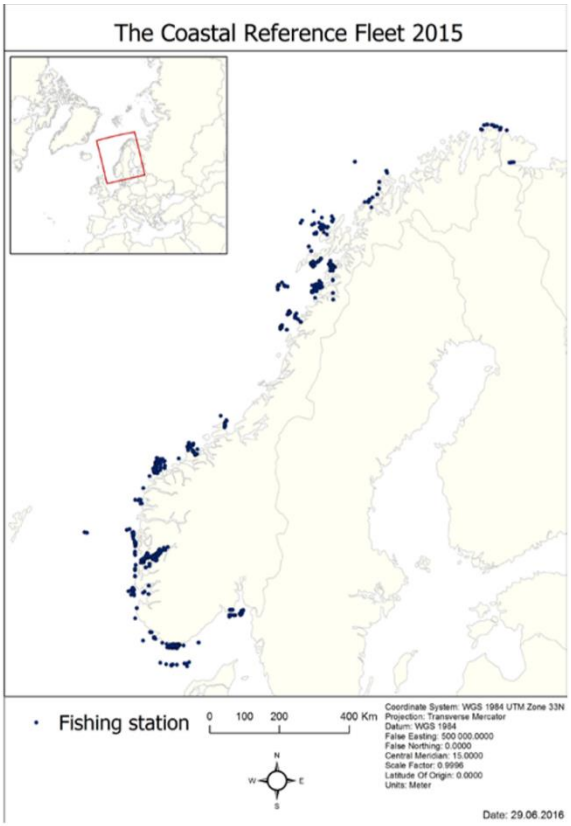

Figure 1.1 *– Registered catches and sample stations from the participants in the Coastal Reference fleet in 2015.* (Williams 2016)

The participating vessels are contracted and paid to register their fishing activity and provide samples and information to IMR from their catches (Nedreaas et al. 2006). The reported discard from the Reference Fleet is the only source of continuous discard data from the Norwegian fisheries.

The participants in the programme are randomly selected within pre-defined coastal strata among vessels applying for the contract. Each vessel has a contact person or mentor employed at IMR that regularly visits the vessels and may help in instructing methods for correct sampling of the catch, including discards and bycatch. If there are reasons to believe that the sampling from a vessel is inconsistent with real data, it might lead to the termination of contract (Bjørge & Moan 2013). To achieve high quality data, the programme is highly dependent on a trust-based relationship between the fishers and the scientists (Nedreaas et al. 2006; Williams 2016).

Estimation of discard of cod in Norwegian coastal fisheries for cod with gillnets were conducted using data from the CRF. Together with the DoF's official Norwegian landing statistics (sales notes), the data was used to calculate discard of cod per catch unit of cod. Under the assumptions that the numbers collected from the CRF are representative for all the vessels in the fishing fleet, the calculated ratio of discard per catch unit can be multiplied to apply for the total fishery in the relevant area and time-period (stratum) (Blom et al. 2015). Preparatory work with the material was done by IMR and the DoF in 2012, which gave an estimated discard rate (in percent weight of total cod landings) of around 0.3 % (Blom et al. 2015).

The aim of the present thesis was to quantify discard of cod with confidence intervals (CIs) from the ratio of discarded cod to total catch for seven years (2012-2018) in three statistical areas (00, 05 and 06) with two different approaches for upscaling:

1) Reported discard from the CRF were scaled to the total Norwegian landing of cod in weight for vessels in the defined areas and periods (with gillnets, vessels < 15 m total length). CIs were calculated by using two methods: the ratio estimator and the percentile Bootstrap method.
2) Reported discard from the CRF were scaled to the total number of sales notes with cod in the defined areas and periods (with gillnets, vessels < 15 m total length). CIs were calculated by using two methods: the standard error of the mean (SE) and the percentile Bootstrap method.

In addition, size-distributions for discarded and landed cod, from length measurements provided by the CRF, were compared to look for indications of high grading in the fishery.

2 MATERIALS AND METHODS

2.1 STUDY AREA AND FISHERY CHARACTERISTICS

In this study, discard numbers and total weight of discard of cod were estimated in three of the DoF's statistical areas in Norway, commonly called "Vestfjorden (Lofoten)", "Røstbanken to Malangsgrunnen" and "Helgeland". For management and scientific purposes, they are numerated 00, 05 and 06 (Figure 2.1), respectively, and will be referred to as these in the following.

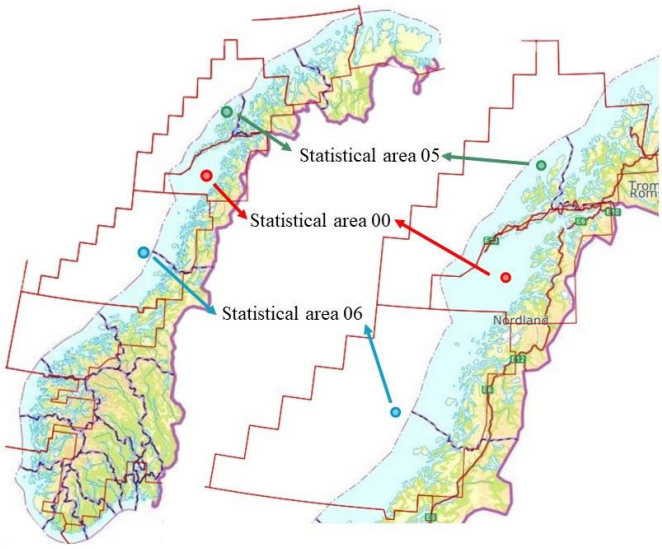

Figure 2.1 *– Statistical areas 00 (Vestfjorden (Lofoten)), 05 (Røstbanken to Malangsgrunnen) and 06 (Helgeland) defined by the DoF. Source: Directorate of Fisheries, accessed February 2019 <https://kart.fiskeridir.no/fiskeri>*

Information about discards (numbers discarded, including zero) from fishing trips during 2012-2018 were used in this study. The reported position of each fishing trip utilized are given in Figure 2.2. The maps were created in RStudio version 1.0.153 with R version 3.4.1 (R Core Team 2017), using packages *tidyverse* (Wickham 2017), *mapdata* (Brownrigg et al. 2018), and *sp* (Pebesma & Bivand 2018).

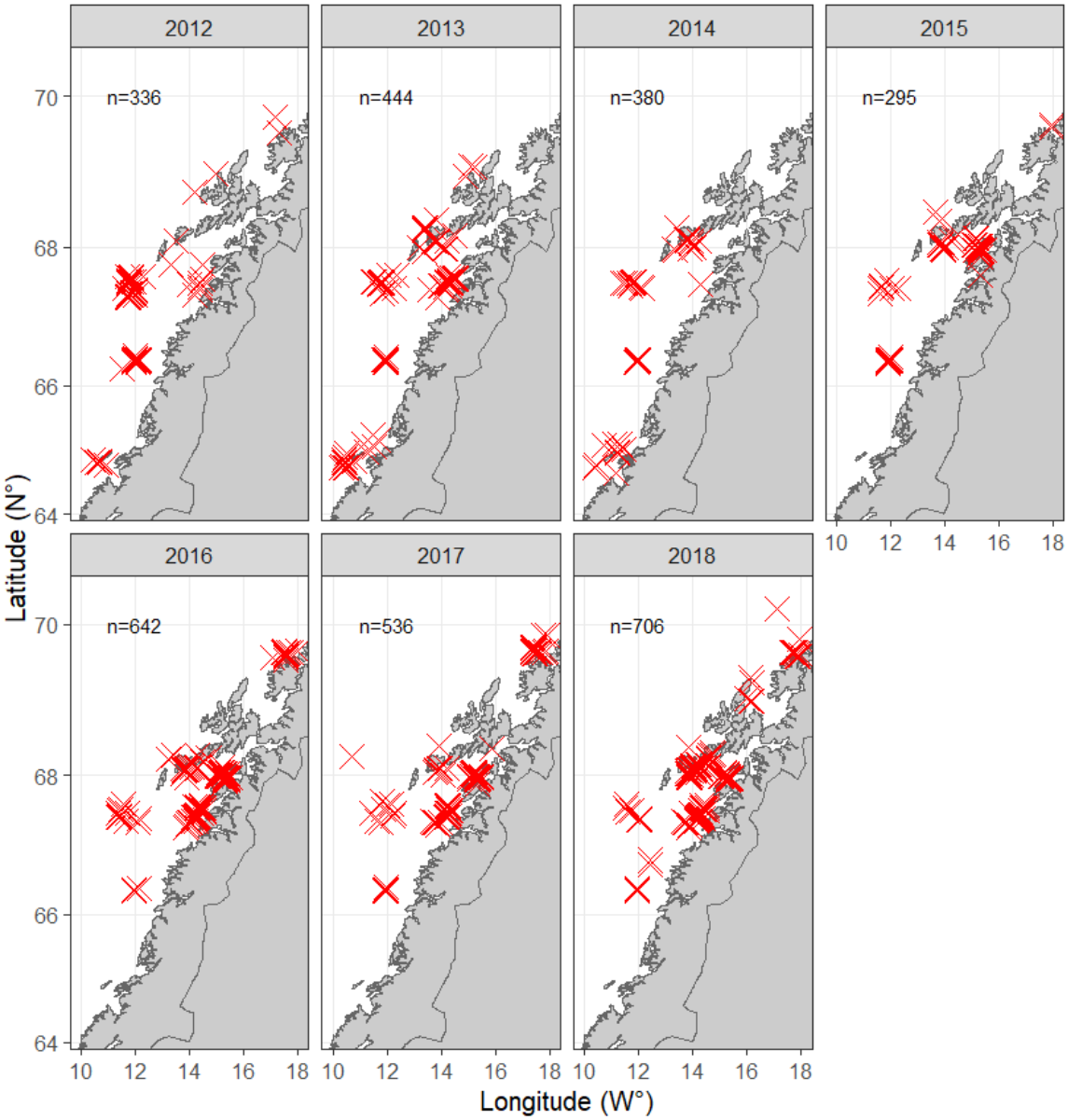

Figure 2.2 *– Location of fishing trips with catch of cod from vessels < 15 m total length, using gillnets. Collected by the CRF in the statistical areas 00, 05 and 06 during 2012-2018.*

2.2 COASTAL FISHERY FOR COD

The study is limited to the coastal fishing fleet, fishing with gillnets. This is usually defined as vessels < 15 m total length operating in proximity to the coast, i.e. within the 12 nautical mile limit (Fangel et al. 2015). In 2018, 5 296 fishing vessels were registered as active in Norway. Of these, 4 861 were < 15 m, which means that the coastal fleet make up around 90 % of the entire Norwegian fishing fleet (Directorate of Fisheries 2019a).

Large portions of the coastal fishing fleet use passive gears, including gillnets, longlines and pots. These gears are often used to target cod and other gadoids. The most common gillnets used in the cod fishery by the small coastal vessels are bottom-set gillnets with a bar length (half mesh size) between 75 and

105 mm (Bjørge & Moan 2013). The total landings of cod from vessels < 15 m total length (along the whole Norwegian coast with gillnets) are listed in Table 2.1.

Table 2.1 *– Total annual landings of cod caught with gillnets by vessels < 15 m total length in Norwegian fisheries during 2012-2018. Source: Norwegian landing statistics,* (Directorate of Fisheries 2019b)

Year	Round weight (tonnes)
2012	73 924
2013	84 026
2014	94 160
2015	83 328
2016	71 101
2017	74 589
2018	75 545

The "skrei fishery" in the Lofoten-area during the spawning season is the largest commercial coastal fishery in Norway (Fangel et al. 2015). Outside of this fishery for NEA cod, the fishers don't always target cod exclusively. Other commercial species that are frequently seen in the catches are saithe, haddock (*Melanogrammus aeglefinus*), pollack (*Pollachius pollachius*) and ling (*Molva molva*). This type of multispecies gadoid fishery use similar mesh sizes as the coastal cod fishery, and is executed all year round along the Norwegian coast (Bjørge & Moan 2013).

In this study, records from fishing trips with only discarded cod and no landed/retained cod were not included in the estimations.

2.3 DATA COLLECTION

2.3.1 The Norwegian Coastal Reference Fleet

The data for this study was reported/collected by fishers participating in the CRF that fished cod within the study areas during the study period using gillnets. The CRF is mostly limited to vessels < 15 m total length. There is one exception relevant in this study that is > 15 m total length. This vessel is still a part of the study, as it is believed to have fishing activities and habits that are representative for vessels < 15 m total length (and was contracted by IMR based on this).

The vessels in the CRF are instructed to register their total catch, including bycatch and discards for every day of fishing. They take samples from their catches and fill out forms to IMR, including where they fished (statistical area and GPS coordinates), the depth of fishing, and information about gear and soak time. The landed catch is reported in round weight per species and preferably also in numbers. The discard is reported in numbers per species (Anon. 2016). There is no information in the data about the reasons for discarding and they are not asked to report "0" in the records if there are no discards. A reported fishing trip with catch of cod and no reported discard of cod were therefore assumed to mean zero discards.

The sampling systems resemble the ones used on board the IMR's research vessels (Nedreaas et al. 2006). Some detailed measurements of the catches are conducted, including length measurements. For each species, a maximum of 20 randomly selected individuals from the landed catch are length measured each week (Anon. 2016). Discarded individuals from a catch are also length measured, also maximum 20 per species each week. The length measurements are in total length (TL), measured from the tip of the snout to the end of the caudal fin.

Information about the date, the vessel's unique call-sign, fishing location (area and coordinates), number of discarded cod and weight of landed cod catches, as well as individual length measurements of landed and discarded cod were extracted from this data material.

The number of contributing vessels and fishing trips utilized in the study are presented in Table 2.2. Fishing trips were included if they contained data on catch of cod and discard of cod or catch of cod without discard of cod. In Table 2.2, the column "No. registered fishing trips, matched with sales notes" have smaller numbers than the column "No. registered fishing trips with catch of cod" because not all the fishing trips registered to the CRF were found in the sales notes. This difference was mostly assumed to be caused by several fishing trips (i.e. catches of cod) contributing to one sales note.

***Table 2.2** – Number of vessels from the CRF in the statistical areas 00, 05 and 06 contributing with sampling for this study. Number of fishing trips reported to IMR containing registered landed catch of cod, and number of trips matched to sales notes with cod for the same vessels.*

Year	Number of contributing CRF vessels	No. registered fishing trips with catch of cod	No. registered fishing trips, matched with sales notes
2012	8	336	231
2013	8	444	336
2014	7	380	303
2015	8	295	228
2016	10	642	470
2017	11	536	418
2018	10	706	529

2.3.2 Official Landing Statistics/Sales notes

The Norwegian fisheries' sales note-system is unique as it combines both the quantity of landed catch and the first-hand value of the products. Generally, the coastal fleet land their catch fresh each day. This means that one sales note per day/fishing trip is the most common. All firsthand sales and all payments for fish are by law (Anon. 2013) channelled through one of the six Norwegian fishermen's sales organisations. Through the Norwegian Fishermen's Sales Organisations, the "lander" and "receiver/buyer" document the date and time of the landing, as well as information about species, quality and state, size-composition (in size groups), weight of the catch, and delivery-method on the sales note (Anon. 2014). This is all done at the landing site, and the sales note data are forwarded from the Norwegian Fishermen's Sales Organisations to the DoF. These sales notes data form the basis for the

official fisheries landing statistics and are also important in terms of management, control and the vessels' quota accounts.

The sales note data were aggregated by sampling period, area, vessel size, and gear type. Sales notes containing cod were extracted, with information about date of catch and landing, vessel name and call sign, fishing location and weight of catch.

The data from the CRF and the sales notes were sorted into strata based on area and date of catch. The strata had two levels.

1st level (referred to as "per annual quarter" later in the thesis):

- area + quarter + year
- one estimation per quarter in each statistical area for every year
- maximum of 12 strata per year (although no years had enough data for estimations in all strata)

2nd level (later referred to as "per year")

- year + all areas
- one estimation per year, which includes all four quarters and three statistical areas
- "sums up" all the information from the 1st level for each year

The estimates per year include all catch of cod in the three statistical areas each year, even though the basis of data-records vary between areas and annual quarters. There are not recorded fishing trips from all statistical areas in all annual quarters throughout the study period. Hence the recorded data on an annual basis are assumed to be representative for the "missing strata" as well.

2.3.3 Upscaling – estimating discard with a ratio-based approach

Records of discard data from the CRF were scaled to the entire fishing fleet in the three statistical areas, using the total quantity (weight) of landed cod and the total number of sales notes with cod in the stratum.

This was considered the best options for estimating the total discard in the fishery, as the official landing statistics do not include effort-data besides quantity (weight) of landed fish and number of sales notes. Estimating discard per unit effort (with other units such as per net, per hour soak time, etc.) would not allow for scaling to the entire fleet in the same way since information about numbers of nets and soaking time do not exist for the whole Norwegian coastal fleet.

Total number of discarded cod per stratum (per annual quarter and per year) was estimated by two different approaches:

Approach 1 – upscaling the discard with total weight of landed cod:

$$Total\ no.\ discarded\ cod = No.\ discarded\ cod\ per\ tonnes\ landed\ cod\ from\ the\ CRF * Total\ weight\ of\ landed\ cod\ (t) \quad (1)$$

Approach 2 – upscaling the discard with total number of sales notes:

$$Total\ no.\ discarded\ cod = No.\ discarded\ cod\ per\ sales\ note\ with\ cod\ from\ the\ CRF * Total\ no.\ sales\ notes \quad (2)$$

In order to estimate the mean individual weight of discarded cod each year, the mean length of discards was retrieved from the CRF's length measurements. The mean length for discarded cod for each of the years in the study period were then converted to mean individual weight per year. This was done using an equation based on an assumption that the weight of a cod is proportional to its length to the third power (Løkkeborg et al. 2014):

$$Weight\ (kg) = 0.000009 * (Length\ (cm))^3 \quad (3)$$

These are general assumptions about isometric growth in cod (every dimension increases in the same rate), and the parameters are in accordance to data used by IMR in stock assessments.

The total numbers of discarded cod (Equation 1 and 2) and the mean individual weight of discarded fish (Equation 3) were used to estimate the total weight of discard within each stratum:

$$Total\ weight\ of\ discard\ (t) = \frac{Mean\ weight\ of\ individual\ discarded\ cod\ (kg) * Total\ no.\ discarded\ cod}{1000} \quad (4)$$

And the estimated discard rate, as percentage of total catch of cod in weight is:

$$Discard\ rate\ for\ cod\ (\%) = 100 * [Weight\ of\ discard\ of\ cod\ (t)/ [Weight\ of\ landed\ cod\ (t) + Weight\ of\ discard\ of\ cod\ (t)]] \quad (5)$$

2.4 DATA ANALYSES

The vessels from the CRF that had registered discards of cod were identified in the sales note data through their individual call signs. There was some inaccuracy in the registered statistical areas in some of the sales notes for some vessels fishing around or on the border between two statistical areas. In cases where vessels had their catch registered in one area in the sales notes and another as part of their CRF records, (and it was clear that it was the same catch) the catch in the sales note data was in the analyses moved to the area given in the data from the CRF.

To estimate the ratio of discard per tonnes catch of cod and per sales note with cod, the data from the CRF and the sales notes data were matched. Fishing trips reported by the CRF with catch of cod were matched with sales notes for the same date. A fishing trip is defined as one day in this study, both for simplicity and because generally most coastal vessels land their catch on the same day as catching it

(Table 2.2). Most vessels in the coastal fleet will commonly have one sales note per fishing trip, but the two terms are not equivalent in this study.

Not all CRF-vessels have shown consistency in their reporting. Some fishing trips present in the sales notes were not visible in the CRF data material, meaning that the vessels did not sample every catch or that there was some kind of technical error in one of the data systems. For such fishing trips, there were no information about discard, and these were consequently omitted from the estimations.

In some cases, the CRF-vessels had registered catch weights in their records that deviate from the catch weights given in the landing statistics on the same date. On other dates vessels had a registered catch in only one of the two data systems. In these cases, a "weight-rule" was established: if there is a value from the sales notes, this weight is prioritized. If not, the weight reported from the CRF records is used instead. This was done to get as many data records as possible for further analyses.

Estimations of discard were done for each stratum (per year and per annual quarter), as long as it had ten or more fishing trips with catch of cod recorded to the CRF.

The total weight of discard (Equation 4) in each stratum (annual quarter and year) was estimated using the mean individual weight of discarded cod for each year (as not all strata had length measurements of discard). The estimated average weights of discarded cod are different from year to year and are based on mean length of individual discards with fairly large standard deviations. This input has a large impact on the estimations of total weight of discard of cod. To illustrate this the estimated total mean weight of individual discards for all years combined were used as an alternative input in some figures.

The total numbers of fishing trips with landing of cod, the total quantity of landed cod and the total number of sales notes containing cod for the entire fleet within each stratum were extracted from the official landing statistics. Data was extracted using the same criteria as before (vessels fishing with gillnets in the statistical areas 00, 05 and 06). All vessels > 15 m total length were excluded.

Processing and analyses of data was conducted in RStudio version 1.0.153 with R version 3.4.1 (R Core Team 2017) and in Microsoft Excel for Office 365. R packages used include *tidyverse* (Wickham 2017) for data manipulation (*dplyr*) and plotting (*ggplot2*) and *reshape2* (Wickham 2007).

2.4.1 Approach 1: upscaling discard with total weight of landed cod

This approach for upscaling is based on equation 1.

2.4.1.1 Relationship between discard and size of catch; Poisson regression model

Discards can be upscaled with the total weight of landed cod by using the ratio estimator (Cochran 1977, Ch. 6.2). This estimator describes a relationship between two correlated variables, in this case the numbers of discarded cod and the size of the catch of cod.

The response variable in the data (discards) represents count data (number of fish) and has a Poisson distribution (the shape of the distribution changes with the mean). Therefore, a Poisson regression model was used to investigate the relationship between number of discards and the weight of the catch. This model uses maximum log likelihood to find the best suited model for the data. The data was checked for overdispersion, occurring when the variance in the data is greater than the mean. This results in variability greater than what the model accounts for, and the discard data was corrected for overdispersion using a quasi-Poisson error term.

The mathematical equation for a Poisson regression model is (Ozonur et al. 2017):

$$log_e(\mu_j) = \sum_{i=1}^{p} x_{ji}\beta_i \quad (6)$$

Where:

μ_j is the conditional mean of the Poisson regression, $E(Y_j|x_j)$

Y: the response variable (discards)

x: the predictor variable (size of catch), which is a vector of covariates, $\beta = \beta_1, \beta_2, \ldots, \beta_p$

p: defines the dimension of the vector of the covariates

The relationship between the number of discarded cod and the weight of landed catch of cod was plotted. One analysis was done per year. The Poisson regression was done in RStudio (R Core Team 2017) and plotting with R package *ggplot2* (Wickham 2016).

2.4.1.2 The ratio estimator

The ratio estimator is based on the basic assumption that if we know the total weight of the landed catch in a stratum and the mean ratio of discard per weight-unit, we can calculate the total number of discarded fish (Cochran 1977).

The estimator requires the variables *x*, *y* and *X*.

x: The weight of landed catch of cod per fishing trip (t), available from both the CRF records and the sales note data.

y: The number of discarded cod per fishing trip, estimated from the CRF records.

X: The total population of x: the total amount of cod landed (t) from the whole fleet in the stratum.

With this information, we can estimate the total population of y: the total numbers of discard in the stratum ($\hat{Y}_{\hat{R}}$) using the following formula (Cochran 1977, Ch. 6.2):

$$\hat{Y}_{\hat{R}} = \frac{\bar{y}}{\bar{x}}X = X * \hat{R} \quad (7)$$

Where $\hat{R}$ is the estimated ratio ($\hat{R} = \frac{\bar{y}}{\bar{x}}$), $\bar{x}$ is the mean weight of catch (t) and $\bar{y}$ is the mean number of discards per fishing trip from the data records in the stratum.

The estimate of the variance for the total discards in the stratum is:

$$var(\hat{Y}_{\hat{R}}) = X^2 var(\hat{R}) \quad (8)$$

Where the estimated variance for the ratio is (Cochran, 1977, Ch. 6.3):

$$var(\hat{R}) = \frac{1-f}{n\bar{x}^2} * \frac{\Sigma(y-\hat{R}x)^2}{n-1} \quad (9)$$

f: Sampling fraction, n/N, where:

N: The total number of fishing trips with catch of cod for the whole fleet in the stratum (extracted from the sales note data).

n: The number of fishing trips with catch of cod in the data records in the stratum (reported from the CRF vessels).

The 95 % CIs for the estimate of total discard of cod in the stratum is (Cochran, 1977, Ch. 6.5):

$$Y: \hat{Y}_{\hat{R}} \pm z\sqrt{var(\hat{Y}_{\hat{R}})} \quad (10)$$

where

z: the normal deviate, chosen confidence probability. In this case; 2

2.4.1.3 Relationship between occurrence of discard and weight of catch; binary logistic regression

To investigate if there was a significant relationship between the occurrence of discard of cod and the weight of the catch of cod, a binary logistic regression was used. This is a generalized linear model, which uses maximum likelihood to create the best suited model for the data. Occurrence of discard represents binary data (presence/absence), and the number of discards per fishing trip was thus ignored in these analyses.

The mathematical equation for a binary logistic regression model is (Kabera et al. 2012):

$$logit(p) = \log\left(\frac{p}{1-p}\right) = \tilde{x}^T\beta, \quad (11)$$

where:

x: predictor variable (size of catch),

Y: response variable (occurrence of discard), with two possible observations; presence/absence, where the probability of absence = p,

β: the vector of model parameters = $(\beta_0, \beta_1, \beta_2, \ldots, \beta_k)^T$,

and $\tilde{x} = (1, x_1, x_2, \ldots, x_k)^T$

The analysis was done in RStudio (R Core Team 2017).

2.4.1.4 The ratio estimator for non-zeros

In an attempt to create a more precise estimation with narrower CIs, an alternative Ratio Estimator was conducted. This was done by separating records of fishing trips that had reported discards (the non-zeros) and the ones that had no reported discards (the zeros).

The estimator for total number of discard using this method uses the proportion of non-zero fishing trips from all the recorded fishing trips, the estimated discard-ratio for the non-zero fishing trips and the total catch of cod in the stratum, X, (Pennington 1983):

$$\hat{Y}_{\hat{R}} = \hat{P} * \widehat{R_{\neq 0}} * X \quad (12)$$

$\hat{P}$ is:

$$\hat{P} = \frac{m * \bar{x}_{\neq 0}}{n * \bar{x}_{total}} \quad (13)$$

where:

m: Number fishing trips in the data records in the stratum that had reported discard (non-zeros) (from the CRF vessels)

$\bar{x}_{\neq 0}$: Mean weight of catches of cod from the non-zero fishing trips (with reported discard) in the stratum

n: Number of fishing trips in the data records in the stratum (from the CRF vessels), both with and without discards

$\bar{x}_{total}$: Mean weight of catches of cod in the data records in the stratum (from the CRF vessels), both with and without discards

$\hat{P}$ is equal to m/n if the average catch with discards and the average of all catches are equal.

$\widehat{R_{\neq 0}}$ estimates the average number of discards, on non-zero fishing trips, divided by the average weight of catches from fishing trips that had discards:

$$\widehat{R_{\neq 0}} = \frac{\bar{y}_{\neq 0}}{\bar{x}_{\neq 0}} \quad (14)$$

Where $\bar{y}_{\neq 0}$ is the mean discard per fishing trip from records of non-zero fishing trips in the data, thus excluding the fishing trips without discards (zeros).

The variance for the alternative ratio can be calculated by:

$$v\left(\widehat{R_{\neq 0}}\right) = \frac{1 - \frac{m}{N}}{(m * \bar{x}_{\neq 0})^2} * \frac{\Sigma(y_{\neq 0} - \widehat{R_{\neq 0}} * x_{\neq 0})^2}{m - 1} \quad (15)$$

Where N is the total number of fishing trips for the whole fleet in the stratum.

The variance for $\hat{Y}_{\hat{R}}$ is:

$$v(\hat{Y}_{\hat{R}}) = \frac{m(m-1)}{n(n-1)} v\left(\widehat{R_{\neq 0}}\right) + \frac{m(n-m)}{n^2(n-1)} \widehat{R_{\neq 0}}^2 \quad (16)$$

If we assume:

$$C_{ratio} = \frac{\bar{x}_{\neq 0}}{\bar{x}_{tot}} \quad (17)$$

an approximate estimate of the variance for $\hat{P}$ is:

$$v(\hat{P}) = v(\hat{Y}_{\hat{R}}) * (C_{ratio} * X)^2 \quad (18)$$

The CIs for Y, the total estimate of discards, is then:

$$Y = \hat{Y}_{\hat{R}} \pm z\sqrt{v(\hat{P})} \quad (19)$$

z: The normal deviate, chosen confidence probability: 2

2.4.1.5 Bootstrap method

Also called a "computer-intensive method", bootstrapping is a resampling method which utilizes computers to estimate the variability and uncertainty of data (Davidson & Hinkley 1997). The approach involves resampling *n* observations, from the original recorded data, at random with replacement. This resampling process is repeated a number of times (R), until you have many series of new samples, each of the same size as the original data. The number of "Bootstraps"/resampling repetitions (R) is typically 2000. The new series of bootstrapped data are combined, and uncertainty and CIs can be assessed as percentiles from the new distribution of data (Davidson & Hinkley 1997).

The bootstrap-analysis was conducted on the discard ratios (discard per tonne catch of cod) for each observation in the sample and estimates were made for each year and each annual quarter. R was set to 2000. The percentile 95 % CIs are presented in the results, meaning the 2.5 % and 97.5 % percentile from the tail-end on either side of the distribution. Because the data were not normally distributed, the CIs were not symmetrical.

Analyses was done in RStudio (R Core Team 2017), using the R package *boot* (Canty & Ripley 2017).

2.4.2 Approach 2: upscaling discard with total number of sales notes with cod

This approach for upscaling is based on equation 2.

The estimated total number of discards in the relevant stratum, $\hat{Y}$, is calculated using a ratio-based approach, by the formula:

$$\hat{Y} = mean\left(\frac{y}{x}\right) * X \quad (20)$$

Meaning, the average from the distribution of discards per sales note multiplied by the total number of sales notes in the relevant stratum, where:

y: Number of discarded cod per fishing trip from the data records from the stratum (reported by the CRF)

x: Number of sales notes per fishing trip in the data records (from CRF records matched with sales note data)

X: Total number of sales notes with cod from the whole fleet in the stratum

2.4.2.1 Standard deviation

Attempting to measure the variability in the sample, the standard deviation (SD) of the estimated ratio (discard per sales note) was calculated through (Ahn & Fessler 2003):

$$sd(\hat{R}) = \sqrt{\frac{\sum_{i=1}^{n}(\hat{R}_i - \bar{R})^2}{n-1}} \quad (21)$$

where:

$$\hat{R} = mean(\frac{y}{x}) \quad (22)$$

The CIs for estimate of total discard, Y, are then:

$$Y = \hat{Y} \pm z * sd(\hat{R}) \quad (23)$$

where, z: 2

These estimations were very wide and were not suited to produce precision-estimates for the discard.

2.4.2.2 Standard error of the mean (SE)

The SE is calculated by dividing the SD of a sample by the square root of the number of data records (Ahn & Fessler 2003):

$$se(\hat{R}) = \frac{sd(\hat{R})}{\sqrt{n}} \quad (24)$$

Where n is the number of recorded fishing trips with sales notes with cod (from the CRF) and sd($\hat{R}$) is from equation 21.

The corresponding CIs for the estimate of total discard are:

$$Y = \hat{\Upsilon} \pm z * se(\hat{R}) \quad (25)$$

z: The normal deviate, chosen confidence probability: 2

2.4.2.3 Bootstrap method

CIs were also calculated using the percentile Bootstrap method in the same way as when upscaling the discard with Approach 1 (using RStudio (R Core Team 2017) and the package *boot* (Canty & Ripley 2017)).

The Bootstrap-analysis was conducted on the discard ratios (discard of cod per sales note with cod) for each fishing trip in the recorded data and estimates were made for each year and each annual quarter. R was set to 2000. The percentile 95% CIs are presented in the results.

2.4.3 Size distributions

Data with individual lengths of cod from the CRF records were analysed in order to compare the size-distributions of the landed cod and the discarded cod to examine for signs of high-grading in the fishery. The distributions of length of discarded cod in percentage and the weighted distribution of lengths of landed cod, were plotted for comparisons in each stratum included in table 2.3. Strata that had less than 10 length-measurements in either group (landed or discarded) were not included.

Table 2.3*: Number of length-measurements from included strata: annual quarter and statistical areas 00, 05 and 06, for discarded and landed cod. Data collected and reported by the CRF.*

		Strata: Statistical area, annual quarter:								
Year		00, 1	00, 2	00, 3	00, 4	05, 1	05, 4	06, 1	06, 2	06, 3
2012	Discarded	97	16	11	40	-	-	-	-	-
	Landed	345	25	102	25	-	-	-	-	-
2013	Discarded	68	44	29	147	22	-	-	-	-
	Landed	443	244	26	245	728	-	-	-	-
2014	Discarded	44	24	-	-	-	74	-	-	-
	Landed	321	160	-	-	-	113	-	-	-
2015	Discarded	14	-	-	30	-	72	17	-	-
	Landed	220	-	-	251	-	100	126	-	-
2016	Discarded	57	44	59	39	72	-	-	-	30
	Landed	834	136	214	141	757	-	-	-	53
2017	Discarded	42	23	88	63	67	-	-	-	-
	Landed	641	127	220	174	259	-	-	-	-
2018	Discarded	136	10	94	75	67	-	-	13	-
	Landed	978	160	216	316	106	-	-	279	-

Data manipulation and plotting was done in RStudio (R Core Team 2017), with packages *tidyverse* (Wickham 2017), *ggplot2* (Wickham 2016) and *ggpubr* (Kassambara 2018).

2.4.3.1 Calculating weighting factors

In the CRF records, length measurements of landed cod were done on a random sample from the catch. The selected fish in the sample were then assumed to be representative for the entire catch. Because not all the catches were of equal size, the sample of measurements from each catch were weighted based on the size of the catch and the number of individuals that were measured from that catch. In this way, a more accurate picture of the size distribution of all the sampled catches was established.

The weighting factor for each length measurement of landed fish were calculated by this equation:

$$Weigthing\ factor = \frac{Roundweight\ of\ catch\ (kg)}{Numbers\ measured\ from\ the\ catch} \quad (26)$$

The weighting factor for each record was then multiplied by the individual length of the cod, and a new weighted percentage, p, in the distribution was calculated by:

$$p = \frac{Weighting\ factor * Length\ of\ fish}{\sum(Weighting\ factor * Length\ of\ fish)} * 100 \quad (27)$$

It was assumed that all the discards from one catch were length measured, thus weighting factors were not added to the length distributions for discard. Calculations of weighting factors and new percentages were done in Microsoft Excel for Office 365.

3 RESULTS

3.1 DATA BASIS

3.1.1 Observations and frequency distributions

Table 3.1 and 3.2 shows the data records used for discard estimations per annual quarter and statistical area, including all strata which had ten or more reported fishing trips with catch of cod. The amount of records varied from year to year. Most years had an overweight of records from area 00, quarter 1. The exceptions were 2012 and 2013 where there were more records from area 05, quarter 1. As shown in Table 2.2, the number of data records/fishing trips per stratum that were matched with sales notes (Table 3.2) are fewer than the data records/fishing trips that had recorded landing of cod (Table 3.1). The basis for estimations of discard when upscaling with total weight of catch was based on two sets of data: the CRF records and the sales notes. If a records of landed catch was missing in one of the data sets, it could be substantiated from the other data set (if present). The estimations of discard per sales note was based on data from the sales note data only, and sometimes several trips contributed to one sales note.

Table 3.1 *– Number of data records (reported fishing trips with catch of cod) for discard estimations per stratum upscaled with total weight (≥ 10 observations). Data were collected and reported by the CRF and matched with sales notes data from the DoF.*

	Strata: Statistical area, annual quarter											
Year	00, 1	00, 2	00, 3	00, 4	05, 1	05, 2	05, 3	05, 4	06, 1	06, 2	06, 3	06, 4
2012	80		15	17	103				62	35		11
2013	81	51	20	48	88	10			43	65	17	10
2014	91	25		12	42	37		42	33	42	27	
2015	90	26		72				25	27	35		
2016	212	59	48	86	147	10			22	30	26	
2017	195	31	49	79	106	12			23	41		
2018	267	68	53	108	83				33	72		

Table 3.2 *– Number of data records (reported fishing trips with catch of cod) for discard estimations per stratum upscaled with sales notes (≥ 10 observations). Data were collected and reported by the CRF and matched with sales notes data from the DoF.*

	Strata: Statistical area, annual quarter											
Year	00, 1	00, 2	00, 3	00, 4	05, 1	05, 2	05, 3	05, 4	06, 1	06, 2	06, 3	06, 4
2012	37				98				46	25		
2013	71	40	13	38	43				43	51	17	10
2014	73	14			35	37		35	29	27	27	
2015	73	26		53				22	23	22		
2016	187	51	25	48	122				17		10	
2017	166	16	28	40	106				21	37		
2018	230	57	31	46	65				31	53		

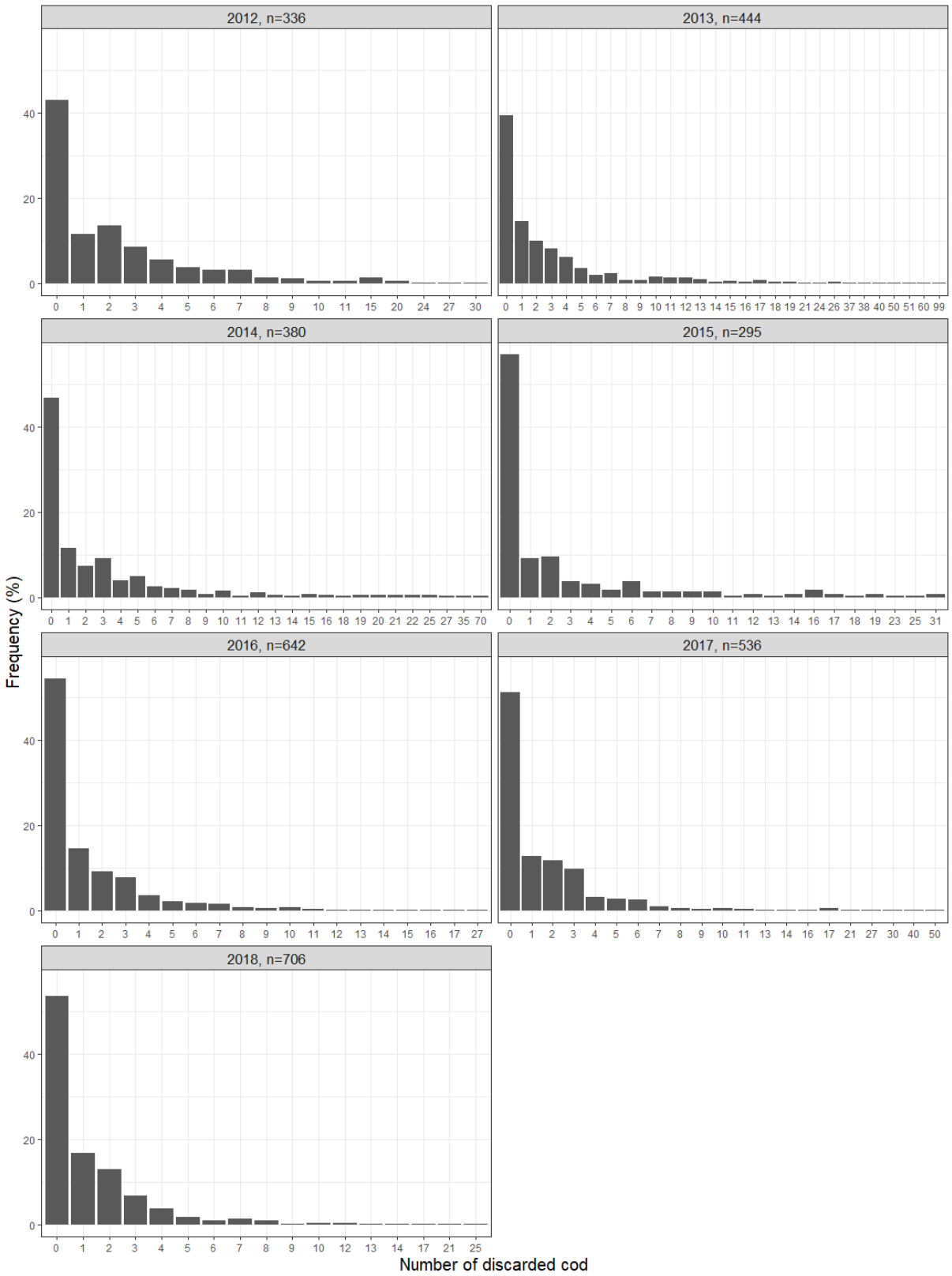

Figure 3.1 *– Frequency distributions of discarded cod from fishing trips with landed catch of cod, in relative numbers, reported by CRF-vessels < 15 m total length in area 00, 05 and 06 during 2012-2018, fishing with gillnets.*

The frequency distributions for number of discards of cod from the reported fishing trips had a similar shape for all the years included in this study (Figure 3.1). All years had an overweight of fishing trips with zero discards, followed by one and two. There was a slight decrease of records with an increase in

number of discards between 3 and 10, and some cases with larger numbers of discards (maximum 99). The relative number of records of zero discards of cod per trip were just below 50 % for 2012-2014, and just above 50 % for 2014-2018. This means that, regardless of the weight of the catch, around half of the fishing trips in the data records had zero discards of cod.

3.1.2 Length-weight relationship

3.1.2.1 Estimated mean individual weight of discarded cod

The average length of discarded cod varied within the study period from a minimum of 55.4 (± 21.2) cm in 2014 to a maximum of 75.6 (± 17.4) cm in 2012, with corresponding estimated mean individual weights of 1.53 and 3.89 kg respectively (Table 3.3). The mean length of discarded cod for all years was 68.7 cm (± 20.5 cm) with a corresponding estimated mean weight of 2.92 kg. The mean individual weights for each year, and the overall mean, were used to estimate total discard of cod in weight (Equation 4) in both upscaling approaches.

Table 3.3 *– Number of length measurements of discarded cod (N) sampled and reported from the CRF, mean length (in total length, cm), standard deviation of the mean lengths (cm), and estimated corresponding mean individual weights of discarded cod (round weight in kg), calculated from the mean lengths per year.*

Year	N	Mean length of discarded cod (cm TL)	SD (cm)	Estimated mean weight of discarded cod, RW (kg)
2012	164	75.6	17.4	3.88
2013	315	72.3	14.1	3.40
2014	152	55.4	21.1	1.53
2015	260	63.7	24.8	2.33
2016	309	69.5	23.8	3.03
2017	290	72.6	20.1	3.45
2018	396	67.9	17.8	2.81
Mean	1886	68.7	20.5	2.92

3.2 ESTIMATIONS OF DISCARDS

3.2.1 Approach 1: upscaling discard with total weight of landed cod

3.2.1.1 Relationship between discard and size of catch; Poisson regression model

A starting hypothesis was that there was a positive relationship between the size of the catch of cod and the numbers of discarded cod. The poisson regression model showed a significant relationship for all years, except for 2012 and 2018 (Figure 3.2). However, very limited data are within the 95 % CIs of the regression model, which means that the discard was highly determined by other factors than the size of the catch. P-values, average numbers of discards of cod and average size of catch of cod, in weight, are included in Appendix table 4.a. The average number of discarded cod per fishing trip varied from 1 in 2018, to 4 in 2013, and the average weight of catch of cod per fishing trip differed between 1 tonne in

2018, and 3 tonnes in 2012. 2018 had both the smallest average number of discards and the smallest average catch per fishing trip.

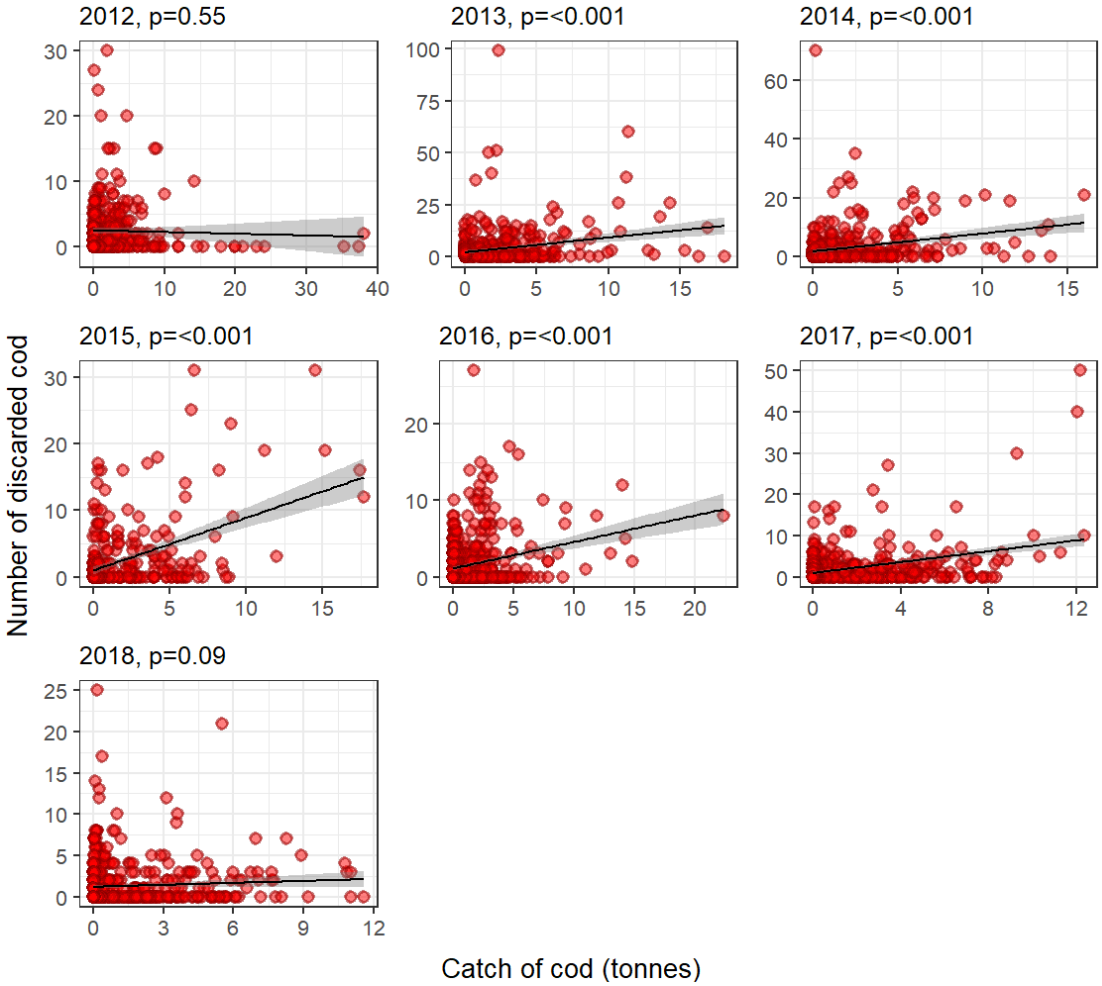

Figure 3.2 *– Relationships between number of discarded cod and weight of catch of cod (t), illustrated with a predicted glm-regression line with 95% CIs (grey areas), 2012-2018. Data from the statistical areas 00, 05 and 06, for vessels < 15 m total length, using gillnets, reported by the CRF.*

3.2.1.2 Estimations of discard rates per annual quarter

The estimates of discard of cod in numbers, total weight of discard and discard rates (% weight of total catch) for each annual quarter during 2012-2018, as well as the total landed catch of cod for the whole fleet in each stratum, are included in Appendix table 1.a – 1.g. Appendix table 3.a and 3.b includes the results compressed to compare the discard rates in the different strata.

The estimated mean discard rates (% weight of total catch) per annual quarter, for the strata with ≥ 10 records, from 2012-2018 varied from 0.07 to 23.03 %. In addition, one stratum had only records of zero-discards. Only the strata “statistical area 00 quarter 1”, “statistical area 00 quarter 4 (2014: only zeros)”, “statistical area 06 quarter 1” and “statistical area 06 quarter 2” had enough data for performing estimations for all years. Statistical area 05 had less records through the study period, than statistical area 00 and 06.

The mean discard rates (% weight of total catch) in the first annual quarter were < 1.5 % in all statistical areas. The second annual quarter had estimated mean discard rates < 5 % in all strata, except for statistical area 05 in 2013 and statistical area 00 in 2017. In the third and fourth annual quarters the estimated mean discard rates were generally higher (maximum ~20 %). The estimates for annual quarters three and four also had larger CIs (Figure 3.3). The arithmetically calculated CIs (from the ratio estimator) gave lower upper and lower limits than the CIs established using the Bootstrap method (Figure 3.3). The CIs established using the percentile Bootstrap method were also not symmetrical, as the data was not normally distributed.

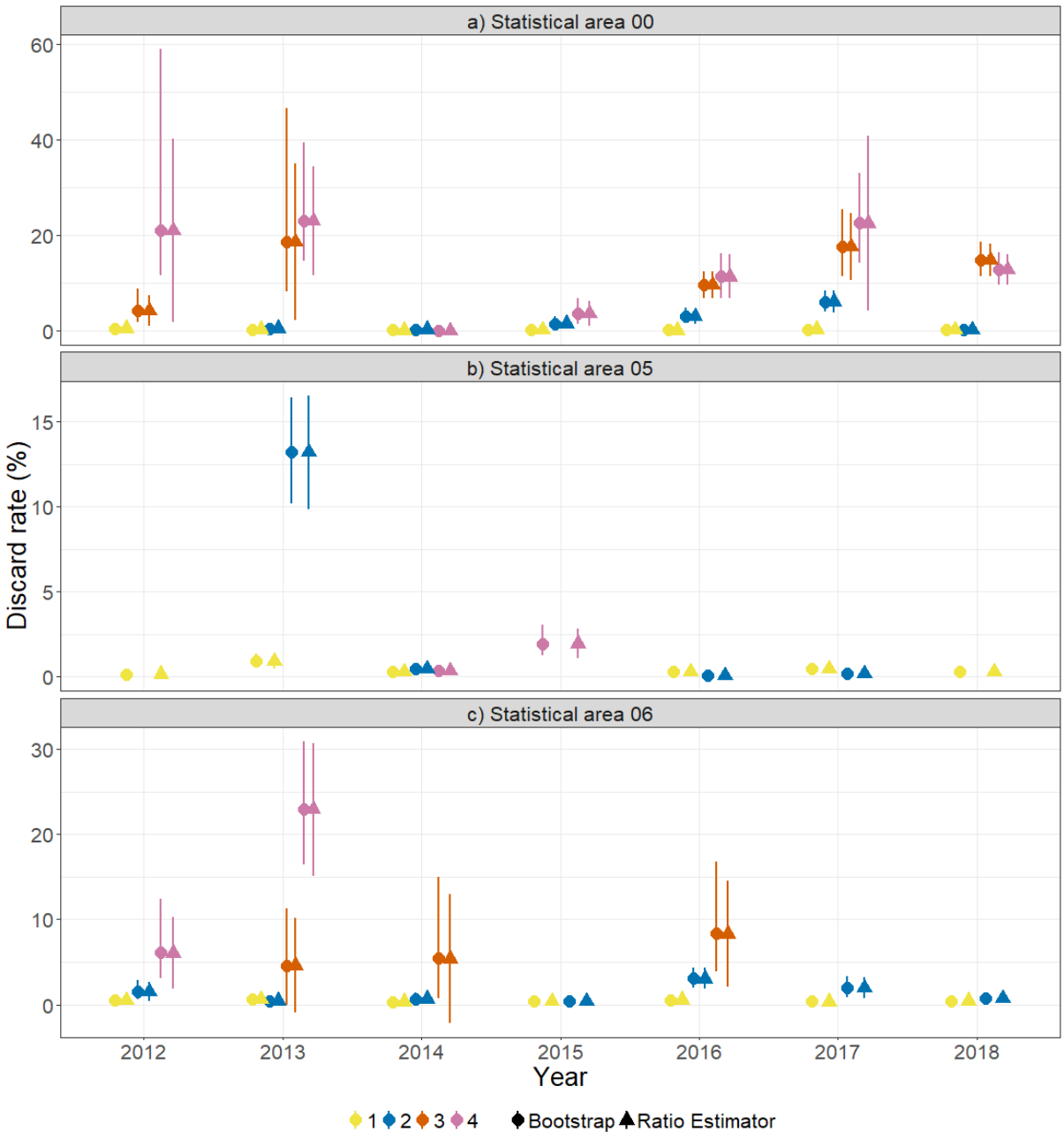

Figure 3.3 *– Upscaled estimated mean discard rates (% weight of total catch) for cod per year/statistical area/annual quarters, during 2012-2018 in the statistical areas 00 (a), 05 (b) and 06 (c) (vessels < 15 m total length, using gillnets). Upscaling was performed using total weight of landing of cod, presented with annual quarters 1 (yellow), 2 (blue), 3 (red), 4 (pink), and two estimates of CIs: from the Bootstrap method (circle) and the Ratio Estimator (triangle).*

3.2.1.3 Estimations of numbers of discarded cod and discard rates per year

Estimations for mean total numbers discarded per year (all areas) gave estimates between 37 686 (in 2012) and 97 915 (in 2013) (Figure 3.4a). The estimated discarded numbers peaked in 2013 and decreased in the following years. The estimated mean discard rate (% weight of total catch) was lowest in 2014 (0.24 %) and highest in 2013 (0.62 %) (Figure 3.4b). From the lowest mean annual discard rate in 2014 the estimates increased to 0.46 % in 2017, before a decrease to 0.35 % in 2018. The CIs were mostly similar in range using the ratio estimator and the Bootstrap method for these estimations, but the Bootstrap method calculates slightly higher confidence limits than the ratio estimator. Details including estimated number of discards per year, mean weight of individual discard, estimated total weight of discard (t), total weight of landed cod of cod per year (t) and estimated discard rate (% weight of total catch) are included in Appendix table 4.b.

Figure 3.4 *- Estimated annual mean number of discards (a) and mean discard rate (% weight of total catch) (b) of cod from 2012-2018 in the statistical areas 00, 05 and 06. Results from upscaling with total weight and with CIs calculated with two different methods: the ratio estimator (blue line), and the Bootstrap method (red line). The intercept between the line and the error bar represents the mean each year.*

The available annual rates of discards are based on estimations of individual mean weights, with large variabilities. 2014 had the second highest mean estimate of discard in numbers, but the smallest mean estimate of discard in percentage of total catch. The low discard rate in 2014 can partly be explained by the low mean individual weight of discard (1.53 kg) estimated this year. In the other years of the study period the mean individual weight of discard ranged between 2.32 and 3.88 kg (Table 3.3). Figure 3.5 shows annual discard rates for cod when estimated using the combined average individual weight (2.82 kg) of discarded cod for 2012-2018 as am input to calculate the total weight of discard. This figure displays the estimated discard rates as a more direct result of numbers discarded and the total catch of cod.

The total weight of landed cod per year, in all three statistical areas, differ between 44 549 tonnes in 2012 to 60 207 tonnes in 2014 (Appendix table 4.b). 2013 and 2014 had approximately the same estimated mean number of discarded cod, but because the total landed quantity of cod were higher in 2014, the estimated mean discard rate was lower.

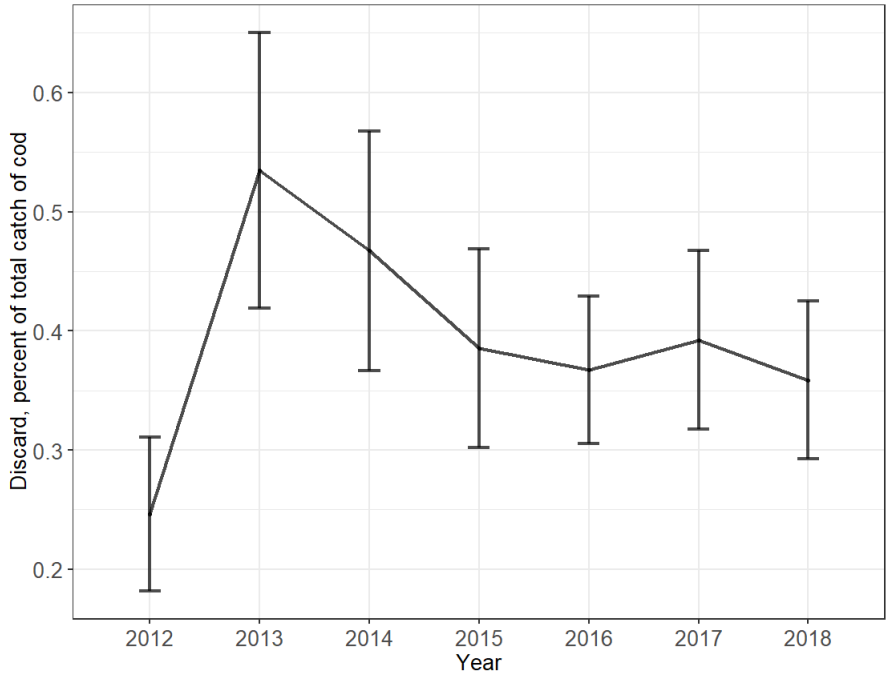

Figure 3.5 *– Annual estimated mean discard rates (% weight of total catch) of cod from 2012-2018 in the statistical areas 00, 05 and 06 applying an average individual weight of discard of 2.82 kg during the whole time period. Discard was upscaled with total annual weights of landing of cod. CIs were calculated using the ratio estimator. The intercept between the line and the error bar represents the mean each year.*

3.2.1.4 Binary logistic regression and the ratio estimator for non-zeros

The results from the binary logistic regression showed that there was a significant relationship between the occurrence of discard and the weight of cod in the catch, with the exceptions of 2012, 2013 and 2018 (Table 3.8). The ratio estimator for non-zeros (fishing trips with reported discards) gave similar results as the ratio estimator (for all reported fishing trips with catch of cod), but the estimated CIs were slightly wider (Table 3.9), which is why this method is not discussed any further in this study.

Table 3.8 *– Mean weight for zero- (no discards), non-zero- (reported discards) fishing trips and total catches (both with and without discards)**.** P-values from a Binary logistic regression, testing the relationship between occurrence of discard of cod and the weight of cod in the catch.*

Year	Mean weight of catch with zero discard (t)	Mean weight of catch with non-zero discard (t)	p-value	Mean weight of all catches (t)
2012	3.39	2.48	0.11	2.87
2013	1.89	2.10	0.47	2.08
2014	1.38	2.35	< 0.001	1.90
2015	1.09	2.92	< 0.001	1.88
2016	0.91	1.60	< 0.001	1.23
2017	1.06	1.74	< 0.001	1.39
2018	1.06	1.01	0.71	1.04

***Table 3.9** - Estimation of numbers and weight of discards and discard rate (% weight of total catch) for cod using the ratio estimator for non-zeros, estimated individual mean weight of discarded cod, and total weight of landing of cod, in the statistical areas 00, 05 and 06 for vessels < 15 m total length using gillnets during 2012-2018.*

Year	No. Discard	Mean individual weight of discarded cod (kg)	Weight of total discard (t)	Total weight of landed cod (t)	Discard rate (%)
2012	37 686 ± 10 218	3.88	146 ± 40	44 549	0.33 ± 0.09
2013	97 915 ± 14 846	3.40	333 ± 50	53 147	0.63 ± 0.09
2014	96 823 ± 20 803	1.53	148 ± 32	60 207	0.25 ± 0.05
2015	72 467 ± 18 566	2.33	169 ± 43	54 654	0.31 ± 0.08
2016	61 086 ± 13 337	3.03	185 ± 40	48 399	0.38 ± 0.08
2017	66 252 ± 140 35	3.45	228 ± 48	49 082	0.47 ± 0.10
2018	60 116 ± 14 757	2.81	169 ± 41	48 739	0.35 ± 0.08

3.2.2 Approach 2: upscaling discard with total number of sales notes with cod

3.2.2.1 Estimations of discard rates per annual quarter

Estimated discard of cod in numbers, total weight of discard and discard rate (% weight of total catch) for cod are given in Appendix table 2.a – 2.g, together with total number of sales notes with cod in each stratum. Appendix table 3.c and 3.d includes the results compressed to compare the discard rates in the different strata.

The estimated mean discard rates (% weight of total catch) per annual quarter from 2012 to 2018 were between 0.09 and 8.06 %. “Statistical area 00 quarter 1”, and “statistical area 06 quarter 1”, were the only two strata which had sufficient data records (≥ 10) for estimates from all years. The CIs calculated arithmetically (SE), were narrower than the CIs established with the Bootstrap method. The percentile Bootstrap method gave asymmetrical CIs, as the data was not normally distributed.

The estimated mean discard rates were lowest for the first and second quarter, all below 3 % with three exceptions (statistical area 06, quarter 1 in 2015 and upper CIs in the statistical area 06, quarter 1 in 2016 and 2017). Quarters 3 and 4 had some higher estimates. All means were below ten percent, but some upper CIs were above (Figure 3.6). A general trend was that the 3rd and 4th quarter had wider CIs than the 1st and 2nd.

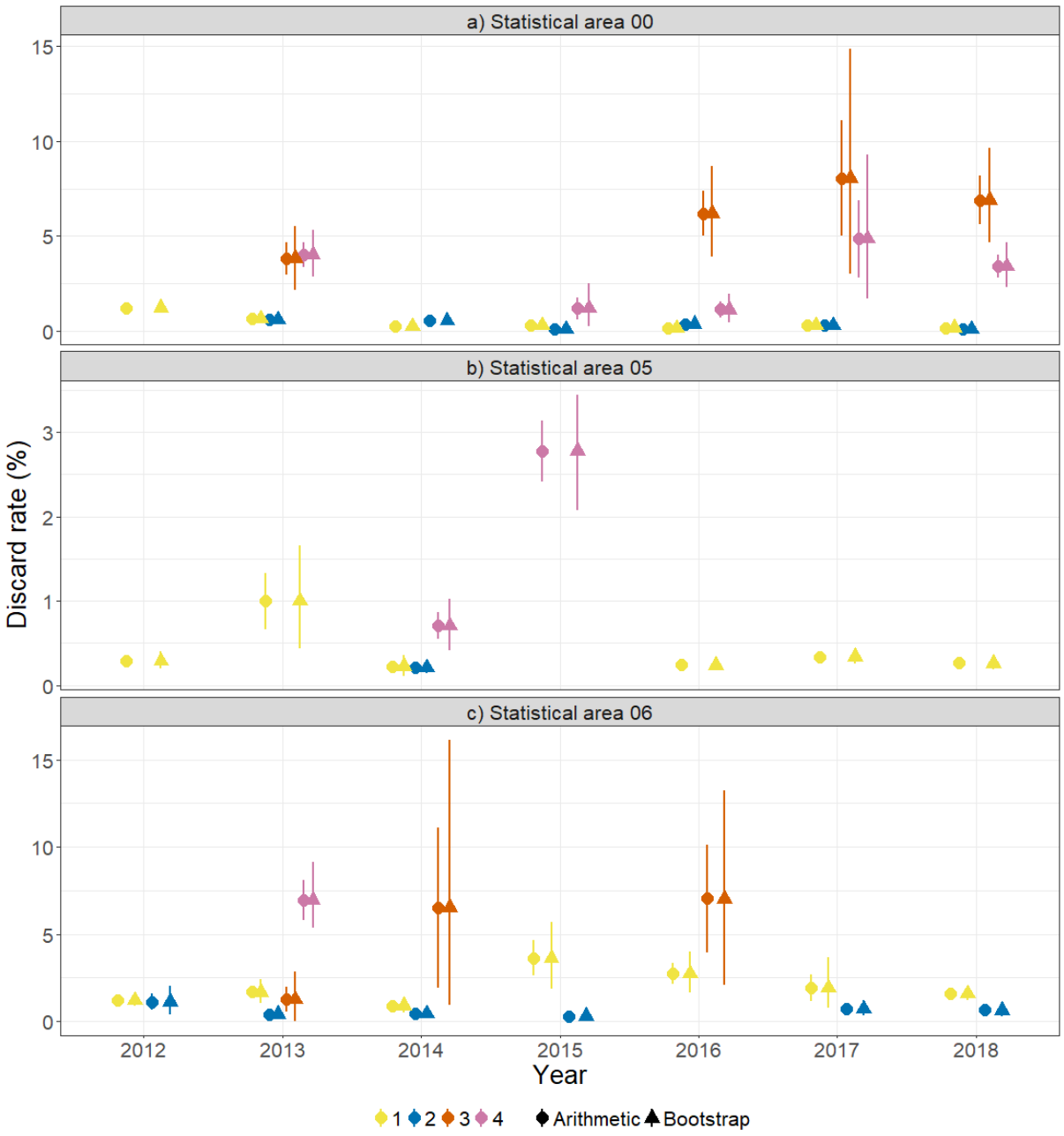

Figure 3.6 *– Estimated mean discard rates (% weight of total catch) for cod per year/statistical area/annual quarter, during 2012-2018 in the statistical areas 00 (a), 05 (b) and 06 (c) (vessels < 15 m total length, using gillnets). Upscaling was performed using total number of sales notes with cod, presented with annual quarters 1 (yellow), 2 (blue), 3 (red) and 4 (pink), and two estimates of CIs: established arithmetically (circle) and by using the Bootstrap method (triangle).*

3.2.2.2 Estimations of numbers of discarded cod and discard rates per year

Estimations for total mean number of discarded cod per year (all areas) varied from a minimum of 39 318 in 2018 to a maximum of 111 919 in 2013. The estimates peaked in 2013, before decreasing steadily until 2016 (Figure 3.7a). In 2017 the estimated numbers increased again, before another decrease in 2018. Estimated mean discard rates (% weight of total catch) were between 0.23 % (2018) and 0.73 % (2012) in the study period. From an estimated maximum in 2012 and 2013, there was a strong decrease from 2013 to 2014, before a general increase from 2014 to 2017. From 2017 to 2018 the discard rate again decreased (Figure 3.7b).

Details, including total number of sales notes with cod each year, annual estimated numbers of discard, mean individual weight of discards, estimated total weight of discard and estimated discard rate (% weight of total catch), are included in Appendix table 4.c – 4.e. The CIs calculated with SDs (Appendix table 4.c) corresponded to numbers larger than the estimated discards, resulting in negative lower CI limits and these estimates will therefore not be discussed further. The arithmetic CIs (SE) were narrower (Appendix table 4.d) than the CIs calculated with the Bootstrap method (Appendix table 4.e).

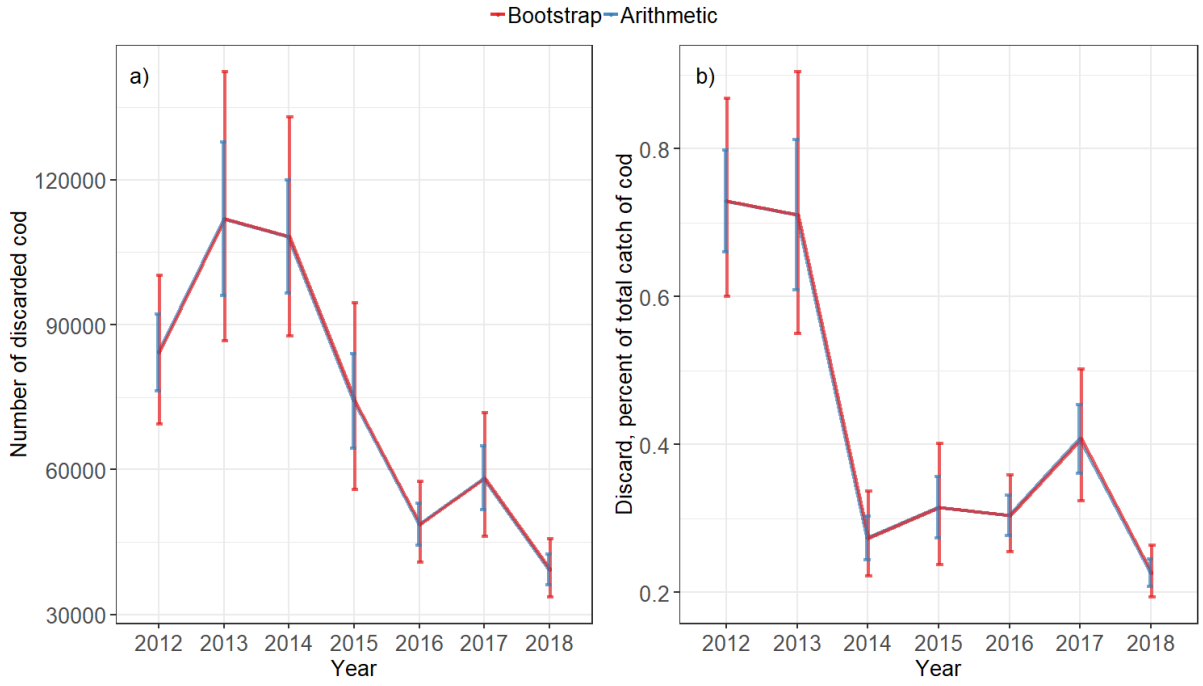

Figure 3.7 *– Estimated mean number of discards (a) and mean discard rate (% weight of total catch) (b) for cod from 2012 to 2018 in the statistical areas 00, 05 and 06. Results from upscaling with total number of sales notes with cod and CIs calculated with two different methods: arithmetically (SE, blue line) and by the Bootstrap method (red line). The intercept between the line and the error bar represents the mean each year.*

Similar to the results from Approach 1, the results from 2014 were contradicting, with a relatively high estimate of mean discarded numbers of cod, but the second lowest estimate of mean discard rate. Figure 3.8 shows the annual discard rates, estimated by using the combined average estimated weight of individual discarded cod (2.82 kg) for 2012-2018 as input in equation 4 for all years. When the variation in annual estimations of mean weight are not accounted for, 2014 gave the third highest estimate of mean discard rate (Figure 3.8). With this method, the estimated mean discard rates decreased steadily from 2013 to 2018, except for a small increase in 2017.

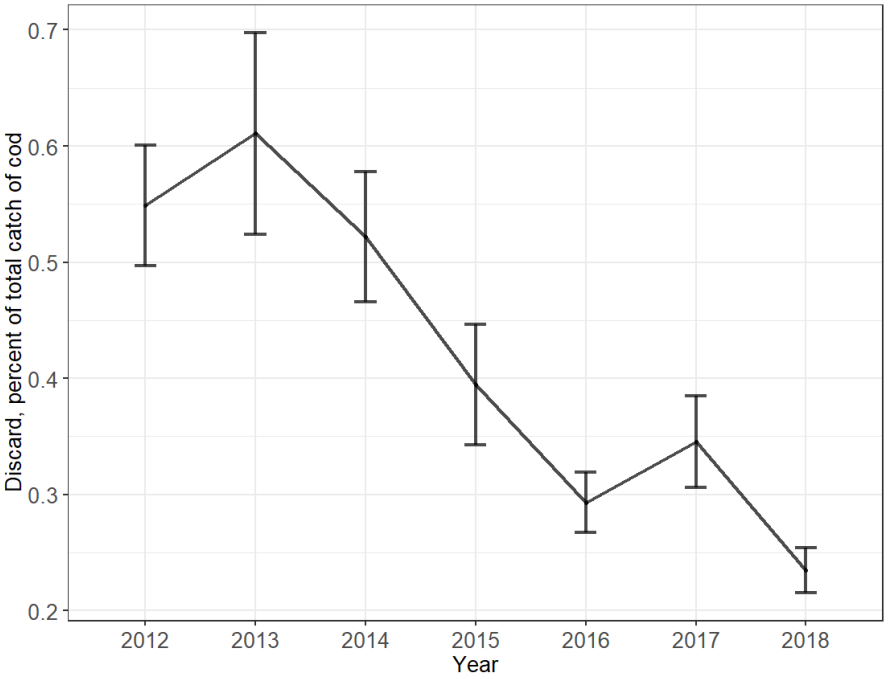

Figure 3.8 *– Annual estimated mean discard rates (% weight of total catch) for cod from 2012-2018 in the statistical areas 00, 05 and 06 applying an average individual weight of discard of 2.82 kg during 2012-2018. Discard was upscaled with total number of sales notes and CIs were calculated arithmetically (SE). The intercept between the line and the error bar represents the mean each year.*

3.2.3 Comparing Approach 1 and 2: two different upscaling-strategies

3.2.3.1 Estimations of discard rates per annual quarter

Upscaling with total weight of landed cod (Approach 1), provided higher estimates of discards, than upscaling with number of sales notes with cod (Approach 2) in many strata (Figure 3.9). In some cases, Approach 2 gave higher estimated mean discard rates, but all the estimated mean discard rates above 10 % are from Approach 1.

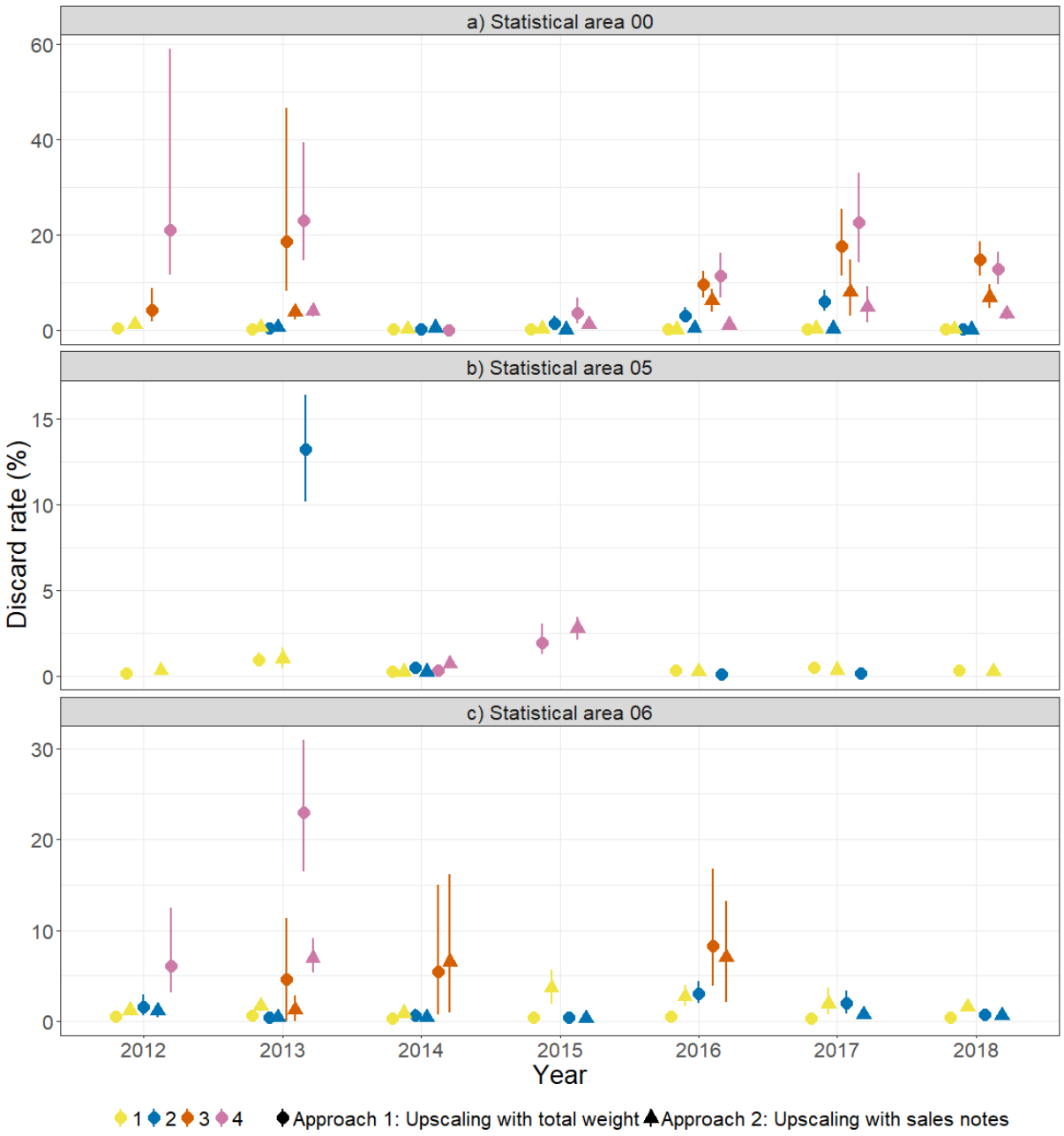

Figure 3.9 *– Estimated mean discard rates of cod per annual quarter in the statistical areas 00 (a), 05 (b) and 06 (c) (vessels < 15 m total length, using gillnets). Comparison of upscaling with total weight of landing of cod (Approach 1, circle) and upscaling with total number of sales notes with cod (Approach 2, triangle). CIs were established using the Bootstrap method. Divided in annual quarters 1 (yellow), 2 (blue), 3 (red) and 4 (pink).*

3.2.3.2 Estimations of numbers of discarded cod and discard rates per year

The two approaches for upscaling gave occasionally similar results when doing estimations per year (Figure 3.10). Estimated discard both in mean numbers and discard rate (% weight of total catch) gave a peak in 2013. Estimates were also almost identical for 2015. However, some of the results were significantly different (no overlapping CIs). Estimates from upscaling with sales notes (Approach 2) were much higher for 2012 and lower for 2018 then the estimates from upscaling with total weight (Approach 1). In fact, Approach 2 gave a mean discard rate in 2012 that was the highest estimated (0.73 %). Approach 1 estimated the third lowest mean discard rate for this year (0.33 %). The general trend

was that from 2012-2014, upscaling with sales notes gave higher estimates for discard, than upscaling with total weight. In 2015 the two approaches gave similar results, but from 2016-2018 upscaling with total weight gave higher estimated total discards than upscaling with sales notes.

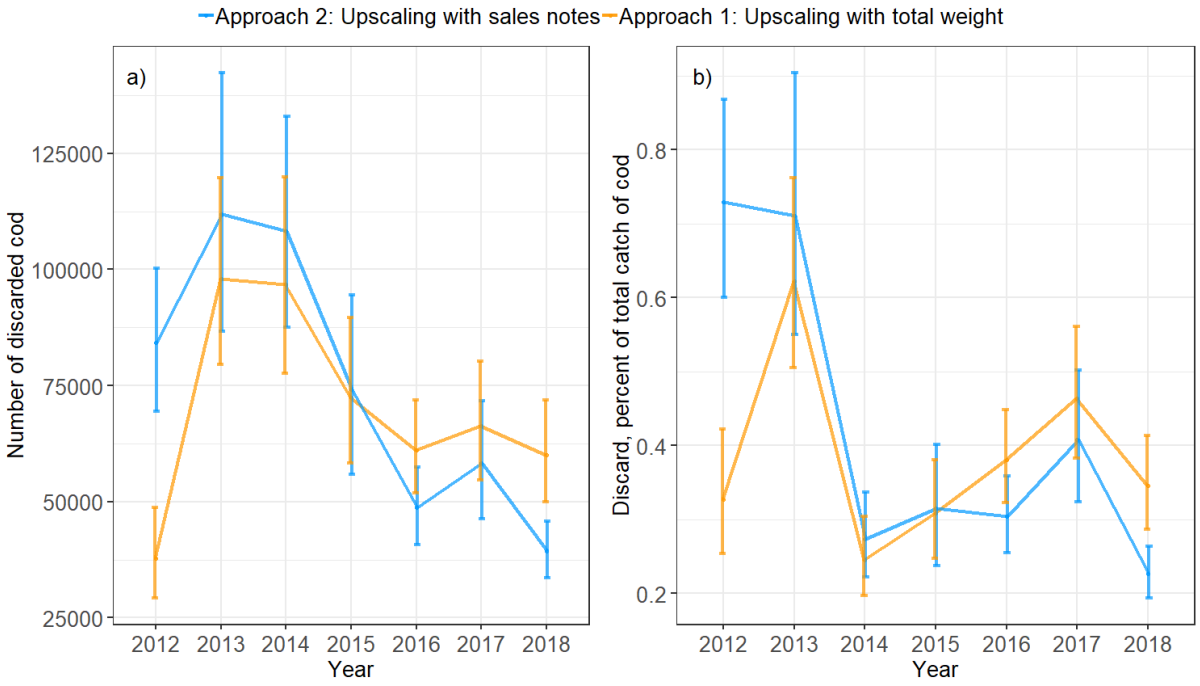

Figure 3.10 *– Estimated mean number of discards and mean discard rate (% weight of total catch) of cod in the statistical areas 00, 05 and 06 for vessels < 15 m total length, using gillnets. Comparison of upscaling with total weight of catch of cod (Approach 1, yellow line) and upscaling with total number of sales notes with cod (Approach 2, blue line). CIs were established using the Bootstrap method. The intercept between the lines and the error bars represents the means each year.*

3.2.4 Size distributions

Statistical area 00.

Statistical area 00, 1st quarter was the only stratum that had sufficient length measurements for comparing the length distributions from discarded and landed cod for each year in the study period. The difference in length distributions of discarded and landed fish was pronounced for each year in this stratum which points to high grading (Figure 3.11). Especially during 2012-2014 and 2017-2018 a large number of measured discards were smaller than the measured landed cod. In general, the length distributions of landed cod had different shapes than the length distributions of discard.

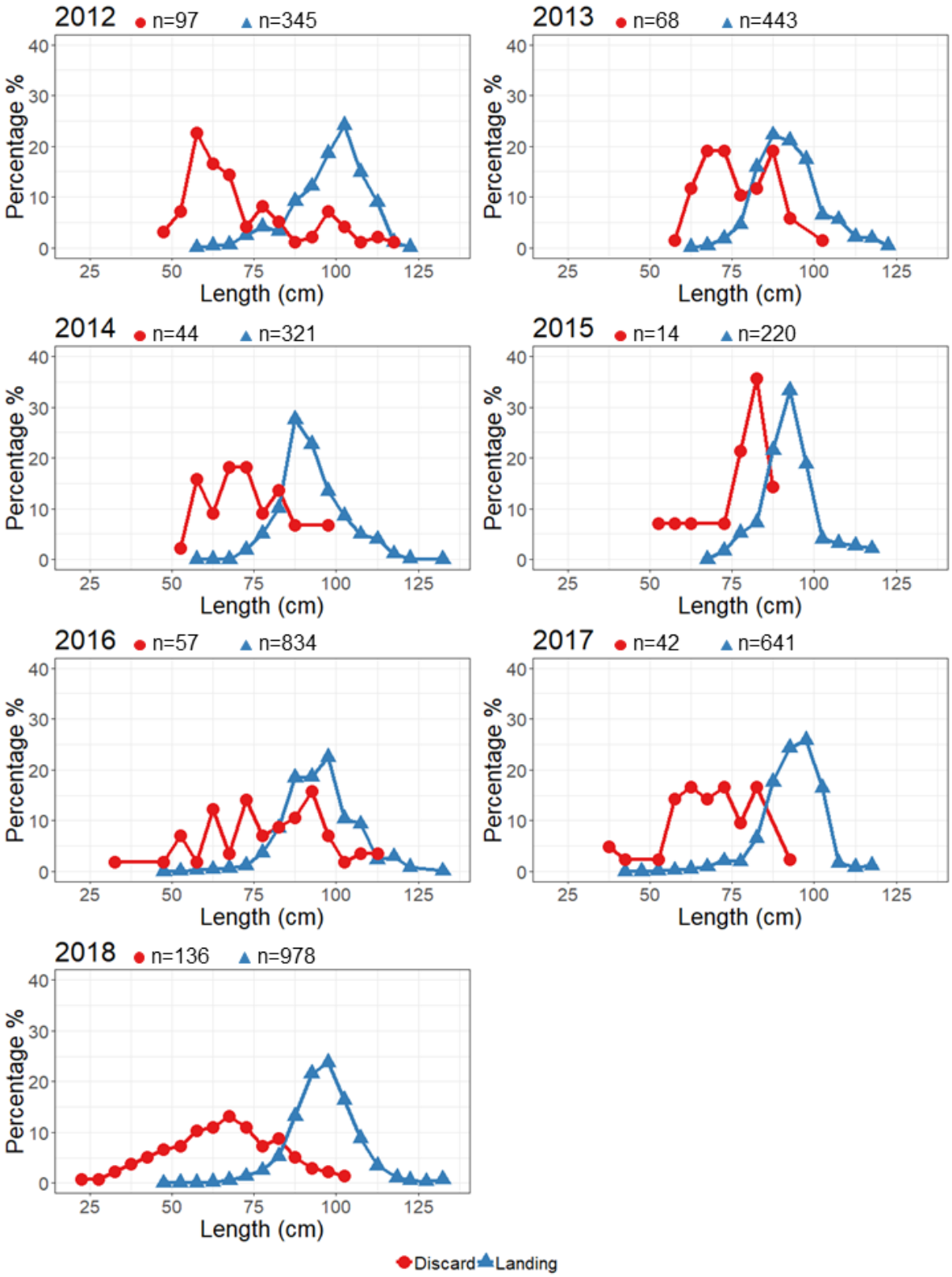

Figure 3.11 *– Length distributions of cod; percentage distributions for landing (blue) and discard (red), respectively, in the statistical area 00, 1st quarter 2012-2018. Measurements collected and reported by vessels < 15 m total length, using gillnets, in the CRF. n represents the number of individuals length measured.*

Statistical area 00, 2nd quarter showed similar results, but the differences in the length distributions between landed and discarded cod were not quite as obvious for all years as for quarter 1 in the statistical area 00 (Figure 3.12).

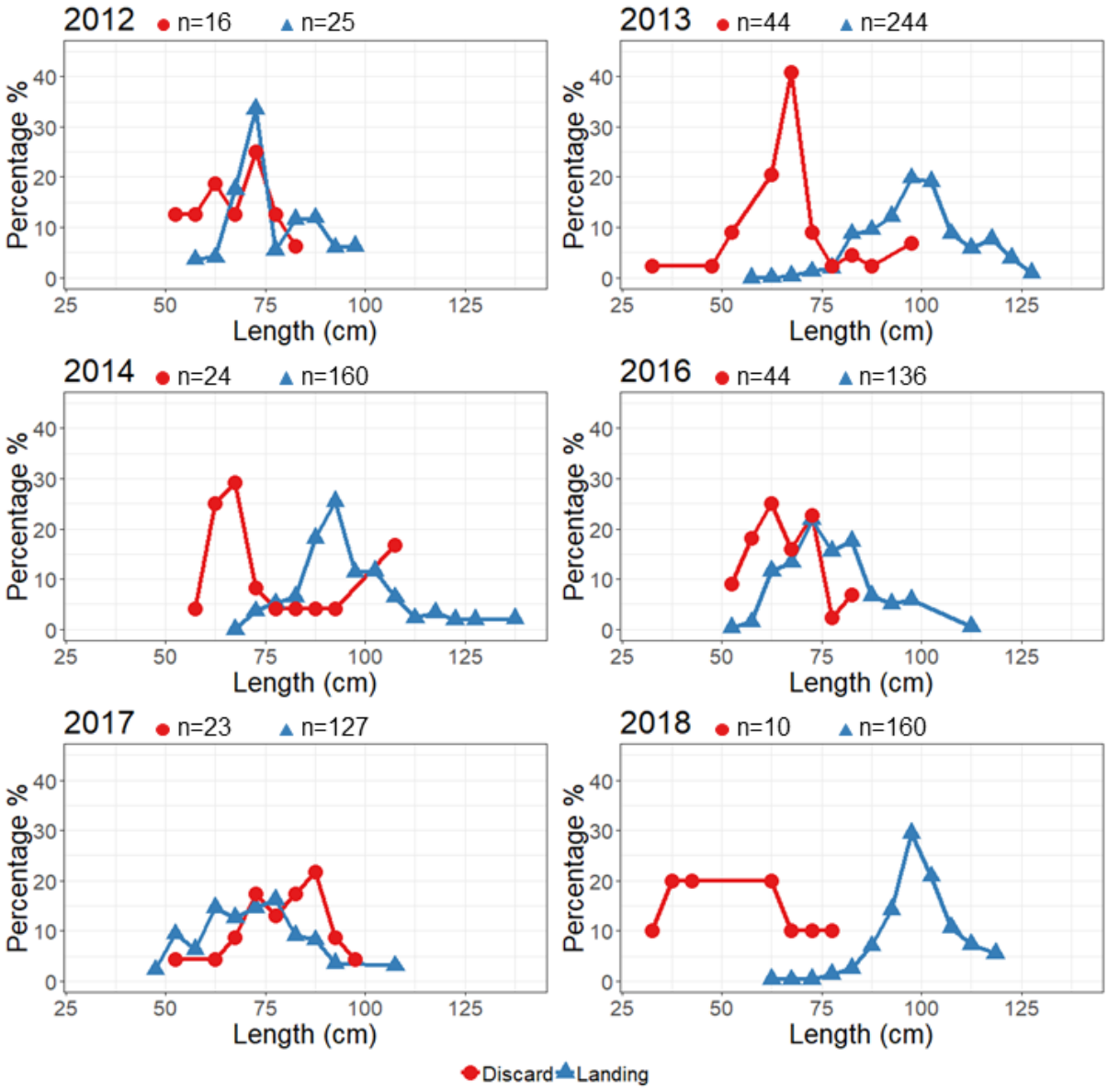

Figure 3.12 *– Length distributions of cod; percentage distributions for landing (blue) and discard (red), respectively, in the statistical area 00, 2nd quarter during 2012-2014 and 2016-2018. Measurements collected and reported by vessels < 15 m total length, using gillnets, in the CRF. n represents the number of individuals length measured.*

In the statistical area 00, 3rd quarter, differences in length distributions for the two groups were no longer clear. For example, in 2013 a higher proportion of discarded fish > 100 cm were documented compared with landed fish > 100 cm (Figure 3.13). In 2016-2018 the length distributions were similar for both groups for fish lengths between ~60 and ~100 cm.

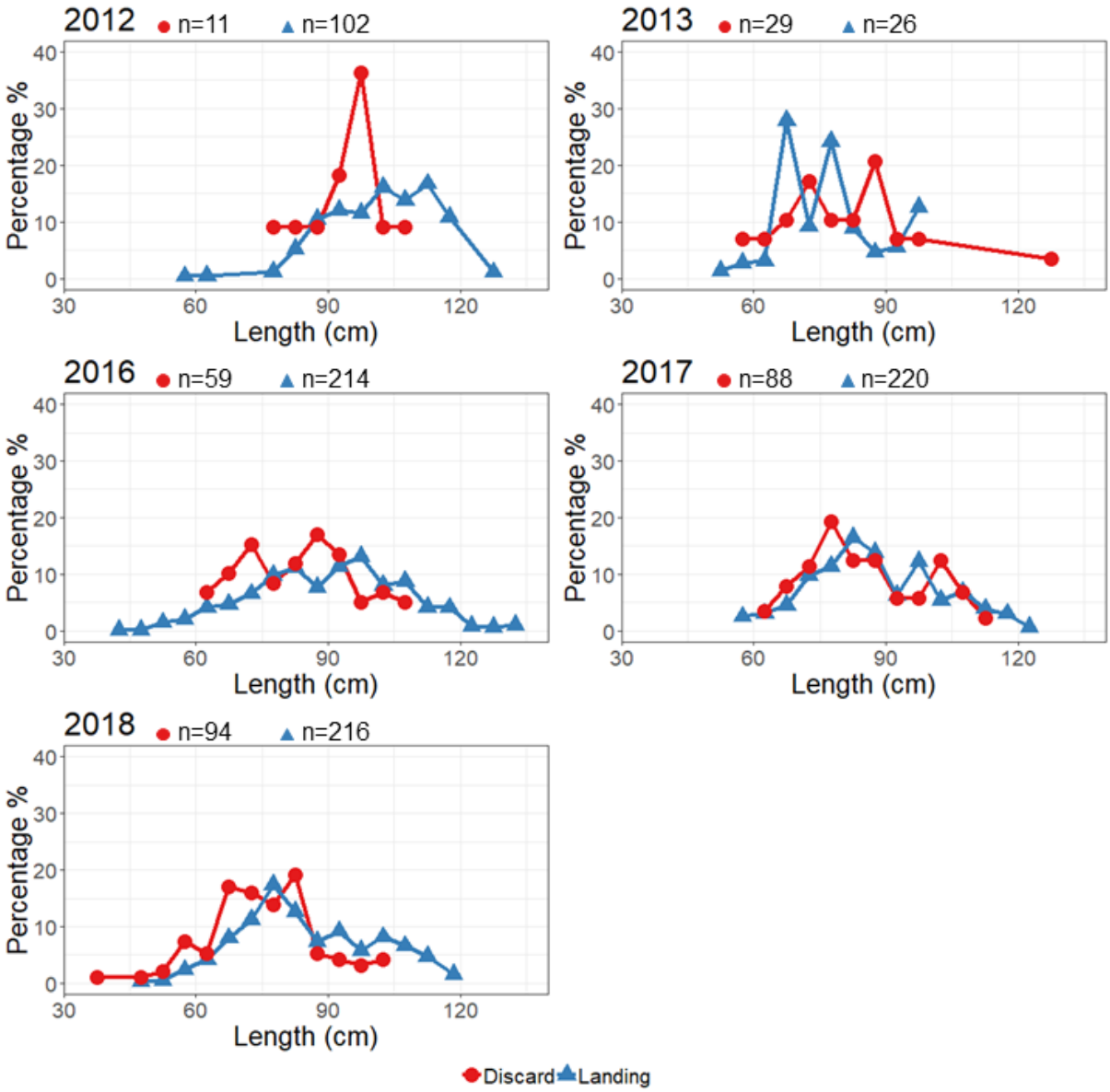

Figure 3.13 *– Length distributions of cod; percentage distributions for landing (blue) and discard (red), respectively, in the statistical area 00,3rd quarter during 2012-2013 and 2016-2018. Measurements collected and reported by vessels < 15 m total length, using gillnets, in the CRF. n represents the number of individuals length measured.*

Statistical area 00, quarter 4 showed some of the same trends as quarter 3. In 2016, the mean length of landed cod (83.32 cm) was slightly smaller than mean length of discard (89.74 cm) (Figure 3.14). Both quarter 3 (Figure 3.13) and quarter 4 (Figure 3.14) had different shaped length distributions of landed cod compared with quarters 1 and 2.

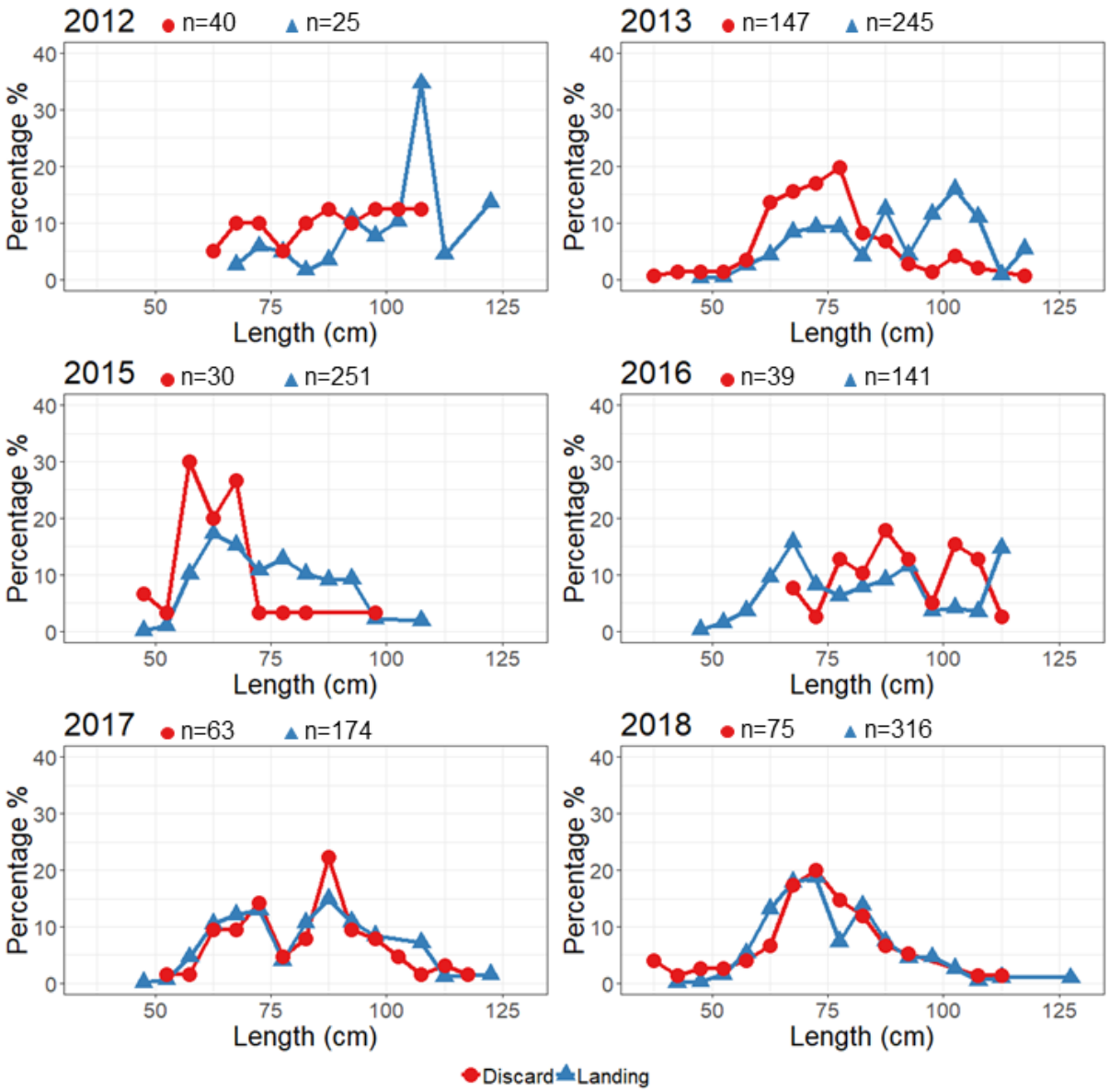

Figure 3.14 *– Length distributions of cod; percentage distributions for landing (blue) and discard (red), respectively, in the statistical area 00, 4th quarter during 2012-2013 and 2015-2018. Measurements collected and reported by vessels < 15 m total length, using gillnets, in the CRF. n represents the number of individuals length measured.*

Statistical area 05.

In the statistical area 05, 1st and 4th quarter, the discarded cod were much smaller than the landed cod for the years that had enough data (except for quarter 1 2018) (Figures 3.15 and 3.16).

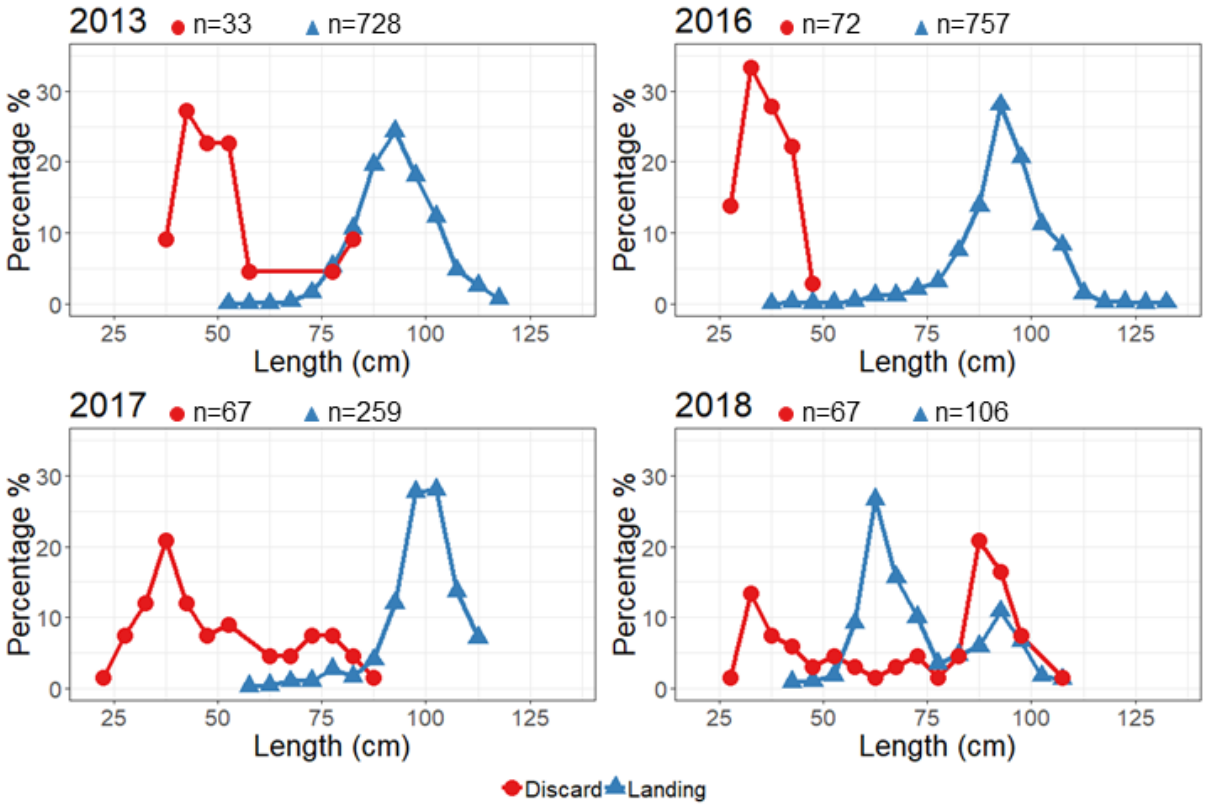

Figure 3.15 *– Length distributions of cod; percentage distributions for landing (blue) and discard (red), respectively, in the statistical area 05, 1st quarter during 2013 and 2016-2018. Measurements collected and reported by vessels < 15 m total length, using gillnets, in the CRF. n represents the number of individuals length measured.*

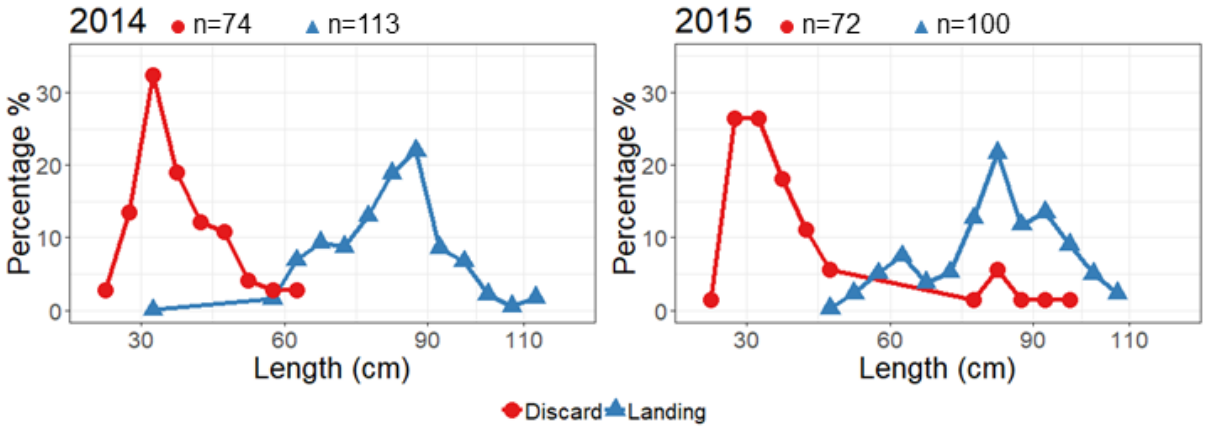

Figure 3.16 *– Length distributions of cod; percentage distributions for landing (blue) and discard (red), respectively, in the statistical area 05, 4th quarter during 2014-2015. Measurements collected and reported by vessels < 15 m total length, using gillnets, in the CRF. n represents the number of individuals length measured.*

Statistical area 06.

In the statistical area 06 there were only sufficient data for comparisons of length distributions in three strata; 1st quarter 2015, 2nd quarter 2018 and 3rd quarter 2016. Like the other figures that represent the 1st and 2nd quarter of the year, Figure 3.17 and 3.18 show tendencies of a difference in length distribution

between the two groups, where the landed fish were generally larger than the discarded ones. In the 3rd quarter 2016, many of the discarded fish were generally larger than the landed fish (Figure 3.19).

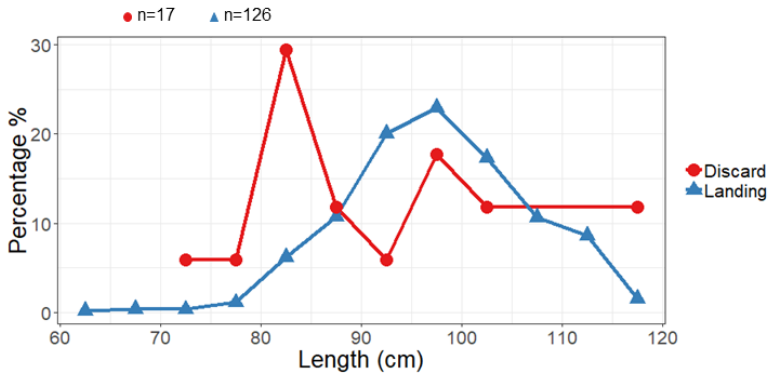

Figure 3.17 *– Length distribution of cod; percentage distributions for landing (blue) and discard (red), respectively, in the statistical area 06, 1st quarter in 2015. Measurements collected and reported by vessels < 15 m total length, using gillnets, in the CRF. n represents the number of individuals length measured.*

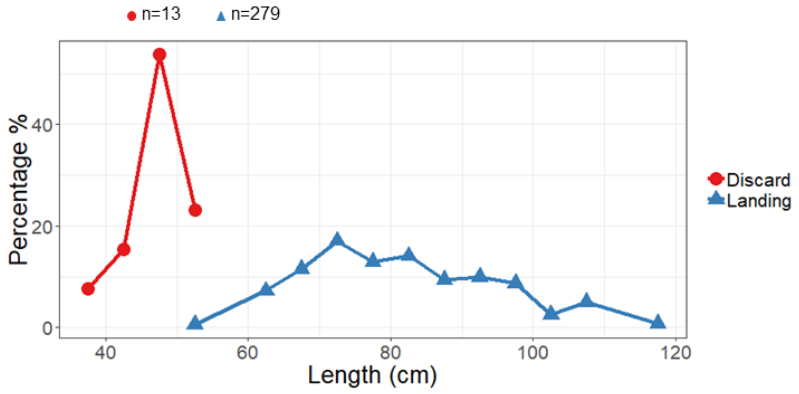

Figure 3.18 *– Length distribution of cod; percentage distributions for landing (blue) and discard (red), respectively, in the statistical area 06, 2nd quarter in 2018. Measurements collected and reported by vessels < 15 m total length, using gillnets, in the CRF. n represents the number of individuals length measured.*

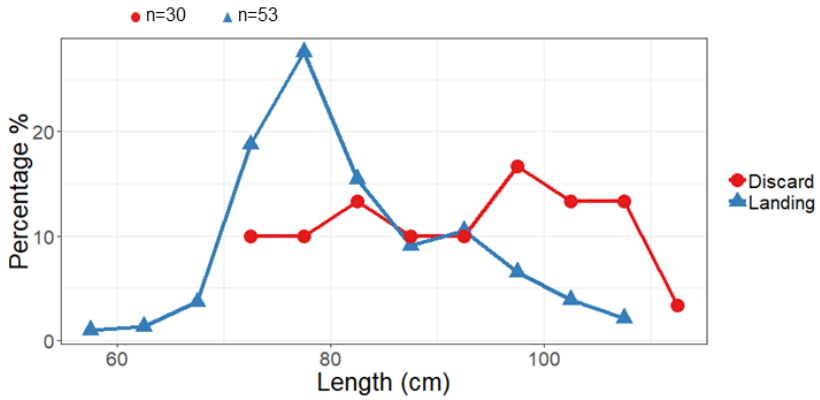

Figure 3.19 *– Length distribution of cod; percentage distributions for landing (blue) and discard (red), respectively, in the statistical area 06, 3rd quarter in 2016. Measurements collected and reported by vessels < 15 m total length, using gillnets, in the CRF. n represents the number of individuals length measured.*

4 DISCUSSION

The mean annual discard rates of cod were ≤ 0.73 % of total catch in weight, in gillnet-fisheries for vessels less than 15 m total length in the statistical areas 00, 05 and 06, irrespective of the two calculation methods used for upscaling. The highest mean annual discard rates were calculated in 2013 with 0.62 % when upscaling with total weight of landed cod (Approach 1) and in 2012 with 0.73 % when upscaling was done with total number of sales notes with cod (Approach 2). The estimated annual rates then decreased to levels between 0.24 and 0.46 % (Approach 1), and between 0.23 and 0.41 % (Approach 2) from 2014 to 2018. Mean discard rates per annual quarter were higher (maximum of 23.03 % from Approach 1 and 8.06 % from Approach 2) in quarters 3 and 4, than in quarters 1 and 2 (maximum of 13.20 % from Approach 1 and 3.63 % from Approach 2). Comparison of length distributions for landed and discarded fish showed occasional signs of high grading, especially in quarters 1 and 2.

4.1 DATA

4.1.1 Data records and frequency distributions of discard

The discard estimations per annual quarter in the statistical areas 00, 05 and 06 were based on a varying number of data records throughout the study period, from 10 recorded fishing trips (which was set as the minimum limit for estimation) to 267 recorded fishing trips per annual quarter (Table 3.1 and 3.2). Most records were found in quarter 1, in the statistical area 00, most years and there were most data overall in this stratum. Other strata, e.g. statistical area 06, quarter 4, only had sufficient records of fishing trips with catch of cod for performing discard estimations for two years when upscaling with Approach 1. The same stratum only had ≥ 10 fishing trips from the CRF matched with sales notes for one year, which makes it impossible to get a continuous time-series for discards in this stratum, and others like it. One cause of the variation in the amount of data is the fluctuations in the number of vessels participating in the CRF in the relevant fishery (with a minimum of 7 vessels in 2014 and a maximum of 11 vessels in 2017) (Table 2.2). The fishing activity throughout the years has also fluctuated, and there are continuous changes in activity between areas and quarters of a year. The high data coverage of area, 00 quarter 1 might be explained by the importance of this period and area in the annual coastal fishery for NEA cod. In general, there was less data coverage in the northernmost statistical area, 05, than in the other areas (Figure 2.1). In warmer periods, as experienced in the latest years, the NEA cod tend to spawn more in areas further north, than they will in colder periods (Aglen 2009; Sundby & Nakken 2008). This indicates that the statistical area 05 might have an increasing importance in the fishery for cod in upcoming years, as more and more of the quota of NEA cod for the Norwegian coastal fleet may be taken there.

A weakness in the data records in this thesis is the lack of randomization. The vessels cannot be randomly selected because the law requires an open bidding for the contracts. However, the participants are randomly selected to some degree from the vessels applying for the contract. The programme aims to ensure representative coverage of the Norwegian fleet, and the vessels are therefore also selected on the basis of their fishing activity and area (Fuglebakk et al. 2018). There are also uncertainties linked to whether the vessels that choose to apply for the contract have the same discarding-behaviour as the rest of the fleet (Anon. 2011), which is discussed further in chapter 4.5. It is also possible that the training for the self-sampling, after contracting with IMR, can affect a vessel's habits of discarding.

4.1.2 Length-weight relationship

The estimated mean annual weights of individual discarded cod were calculated based on length measurements from the CRF during 2012-2018. The SDs (Table 3.3) around the mean lengths from these measurements were large. This means that there will also be corresponding uncertainties linked to the estimations of mean weight of individual discards, and in turn the calculations for total weight of discarded cod.

All the years in the study period had estimated mean individual weight of discard between 2.33 kg (2015) and 3.88 kg (2012), except for 2014 when the discarded fish were smaller than average (1.53 kg) (Table 3.3).

The factors used to convert the reported mean lengths to weights (from equation 3) were general assumptions in terms of the a- and b-values estimating the length-weight relationship of cod. More specific a- and b- values were tested. However, these values gave results that corresponded to the results from the general a- and b-values from equation 3 if one takes account for natural variation in growth in cod. The original values were therefore kept.

To illustrate the importance of the average individual weight of discarded cod on the total estimations; mean lengths of 50, 60 and 70 cm give estimated mean weights of 1.1, 1.9 and 3.1 kg, respectively. Using an imaginary value of 100 000 for estimated number of discarded cod in one stratum, the three different values for mean individual weights estimate 112.5, 194.4 and 308.7 tonnes total discard of cod, respectively. The mean lengths of discards will therefore have a large impact on the final estimations of total discard and in turn percentage of total catch.

4.2 UPSCALING DISCARDS WITH TOTAL WEIGHT OF LANDING OF COD AND WITH TOTAL NUMBER OF SALES NOTES WITH COD (APPROACH 1 & 2)

4.2.1 Relationship between discard and size of catch

The assumption that there is a linear/proportional relationship between the size of the catch/landings and discards in the fishery is one that is widely used for estimations of total discards from sample discard rates (Pérez-Roda et al. 2019; Rochet & Trenkel 2005). Landing-statistics are available in many different fisheries and are often the easiest way to upscale the discard to fleet level. This relationship is often hard to prove. Rochet & Trenkel (2005) claimed that unless conclusive knowledge on the correlation is obtained, the estimated discards should be interpreted with great care, when it is tied to the assumption of proportionality to catch.

The Poisson regression conducted on numbers of discarded cod and the size of catch of cod from the recorded fishing trips, showed a weak but significant relationship for 2013-2017, but not for 2012 and 2018. It can be argued that despite lack of significant relationships from these two years in the study, the uncertainties linked to the ratios were valid, because they were used as scaling factors and not for predictions.

Plotting of the expected model with the recorded data showed large spread in the data, and even in the years with significant relationships very little of the variation was explained (Figure 3.2). This indicates that even though it was expected that the number of discarded cod should increase with the size of the catch of cod, a lot of the discard must be caused by other factors. Discarding is a result of sorting the catch, and this sorting-process is highly complex (Rochet & Trenkel 2005). Possible factors that can impact discard quantities and rates are discussed in chapter 4.4.

4.2.2 Discard rates per annual quarter

In the statistical areas 00 and 06 there were strong indications of higher discard rates in quarter 3 and 4 (fall and beginning of winter) than during quarters 1 and 2 when upscaling the discard with total landed weight (Approach 1) (Figure 3.3). Also in figure 3.6 (upscaling with total number of sales noteswith cod, Approach 2), we see generally higher estimated discard rates in the second half of the year.

Because of large variation in the data, due to irregular patterns in the discarding, establishing CIs for the estimated means, and consequently CIs for the total discard proved to be challenging. Arithmetic methods for calculating CIs do not accommodate for skewed distributions, which sometimes resulted in negative lower CI limits. The percentile Bootstrap method do accommodate skewed distributions, and the estimated CIs are often asymmetrical. Matching the discard to number of sales notes (usually 1, sometimes 2) instead of tonnes landed catch (varying from a few kilos to many tonnes) reduced the spread in the data.

All estimates for discard rates above 10 % in weight of total catch were calculated using Approach 1. Approach 2 gave slightly lower estimated discard rates for most strata, especially the ones with larger variation in the data records, i.e. quarter 3 and 4 in many cases. When calculating discards with Approach 2 the maximum estimated mean discard rate for quarter 3 and 4 was 8.1 % (Appendix table 2.f). From Approach 1 the maximum estimated mean discard rate for these quarters was 23.0 % (Appendix table 1.b).

The alteration in discard rates from the first to the second half of the year might be caused by the nature of the fishery. The main season for direct cod fishery is in late winter and spring (quarter 1 and 2). In quarter 3 and 4 a more mixed fishery is usually practiced, targeting cod along with other species. Firstly, if the fishers fill up their quota for cod during quarter 1 and 2, there might be higher discard rates in the second half of the year as they have exhausted their quota. Secondly, there may be an increase of smaller cod outside the peak of the fishery (as the large NEA cod leaves the coast in the late spring after spawning). However, the size-distributions of landing and discard (Figure 3.11-3.19) do not show clear signs that the discards were smaller in quarter 3 and 4 than in quarter 1 and 2.

More gillnets with larger mesh sizes were used in the 3rd and 4th quarter, than in the 1st and 2nd (Figure 4.1). Fishing with gillnets > 130 mm bar length often targets anglerfish (*Lophius piscatorius*) (Anon. 2004). From the regulations on the practice of fishing in the sea, the fishers are obliged to haul the gillnets in fishery for cod, haddock and saithe every day. The fishers are only obliged to haul the gillnets in fishery for anglerfish every third day (Anon. 2004). Cod caught in gillnets targeting anglerfish might therefore have lower quality as a result of longer average soak time, which may increase the discard rate.

We do not know if the individual recorded discards represent NEA cod or coastal cod. However, there are general assumptions around the distribution of NEA cod and coastal cod in the coastal fishery, as well as records on the proportions of the two in landings. In the 1st and 2nd quarter the catches consist of predominantly NEA cod in the statistical areas 00 and 05, and a mixture of NEA cod and coastal cod in the statistical area 06. The fractions of coastal cod in the catches increases quickly in the second half of the year, and in the 3rd and 4th quarter the catches are almost exclusively coastal cod most years, in all three statistical areas (ICES 2014, 2016, 2018b). Considering this, the results from this thesis generally predict a higher discard rate for coastal cod than for NEA cod in the coastal fishery. In the 3rd and 4th quarter estimates have been up to around 20 % in several strata, however with wide CIs (Figure 3.3). For example, in 2017, statistical area 00 quarter 4, the estimated discard is 22.56 % [95 % CI (the ratio estimator): 4.25 - 40.87 %] (Approach 1, Appendix table 1.f). The coastal cod stock north of 62°N is low, but not as low as the stock south of 62 °N. A revised rebuilding plan for the stock is currently being developed (ICES 2018a).

Even though the discard in quarters 3 and 4 would affect the coastal cod stock more specifically, the generally higher estimated discard rates did not account for the largest quantities (numbers and weight) of discard. This is because there was generally less catch of cod in the second half of the year. As an example, in 2013 the discard rate in the statistical area 05, 1st quarter was estimated at 0.90 % [95 % CI (Bootstrap method): 0.52 - 1.35] (Approach 1). This percentage originated from an estimated weight of discarded cod of 209 tonnes [95 % CI: 109 - 308] (Appendix table 1.b). The highest estimated discard rate this year was 23.0 % [95 % CI (Bootstrap method): 14.6 - 39.5 %] (Approach 1) from the statistical area 00, 4th quarter which originated from 76 [95 % CI: 48 - 131] tonnes of discarded cod.

The methods for calculating the ratio of numbers discarded per tonne landed catch of cod (Approach 1) do, to some extent, amplify the increase in estimated discard when the landed catches were lower. To illustrate, a fishing trip with 4000 kg of landed cod and 4 discarded cod would give a ratio of 1 per tonne (4/4t = 1). A fishing trip with 4 kg of landed cod (could be caught in a fishery targeting other species) and 4 discarded cod would give a ratio of 1000 per tonne (4/0.004 = 1000). This might also be part of the explanation for why the estimated discards in quarters 3 and 4 were generally higher when upscaling with total weight of catch of cod (Approach 1), and lower when upscaling with total number of sales notes (Approach 2). As already mentioned, Approach 2 reduce the spread in the data, as the number of sales notes per fishing trip is usually 1 or 2 throughout the whole year.

The preparatory work done by IMR and DoF in 2012 (Blom et al. 2015) estimated total numbers of discarded cod, total weight of discard and total discard in percent of landed quantity of cod, upscaled with total number of sales notes and with landed quantity. Estimates were established for the 1st quarter in 2012 and without identifying the discard to the level of fishing trips, like in this study. The estimates were therefore without CIs.

The estimates of discard rates (% of landed quantity of cod) in quarter 1, 2012, were (Blom et al. 2015):

- 0.87 % in the statistical area 00, 0.09 % in the statistical area 05, and 0.48 % in the statistical area 06 when upscaling with landed quantity.
- 0.89 % in the statistical area 00, 0.14 % in the statistical area 05 and 1.19 % in the statistical area 06 when upscaling with number of sales notes.

The estimates assumed an average length of 70 cm for discarded cod, corresponding to 3.0 kg.

In comparison, the estimates from this study in quarter 1, 2012 for the statistical area 00, gave discard rates (% of total catch of cod) of:

- 0.47 [95 % arithmetic CI: 0.26 - 0.69] % in the statistical area 00, 0.15 [95 % arithmetic CI: 0.08 - 0.21] % in the statistical area 05, and 0.48 [95 % arithmetic CI: 0.27 - 0.68] % in the statistical area 06 when upscaling with total weight of landed cod (Appendix table 3.a).

- 1.23 [95 % arithmetic CI: 1.08 - 1.38] % in the statistical area 00, 0.29 [95 % arithmetic CI: 0.23 - 0.33] % in the statistical area 05, and 1.20 [95 % arithmetic CI: 1.01 - 1.38] % in the statistical area 06 when upscaling with total number of sales notes with cod (Appendix table 3.c).

These estimates were based on an assumed average length of 76 cm for discarded cod, corresponding to 3.9 kg (Table 3.3).

For the estimations of discard rates when upscaling with total landed quantity, the results are the same for statistical area 06 and within the CI for statistical area 05. For statistical area 00 the method established in this thesis estimated a lower discard rate. When upscaling with total number of sales notes the results from this study gave higher discard rates in the statistical area 00 and 05 than the ones from the preparatory work. For statistical area 06 the estimate from Blom et al. (2015) is within the CI of the estimate from this thesis. It would be expected that the discard rates from this thesis were somewhat higher as an assumed average weight of 3.9 kg was used, compared to 3.0 kg. The reason why the estimates were not always higher could be because the preparatory work used the sum of discarded cod per annual quarter and per statistical area, to scale to the total number of sales notes with cod and total landed quantum of cod in the stratum. It did not account for each fishing trip individually, as in this thesis.

A modelling-approach from the same preparatory work, estimated the discard rates of cod in 1st quarter of 2012 in the statistical area 00 estimated to 1.44 [95 % CI: 0.90 – 2.22] % (Blom et al. 2015). This is most comparable to the estimate for the same strata when upscaling with the total number of sales notes (1.23 [95 % CI: 1.08 - 1.38] %).

It has been advised that if the estimated discards are relatively large, annual estimations of the fishery should be conducted. If the estimated discards are relatively small, the estimates can be used as a proxy for the annual discard in the specific fishery, and new estimations do not have to be conducted annually, but perhaps every five years (Blom et al. 2015). The estimations from this thesis may be classified as "relatively small" in the 1st and 2nd quarter, proposing that estimations of discards for the annual fishery for spawning NEA cod do not have to be conducted every year. Estimations of discard rates in the fishery for coastal cod in the 3rd and 4th quarter were higher, and estimations of discards should be included in the revised rebuilding plan for the stock. Some of the discarded cod in the estimates originate from cod under minimum fishing size. These fish might have survived and were then not illegal discards.

4.2.3 Numbers of discarded cod and discard rates per year

The general trends for estimated total number of discards per year is an increase from 2012 to 2013, before a gradual decrease until 2016. In 2017 both approaches for estimation showed a smaller peak, and another decrease from 2017 to 2018 (Figure 3.4a and 3.7a). The estimated discard rates in percentage of total catch in weight showed similar trends for most years, but the two approaches gave different

estimates for 2012 (Figure 3.4b and 3.7b). When upscaling with number of sales notes, 2012 is estimated to have the highest discard rate of all years, whereas when upscaling with total weight of landing, 2012 had the third lowest discard rate of the whole study period.

Special for 2014, irrespective of upscaling approach, is that this year had relatively high estimated mean numbers of discards, but relatively low estimated mean discard rates (in % of total catch of cod) (Figure 3.10). In 2014 the DoF gave all vessels < 11 m, registered length, in coastal fisheries north of 62°N an unlimited quota for cod (Directorate of Fisheries 2014). This resulted in an over average total, annual landing of cod, both in the statistical areas 00, 05 and 06 (Appendix table 4.b) and along the whole Norwegian coast (Table 2.1). With increased landings of cod, it is also expected that the number of discards increase. With an unlimited quota, there should be no reason to high grade the catches. This might have resulted in smaller cod, that might have been discarded in other years, being landed, effectively decreasing the mean length of discards this year. The under average estimated mean individual weight of discarded cod, then contributed to estimations of a relatively low total weight of discarded cod. The low total weight of discarded cod and high total weight of landed cod gave a low estimated discard rate. In 2014 more gillnets with mesh sizes typical for targeting cod (~80 - ~110 mm bar length) were used during the whole year (Figure 4.1). In other years, a higher proportion of gillnets with larger mesh sizes (targeting anglerfish) were used in the second half of the year, possibly as the vessels had exhausted their quota for cod. The larger proportions of gillnets with smaller mesh sizes in 2014 might have also contributing to the smaller average length of discarded cod, and can reflect that there were more catches of small cod during the whole year.

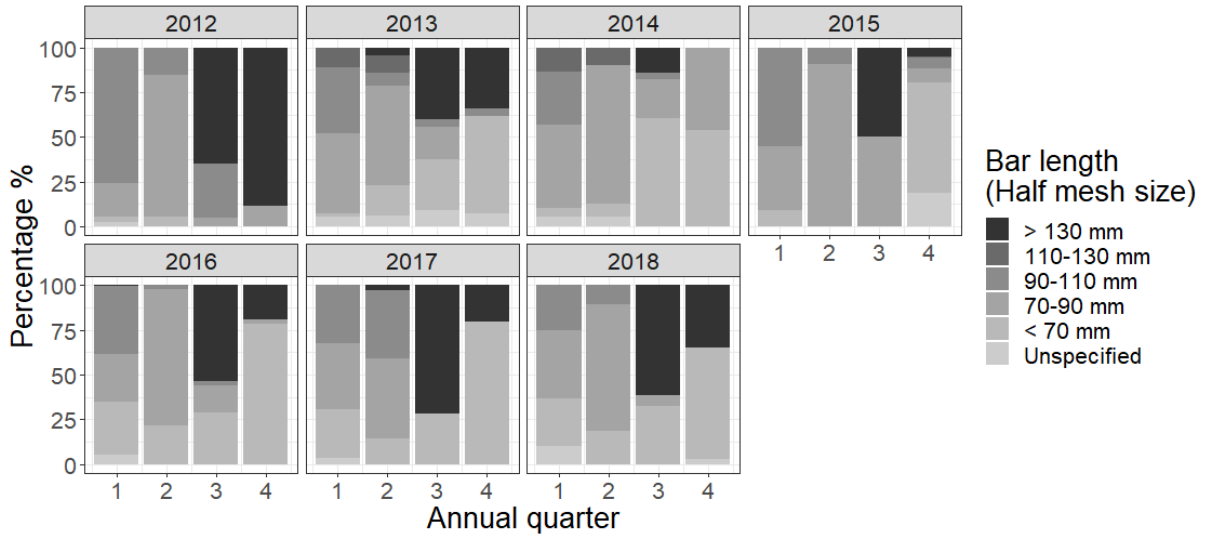

***Figure 4.1** – Utilization of gillnets with different half mesh sizes by vessels < 15 m total length in the CRF, to catch cod in the statistical areas 00, 05 and 06, during 2012-2018.*

The estimated discard (in number and to some extent in rate (% weight of total catch)) were lower in 2018 than in many other years in the study (Figure 3.10). The total first-hand value and the total landed weight of cod (in kg), from the Fishermen's sales organization (for the coastline from Finnmark to

Nordmøre, Norges Råfisklag n.d.a) can indicate cod prices in NOK/kg each year. This shows approximate prices ≤ 12 NOK/kg for 2012 to 2015, with an estimated low point in 2013 with 8 NOK/kg (for catches of cod from all vessels and gears). From 2016, 2017 and 2018 the approximate prices were 14, 16 and 17 NOK/kg, respectively. When the prices initially are low, there might be higher incentives for discarding cod of smaller sizes and lower quality. The estimated decrease in discards of cod from 2012/2013 to 2018 might be a result of increasing prices.

The estimates for discard rates are < 1 % (including CIs) of the total catch of cod in weight for all years irrespective of approach for upscaling. These are low numbers compared to many previous estimates of discards. A third assessment of global marine fisheries discard (Pérez-Roda et al. 2019) estimated an annual global discard rate (in % weight of total catch) of 10.8 % (10.1 % - 11.5 %) during the period 2012-2014. Global marine fisheries catch reconstructions, from the Sea Around Us project (Zeller et al. 2018) has estimated that global annual discard rates were between 10-20 % (in % weight of total catches) before year 2000, and since then it has been slightly less than 10 %. Before this, estimates have been 27 % of global, annual catches in weight in 1994 (Alverson et al. 1994) and 8 % in 2005 (Kelleher 2005).

These estimates of global discard rates from larger assessments and projects pool all the world fisheries, and discard of all species, together. For example, from the third assessment of global marine fisheries discard (Pérez-Roda et al. 2019) about 46 % of the total discards were predicted to be from bottom trawls. Comparing the specific discard rates from this study (for cod in coastal fishery from Norwegian vessels fishing with gillnets), with global discard rates for all species and gears, is not optimal. However, there are very few previous estimates of discard rates specifically for coastal fishery for cod. The few that exist also estimates discard rates that are mostly above the annual estimates in this study.

The third and currently last global assessment of marine fisheries discard (Pérez-Roda et al. 2019) estimated a discard rate, for all species, of about 10.1 % for global gillnet fisheries, with the majority originating from bottom gillnets. Estimations of discard of cod in Icelandic gillnet fisheries were established in 2003, based on comparing the length distributions of landings and catch in samples from 2001. These estimates were of 560 000 discarded cod, which corresponded to 1 620 tonnes and 3 % of weight of total catch (Pálsson et al. 2003a).

Valdemarsen & Nakken (2002) established guesstimates for Norwegian discard rates in an investigation based on questionnaires/surveys from fishers and fisheries statistics. They calculated a discard rate of 2-8 % of the total catches for the whole of the Norwegian fisheries. For gillnet fisheries after gadoid-species they calculated a discard rate between 5 and 15 % (1 500 - 4 650 t), and for the cod fishery in Lofoten in the spring, a discard rate between 1 and 10 % (170 - 1 700 t) was calculated. The estimates in this thesis which were all between 0.23 and 0.73 % (111 and 327 tonnes, Appendix table 4.d) are lower in terms of percentage compared with estimates from Valdemarsen & Nakken (2002), as well as the ones from Pérez-Roda et al. (2009) and Pálsson et al. (2003a). In tonnes, some estimates from this

thesis, do however fall within the lower limits for calculated discard in weight in the cod fishery in Lofoten by Valdemarsen & Nakken (2002). From year 2000 to 2002 the total annual landings of cod caught with gillnets by vessels < 15 m total length along the Norwegian coast were between 34 954 and 41 028 tonnes (Directorate of Fisheries 2019b). In comparison, during the study period in this thesis the annual landings were between 71 101 and 94 160 tonnes (Table 2.1). Because the annual landings are higher during the study period in this thesis, than in the years before the calculations of Valdemarsen & Nakken (2002), the same estimated discard in weight, correspond to lower discard rates (in % weight of total catch) for 2012-2018.

The preparatory work done by IMR and DoF in 2012 also estimated the annual total numbers of discarded cod (Blom et al. 2015), total weight of discard and discard rate (% of landed quantity of cod) in 2012 for all three statistical areas. These estimates gave a discard rate of 0.58 % both when upscaling with number of sales notes and total landed quantity of cod, when assuming an average individual weight of discarded cod of 3.0 kg. In comparison, the results from this study gave a discard rate of 0.33 % [95 % CI (the ratio estimator): 0.24 - 0.41 %] when upscaling with total weight of landed cod (Appendix table 4.b). When upscaling with total number of sales notes the estimated discard rate was 0.73 % [95 % CI (SE): 0.66 - 0.80 %] (Appendix table 4.d). The estimate from the preparatory work is above the CI for Approach 1 (upscaling with total weight) and below the CI for Approach 2 (upscaling with sales notes). The estimated numbers of discarded cod from the preparatory work (85 832 – nos. sales notes and 85 467 – landed quantity) are close to the estimated numbers of discarded cod from this thesis when upscaling with sales notes (84 270 [95 % CI: 76 306 - 92 235]) (Appendix table 4.d). Approach 1, upscaling with landed weight, estimate much lower numbers (37 686 [95 % CI: 27 827 - 47 545]) (Appendix table 4.b).

When the estimates were done by using the combined average individual weight of discard for all the years in the study period, we see a more gradual decrease in discard rate from 2013 to 2018 with both approaches (Figure 3.5/3.10). Upscaling with Approach 1 still gives a much lower estimate in 2012 (~0.25 %), than upscaling with Approach 2 does (~0.55 %). Both estimations predict that the highest mean discard rate in the study period was in 2013 and that the mean rates from 2015 to 2018 were < 0.40 %. However, Approach 1 estimated a discard rate of ~0.35 % in 2018, while Approach 2 estimated a discard rate of < 0.25 %. The most important aspect these figures illustrate is that the quantities of discard have changed throughout the study-period, independently of the varying average weight of individual discarded cod. I believe there is evidence to propose that the quantities of discard in the latest 3-4 years are smaller than they have been in the other years during the study period.

For the estimations per year, only data from some strata are used in the estimations (as not all strata had records each year), as mentioned in Ch. 2.3.2. This leads to uncertainties in the results. The estimations are dependent on an assumption that the reported discarding in the records are representative for discarding in the "missing" strata as well. Still, it was done this way because upscaling with the total

amount of landed tonnes or total number of sales notes for the entire year and all areas was the only way to get an estimate that can be compared throughout the study period, with a substantial data basis.

4.3 SIZE DISTRIBUTIONS

There is evidence of high grading in the figures with comparisons of size distributions (Figure 3.11-3.19). Generally, the signs are clearer in the length distributions from quarters 1 and 2, than from quarters 3 and 4. The difference in the distributions from the latter half of the year is less obvious, and sometimes time distributions are similar. Comparisons from a few strata in quarter 3 and 4 indicate that the discarded fish were generally larger than the landed fish (e.g. Figure 3.14). The overall number of length measurements varied throughout the study period and in the different statistical areas. The numbers of length-measured discarded fish were almost always fewer than the numbers of length-measured landed fish, and statistical area 00 have more recorded length measurements than the other statistical areas.

High grading will usually be affected by regulations, quotas and prices, and high grading of a species is presumably more common when the species is targeted in the fishery, than when it is not. This can possibly explain the trends indicating a larger difference is the size distributions of landed and discarded fish in the first half, than in the second half of the year. High grading is motivated by the economic advantage for the fishers that can result from discarding the less valuable parts of the catch in order to increase the overall value of the landing (Kristofferson & Rickertsen 2005). The prices per kg for landed cod increases with increasing weight of the fish (Norges Råfisklag, n.d.b). Many of the coastal fishing vessels using gillnets will fill most of their annual quota for cod during the main spawning season of NEA cod in the 1st and 2nd quarter of the year. If the remaining catch of cod is taken in a mixed species fishery, there might be other factors than the size of the fish that determines the rate of discarding. Diamond & Beukers-Stewart (2011) claimed that high grading will in many cases be determined by the fishers belief of whether they will have an opportunity of retrieving a more profitable catch at a later time. It seems reasonable to assume that this belief might be stronger in quarter 1 and 2.

The presumed economic advantages to the fishers from the high grading estimated in this study can be questioned when regarding the estimates of quantities of discard. With the small amounts of discard in quarter 1 and 2 from the estimates in this study, the economic gain from the high grading must be relatively small. This implies that something else than economy could be motivating this discard of smaller cod. One potential cause might be the types and mesh sizes of gillnets used in the main spawning/fishing season for cod, compared to the ones used in the mixed fishery in the second half of the year. In quarters 3 and 4, there was a more polarized use of gillnets by the fishers in the CRF in the different years (Figure 4.1). More gillnets with bar length < 70 mm and > 130 mm were used, which will have affected the size distributions of the catches.

There are some weaknesses in the data that needs to be addressed. All the discards from a catch is assumedly length measured. However, it seems probable that this is not always the reality. During the

hauling of the gillnets the fish are removed from the nets and handled continuously as they emerge. Sometimes, if there are several fish in the net within a close distance to each other, the fish are left over water for some time before they are handled. It is therefore possible (and have been observed by the author) that smaller fish are being discarded directly from the gillnet because of their size (possibly under minimum fishing size) and the fact that they are still alive. These are therefore not length measured. Measuring the length takes time, and the fishers will likely be interested in releasing the fish back into the sea quickly to increase its chances of survival. Larger individuals are typically discarded because of damage or reduced quality. As this larger fish is often already dead, the fishers are not in the same haste to discard these individuals. These discards can therefore be length-measured by another member of crew on the vessel (if there is more than one person onboard), or after hauling of the gillnet is over. From the comparison of length distributions, it is apparent that some fish under minimum fishing sizes have been length measured, as there are recorded discards under 30 cm. Still, there might be reasons to suspect that the estimated average length of discarded cod could be a little larger than the real values. If that is the case, it effects the results in two ways. Firstly, the results from comparisons of the size distributions of discarded and landed cod might be somewhat incorrect. Perhaps there is more high grading than what is expected from the figures. Secondly, the final estimates of total quantity of discarded cod in weight can be overestimated. This is if the average individual mean weight of discarded cod, calculated from the length measurements from the CRF, are larger than the real mean (Equation 3 and 4).

The estimations rely on an assumption that the 20 length measurements for landed and discarded cod conducted each week are representative for all the catches. Despite this assumption possibly not being one hundred percent fulfilled, figure 3.11-3.19 give an idea of the general trends in the size distributions of landed and discarded cod in coastal gillnet-fisheries in the study-areas.

4.4 REASONS FOR DISCARDING

Much research state that discards are highly variable, and depend on several factors which again will be different for different fisheries, areas, seasons, vessels, etc. (Morandeau et al. 2014; Rochet & Trenkel 2005; Karp et al. 2019). Morandeau et al. (2014) studied the causes for discarding on vessels fishing with passive gears (i.e. gillnets and longlines) from on-board surveys conducted by scientific observers in the Southern Bay of Biscay. Their results accounted for discard of all species. In the catches with gillnets, around 3 % of the discarded fish were still alive when returned to the sea, 21 % were discarded because of inadequate size for the common market, 19 % because of poor/insufficient quality and around 3 % were under minimum legal sizes. Around 40 % were discarded due to absence of market, no commercial opportunity or unattractive prices (considered irrelevant for this study, as it does not refer to cod) and 15 % of the discard was damaged or had degraded quality because of scavengers or opportunistic predators. Even though the factors determining discards may be different from the Bay of

Biscay to the Norwegian coastal fishery, they give some indications to the behaviour and habits of fishers using passive gears.

The main target species of the fleet in the Bay of Biscay-study (e.g. European hake (*Merluccius merluccius)*, anglerfish (*Lophius budegassa* and *L. piscatorius)*, European sea bass (*Dicentrarchus labrax)*, common sole (*Solea solea)*, turbot (*Scophthalmus maximus)* and Sparidae) differ from the main target species in the fleet used in this study. This might change some of the incentives for discarding. For example, the motivations for high grading might be higher for fishers targeting cod than for fishers targeting the species mentioned above, because of the considerable increase in prices per kg cod with increase in size (Norges Råfisklag, n.d.b).

Valdemarsen & Nakken (2002) stated that the discard from the Norwegian coastal fleet fishing with gillnets first and foremost originate from bad quality, often due to long soak time. Challenging weather conditions (which are common in the studied areas) often prolong the soak time. This may increase the discard rates in two ways. Firstly, if the fish die whilst in the gillnet and are not bled shortly after, the quality of the meat is reduced. Secondly, longer soak time increases the probability of scavenger/predator-attacks. Common scavengers on fish in gillnets along the Norwegian coast are Atlantic hagfish (*Myxine glutinosa*) and isopods/amphipods (e.g. *Tmetonyx cicada*).

Some small individuals of fish that are alive and may survive are discarded. These might be over the minimum fishing size, and discarded because of lower prices, or under the minimum fishing size, and legally discarded. The survival of these individuals over time is uncertain as there is always a risk related to being stuck in the gillnet and the handling when removing the fish from the gillnet. Delayed mortality from discarding can be caused by several stressors and are not always accompanied by visible injury (Davis 2002). Generally, smaller fish show greater discard mortality than larger fish, especially when fishing at deeper waters (Pálsson et al. 2003b; Davis 2002). This indicate that smaller fish generally respond worse to rapid pressure changes than larger individuals.

4.5 RELIABILITY OF THE DATA

There are some uncertainties linked to using self-sampling data, from one section of the fishing fleet, as it relies on an assumption that the section is representative for the entire fishing fleet.

There is a possibility that the behaviour of the fishers in the CRF deviate from the behaviour of the rest of the fleet (Anon. 2011). It is possible that the fishers that apply for the contract with IMR are more likely to follow the regulations, as they might have interests in fisheries biology and conservation. As they are willing to cooperate with scientists, they might be more honest and have different views on discarding than the rest of the fleet. The reliability of the discard-data from the reference fleet has been discussed, and it has been recommended to conduct more validation studies on this topic (Nedreaas et al. 2006). The work that the fishers do in the CRF is paid, and it might have been other things than an

interest in science and management that drove them to apply for the contract. There is also a possibility that the fishers in the CRF can avoid reporting the actual numbers of discard, e.g. they can avoid reporting large discarding events or forget to report. Actions are taken within the Reference Fleet programme to promote reliable reporting. It is stated in the contract between IMR and the vessels that the information collected by the Reference Fleet project is the property of IMR and that the DoF and the Coast Guard have agreed that it shall not be used by these agencies for inspections or enforcements (Anon. 2011). The authorities have so far respected that the data shall only be used for scientific purposes, and this is one of the key elements in the collaboration. The CRF fishers are paid to report complete and correct, and if it had been discovered that reported data were inadequate or wrong, this would be a breach of the contract (Bjørge & Moan 2013).

In the last global assessment of marine fisheries discard (Pérez-Roda et al. 2019) the authors claim that the most reliable way to gather records on discards is through onboard observer programmes, which is the most common practice for obtaining discard data globally. The authors then go on to explain that observer programmes are the most accurate as the fishers might lack time or training in correct sampling and recording, and they may have disincentives to record the real data (Pérez-Roda et al. 2019). Fisheries observer programmes include either human observers onboard fishing vessels or electronic monitoring on the vessels. These programmes are expensive and are linked to their own sets of uncertainties and challenges. It is of my impression that self-sampling of discards, from trained fishers like in the CRF, have the potential of reducing the cost and effort that go into obtaining samples from the fisheries. Involving the fishers in the science and management-aspects of a fishery might have the potential of changing the fishers' perception of the regulations and their utilization of the marine resources.

With these uncertainties in mind, we can suggest that the estimated discard in this thesis is a minimum estimate of the discard for the fishery for cod in the statistical areas 00, 05 and 06 for vessels < 15 m total length, fishing with gillnets. The DoF's surveillance service and the Coast Guard also have data on discards and other cases of irregularities from the fisheries, giving some numbers on "hidden harvest". It is not advised to raise these data to cover whole segments of the fishing fleet, as they may be biased towards exceptional discarding behaviour (Anon. 2011). The inspections are mostly based on tips or observations (from cameras on aircrafts or vessels) and will therefore not represent average discarding events in the fishery. A combination of discard data from the CRF and the DoF/Coast Guard might though provide valuable information.

5 CONCLUSION

- Highly irregular records of discards indicate that it is the result of many factors besides size of catch and effort (i.e. sales notes). With the available data, using the estimated discard ratio per tonne landed catch of cod and per sales note with cod, was considered to be the best methods to scale the number of discards to the entire fishing fleet through the official landing statistics. However, further studies should be conducted on this matter.
- The estimated discard rates per annual quarter were considerably higher for the second half of the year, than for the first. The estimated discard quantities were, however, in many cases higher in the first half of the year when the catches typically consist of more NEA cod. Still, the estimated discard rates in the second half of the year might have larger effects on the total fishing mortality, as these catches predominantly consists of coastal cod. Discards should be incorporated in future assessments and should be included as an element in the rebuilding-plan for the coastal cod stock.
- The estimated annual discard from this study indicate very small-scale discard rates for cod in coastal gillnet-fisheries in the three statistical areas. The additional mortality from the estimated discarding will not affect the stock assessments for cod, as < 1 % is likely to fall within the 95% CIs for the assessments. The recommendation is therefore that it will be enough to monitor the discarding in this fishery with ~5-year intervals.
- There is evidence of high grading, and this evidence is clearer in annual quarter 1 and 2, than in annual quarter 3 and 4.
- It is important to understand more on the underlying factors impacting the sorting process on fishing vessels, which in turn leads to discarding. A suggestion is for the fishers in the CRF to start reporting discarding due to damage, under minimum fishing size, etc. by comments or a set of codes.
- The estimates of discard of cod are linked to a list of assumptions and uncertainties, but this is the first study that uses real fisheries-data to quantify discards in this fishery. Verification-studies of the representativeness of the CRF should be conducted, and more reliable estimates for discard might be obtained in future studies, using more diverse samples and including other fishing gears.

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7 APPENDIX

7.1 DISCARD PER ANNUAL QUARTER, UPSCALED WITH TOTAL WEIGHT

Appendix table 1.a *– Estimated numbers of discard, weight of discard, discard rate (% of total catch) and total catch of cod (tonnes) in 2012, per annual quarter and statistical areas (00, 05 and 06) for vessels < 15 m total length using gillnets. Upscaled with total weight of cod, CIs calculated using two methods.*

Stratum	Estimator	Total catch (tonnes)	Numbers discarded	Weight of discard (tonnes)	Discard rate (%)
00, 1	Ratio Estimator	14 152	17 407 [9 428, 25 386]	66 [37, 99]	0.47 [0.26, 0.69]
	Bootstrap	14 152	17 407 [11 117, 27 806]	66 [43, 108]	0.47 [0.30, 0.76]
00, 3	Ratio Estimator	163	1 866 [478, 3 255]	7 [2, 13]	4.26 [1.09, 7.42]
	Bootstrap	163	1 866 [832, 3 894]	7 [3, 15]	4.26 [1.90, 8.88]
00, 4	Ratio Estimator	110	7 529 [661, 14 398]	29 [3, 56]	21.00 [1.84, 40.15]
	Bootstrap	110	7 529 [4 138, 21 153]	29 [16, 82]	21.00 [11.54, 58.99]
05, 1	Ratio Estimator	18 216	6 855 [3 707, 10 003]	27 [14, 39]	0.15 [0.08, 0.21]
	Bootstrap	18 216	6 855 [4 360, 10 664]	27 [17, 41]	0.15 [0.09, 0.23]
06, 1	Ratio Estimator	2 725	3 363 [1 900, 4 827]	13 [7, 19]	0.48 [0.27, 0.68]
	Bootstrap	2 725	3 363 [2 183, 5 032]	13 [8, 19]	0.48 [0.31, 0.71]
06, 2	Ratio Estimator	822	3 294 [818, 5 771]	13 [3, 22]	1.53 [0.38, 2.68]
	Bootstrap	822	3 294 [1 240, 6 206]	13 [5, 24]	1.53 [0.58, 2.89]
06, 4	Ratio Estimator	48	800 [244, 1 357]	3 [1, 5]	6.08 [1.86, 10.31]
	Bootstrap	48	800 [408, 1 639]	3 [2, 6]	6.08 [3.10, 12.45]

Appendix table 1.b *– Estimated numbers of discard, weight of discard, discard rate (% of total catch) and total catch of cod (tonnes) in 2013, per annual quarter and statistical areas (00, 05 and 06) for vessels < 15 m total length using gillnets. Upscaled with total weight of cod, CIs calculated using two methods.*

Stratum	Estimator	Total catch (tonnes)	Numbers discarded	Weight of discard (tonnes)	Discard rate (%)
00, 1	Ratio Estimator	15 338	12 337 [8 622, 16 052]	412 [29, 54]	0.27 [0.19, 0.35]
	Bootstrap	15 338	12 337 [8 845, 16 348]	42 [30, 55]	0.27 [0.19, 0.36]
00, 2	Ratio Estimator	6 692	9 636 [6 004, 13 269]	33 [20, 45]	0.49 [0.30, 0.67]
	Bootstrap	6 692	9 636 [6 249, 13 333]	33 [21, 45]	0.49 [0.32, 0.67]
00, 3	Ratio Estimator	64.7	4 364 [510, 8 218]	15 [2, 28]	18.65 [2.18, 35.11]
	Bootstrap	64.7	4 364 [1 927, 10 904]	15 [6, 37]	18.65 [8.23, 46.59]
00, 4	Ratio Estimator	255	22 457 [11 262, 33 652]	76 [38, 114]	23.03 [11.55, 34.51]
	Bootstrap	255	22 457 [14 275, 38 524]	76 [48, 131]	23.03 [14.64, 39.51]
05, 1	Ratio Estimator	23 041	61 411 [32 197, 90 624]	209 [109, 308]	0.90 [0.47, 1.32]
	Bootstrap	23 041	61 411 [35 868, 92 394]	209 [122, 314]	0.90 [0.52, 1.35]
05, 2	Ratio Estimator	2 541	113 737 [84 862, 142 613]	386 [288, 485]	13.20 [9.85, 16.55]
	Bootstrap	2 541	113 737[87 772, 141 442]	386 [298, 481]	13.20 [10.19, 16.42]
06, 1	Ratio Estimator	2 184	4 060 [2 360, 5 760]	14 [8, 20]	0.63 [0.37, 0.89]
	Bootstrap	2 184	4 060 [2 557, 5 937]	14 [9, 20]	0.63 [0.39, 0.92]
06, 2	Ratio Estimator	1 072	1 439 [666, 2 213]	5 [2, 7]	0.45 [0.21, 0.70]
	Bootstrap	1 072	1 439 [742, 2 350]	5 [2, 8]	0.45 [0.23, 0.74]
06, 3	Ratio Estimator	34.1	484 [-104, 1 071]	2 [0, 4]	4.60 [-0.99, 10.19]
	Bootstrap	34.1	484 [0, 1 187]	2 [0, 4]	4.60 [0.00, 11.29]
06, 4	Ratio Estimator	46.3	4 053 [2 677, 5 429]	14 [9, 18]	22.93 [15.12, 30.71]
	Bootstrap	46.3	4 053 [2 902, 5 466]	14 [10, 19]	22.93 [16.41, 30.92]

Appendix table 1.c *– Estimated numbers of discard, weight of discard, discard rate (% of total catch) and total catch of cod (tonnes) in 2014, per annual quarter and statistical areas (00, 05 and 06) for vessels < 15 m total length using gillnets. Upscaled with total weight of cod, CIs calculated using two methods.*

Stratum	Estimator	Total catch (tonnes)	Numbers discarded	Weight of discard (tonnes)	Discard rate (%)
00, 1	Ratio Estimator	16 656	14 396 [10 363, 18 430]	22 [16, 28]	0.13 [0.09, 0.17]
	Bootstrap	16 656	14 396 [10 511, 18 580]	22 [16, 28]	0.13 [0.10, 0.17]
00, 2	Ratio Estimator	6 366	13 184 [7 678, 18 690]	20 [12, 29]	0.31 [0.18, 0.45]
	Bootstrap	6 366	13 184 [8 027, 19 003]	20 [12, 29]	0.31 [0.19, 0.45]
00, 4	Ratio Estimator	135	0.00	0.00	0.00
	Bootstrap	135	0.00	0.00	0.00
05, 1	Ratio Estimator	30 718	56 182 [24 151, 88 213]	86 [37, 135]	0.28 [0.12, 0.44]
	Bootstrap	30 718	56 182 [29 211, 90 974]	86 [45, 139]	0.28 [0.15, 0.45]
05, 2	Ratio Estimator	1 346	4 075 [2 145, 2 655]	6 [3, 9]	0.46 [0.24, 0.68]
	Bootstrap	1 346	4 075 [2 655, 7 160]	6 [4, 11]	0.46 [0.30, 0.81]
05, 4	Ratio Estimator	1 550	3 376 [2 109, 4 644]	5 [3, 7]	0.33 [0.21, 0.46]
	Bootstrap	1 550	3 376 [2 190, 4 692]	5 [3, 7]	0.33 [0.21, 0.46]
06, 1	Ratio Estimator	2 307	5 073 [2 325, 7 821]	8 [3, 12]	0.33 [0.15, 0.52]
	Bootstrap	2 307	5 073 [2 858, 8 270]	8 [4, 13]	0.33 [0.19, 0.55]
06, 2	Ratio Estimator	697	3 046 [691, 5 400]	5 [1, 8]	0.66 [0.15, 1.18]
	Bootstrap	697	3 046 [1 310, 6 387]	5 [2, 10]	0.66 [0.28, 1.39]
06, 3	Ratio Estimator	56.4	2 111 [-848, 5 071]	3 [-1, 8]	5.41 [-2.17, 13.00]
	Bootstrap	56.4	2 111 [290, 5 840]	3 [0, 9]	5.41 [0.74, 14.97]

Appendix table 1.d *– Estimated numbers of discard, weight of discard, discard rate (% of total catch) and total catch of cod (tonnes) in 2015, per annual quarter and statistical areas (00, 05 and 06) for vessels < 15 m total length using gillnets. Upscaled with total weight of cod, CIs calculated using two methods.*

Stratum	Estimator	Total catch (tonnes)	Numbers discarded	Weight of discard (tonnes)	Discard rate (%)
00, 1	Ratio Estimator	20 023	15 612 [10 728, 20 496]	36 [25, 48]	0.18 [0.12, 0.24]
	Bootstrap	20 023	15 612 [11 036, 20 448]	36 [26, 48]	0.18 [0.13, 0.24]
00, 2	Ratio Estimator	6 172	39 966 [10 789, 69 142]	93 [25, 161]	1.48 [0.40, 2.57]
	Bootstrap	6 172	39 966[16 225, 79 292]	93 [38, 185]	1.48 [0.60, 2.95]
00, 4	Ratio Estimator	67.1	1 086 [293, 1 880]	2 [1, 4]	3.63 [0.98, 6.28]
	Bootstrap	67.1	1 086 [419, 2 055]	2 [1, 5]	3.63 [1.40, 6.87]
05, 4	Ratio Estimator	1 102	9 357 [5 191, 13 526]	22 [12, 31]	1.94 [1.07, 2.80]
	Bootstrap	1 102	9 357 [6 143, 14620]	22 [14, 34]	1.94 [1.27, 3.03]
06, 1	Ratio Estimator	2 279	3 628 [1 548, 5 708]	8 [4, 6]	0.37 [0.16, 0.58]
	Bootstrap	2 279	3 628 [1 819, 6 103]	8 [4, 14]	0.37 [0.18, 0.62]
06, 2	Ratio Estimator	631	1 123 [216, 2 032]	3 [0, 5]	0.41 [0.08, 0.75]
	Bootstrap	631	1 123 [419, 2 189]	3 [1, 5]	0.41 [0.15, 0.80]

Appendix table 1.e *– Estimated numbers of discard, weight of discard, discard rate (% of total catch) and total catch of cod (tonnes) in 2016, per annual quarter and statistical areas (00, 05 and 06) for vessels < 15 m total length using gillnets. Upscaled with total weight of cod, CIs calculated using two methods.*

Stratum	Estimator	Total catch (tonnes)	Numbers discarded	Weight of discard (tonnes)	Discard rate (%)
00, 1	Ratio Estimator	18 111	9 386 [6 608, 12 164]	28 [20, 37]	0.16 [0.11, 0.20]
	Bootstrap	18 111	9 386 [7 011, 12 403]	28 [21, 37]	0.16 [0.12, 0.21]
00, 2	Ratio Estimator	2 334	23 683 [11 738, 35 627]	72 [35, 108]	2.98 [1.48, 4.48]
	Bootstrap	2 334	23 683 [14 108, 38 908]	72 [43, 118]	2.98 [1.78, 4.90]
00, 3	Ratio Estimator	45.9	1 620 [1 152, 2 088]	5 [3, 6]	9.65 [6.86, 12.44]
	Bootstrap	45.9	1 620 [1 138, 2 096]	5 [3, 6]	9.65 [6.78, 12.49]
00, 4	Ratio Estimator	48.9	2 068 [1 230, 2 907]	6 [4, 9]	11.35 [6.75, 15.95]
	Bootstrap	48.9	2 068 [1 247, 2 951]	6 [4, 9]	11.35 [6.84, 16.20]
05, 1	Ratio Estimator	23 176	22 420 [16 662, 28 178]	68 [50, 85]	0.29 [0.22, 0.37]
	Bootstrap	23 176	22 420 [17 018, 28 505]	68 [51, 86]	0.29 [0.22, 0.37]
05, 2	Ratio Estimator	1 067	263 [-76, 602]	1 [0, 2]	0.07 [-0.02, 0.17]
	Bootstrap	1 067	263 [0, 726]	1 [0, 2]	0.07 [0.00, 0.21]
06, 1	Ratio Estimator	2 243	4 094 [1 610, 6 579]	12 [5, 20]	0.55 [0.22, 0.88]
	Bootstrap	2 243	4 094 [2 354, 7 829]	12 [7, 24]	0.55 [0.32, 1.05]
06, 2	Ratio Estimator	531	5 518 [3 300, 7 736]	17 [10, 23]	3.05 [1.82, 4.28]
	Bootstrap	531	5 518 [3 566, 7 893]	17 [11, 24]	3.05 [1.97, 4.36]
06, 3	Ratio Estimator	61.5	1 843 [462, 3 224]	6 [1, 10]	8.32 [2.08, 14.55]
	Bootstrap	61.5	1 843 [856, 3 708]	6 [3, 11]	8.32 [3.86, 16.74]

Appendix table 1.f *– Estimated numbers of discard, weight of discard, discard rate (% of total catch) and total catch of cod (tonnes) in 2017, per annual quarter and statistical areas (00, 05 and 06) for vessels < 15 m total length using gillnets. Upscaled with total weight of cod, CIs calculated using two methods.*

Stratum	Estimator	Total catch (tonnes)	Numbers discarded	Weight of discard (tonnes)	Discard rate (%)
00, 1	Ratio Estimator	20 129	17 484 [10 696, 24 271]	60 [37, 84]	0.30 [0.18, 0.41]
	Bootstrap	20 129	17 484 [11 179, 24 524]	60 [38, 84]	0.30 [0.19, 0.42]
00, 2	Ratio Estimator	3 348	62 876 [39 000, 86 753]	217 [134, 299]	6.08 [3.77, 8.39]
	Bootstrap	3 348	62 876 [41 681, 87 148]	217 [144, 300]	6.08 [4.03, 8.42]
00, 3	Ratio Estimator	38.9	2 419 [1 460, 3 372]	8 [5, 12]	17.63 [10.65, 24.60]
	Bootstrap	38.9	2 419 [1 561, 3 497]	8 [5, 12]	17.63 [11.39, 25.52]
00, 4	Ratio Estimator	41.0	3 466 [653, 6 278]	12 [2, 22]	22.56 [4.25, 40.87]
	Bootstrap	41.0	3 466 [2 194, 5 085]	12 [8, 17]	22.56 [14.28, 33.10]
05, 1	Ratio Estimator	21 069	28 413 [20 194, 36 633]	98 [70, 126]	0.46 [0.33, 0.60]
	Bootstrap	21 069	28 413 [21 034, 37 872]	98 [72, 130]	0.46 [0.34, 0.62]
05, 2	Ratio Estimator	2 247	1 097 [756, 1 438]	4 [3, 5]	0.17 [0.12, 0.22]
	Bootstrap	2 247	1 097 [748, 1 404]	4 [3, 5]	0.17 [0.11, 0.21]
06, 1	Ratio Estimator	1 410	1 478 [333, 2 622]	5 [1, 9]	0.36 [0.08, 0.64]
	Bootstrap	1 410	1 478 [636, 2 823]	5 [2, 10]	0.36 [0.15, 0.69]
06, 2	Ratio Estimator	449	2 602 [914, 4 289]	9 [3, 15]	1.96 [0.69, 3.23]
	Bootstrap	449	2 602 [1 140, 4 445]	9 [4, 15]	1.96 [0.86, 3.34]

Appendix table 1.g *– Estimated numbers of discard, weight of discard, discard rate (% of total catch) and total catch of cod (tonnes) in 2018, per annual quarter and statistical areas (00, 05 and 06) for vessels < 15 m total length using gillnets. Upscaled with total weight of cod, CIs calculated using two methods.*

Stratum	Estimator	Total catch (tonnes)	Numbers discarded	Weight of discard (tonnes)	Discard rate (%)
00, 1	Ratio Estimator	19 589	15 796 [10 864, 20 727]	44 [30, 58]	0.23 [0.16, 0.30]
	Bootstrap	19 589	15 796 [11 441, 21 353]	44 [32, 60]	0.23 [0.16, 0.31]
00, 2	Ratio Estimator	1 912	1 544 [572, 2 515]	4 [2, 7]	0.23 [0.08, 0.37]
	Bootstrap	1 912	1 544 [813, 2 980]	4 [2, 8]	0.23 [0.12, 0.44]
00, 3	Ratio Estimator	26.8	1 656 [1 282, 2 029]	5 [4, 6]	14.80 [11.46, 18.14]
	Bootstrap	26.8	1 656 [1 288, 2 075]	5 [4, 6]	14.80 [11.51, 18.55]
00, 4	Ratio Estimator	51.1	2 676 [2 017, 3 335]	7 [6, 9]	12.83 [9.67, 15.99]
	Bootstrap	51.1	2 676 [2 010, 3 434]	7 [6, 10]	12.83 [9.64, 16.47]
05, 1	Ratio Estimator	22 820	23 165 [13 680, 32 650]	65 [38, 92]	0.28 [0.17, 0.40]
	Bootstrap	22 820	23 165 [15 392, 35 010]	65 [43, 98]	0.28 [0.19, 0.43]
06, 1	Ratio Estimator	1 435	2 201 [1 160, 3 243]	6 [3, 9]	0.43 [0.23, 0.63]
	Bootstrap	1 435	2 201 [1 418, 3 665]	6 [4, 10]	0.43 [0.28, 0.71]
06, 2	Ratio Estimator	587	1 476 [776, 2 176]	4 [2, 6]	0.70 [0.37, 1.03]
	Bootstrap	587	1 476 [742, 2 152]	4 [2, 6]	0.70 [0.35, 1.02]

7.2 DISCARD PER ANNUAL QUARTER, UPSCALED WITH SALES NOTES

Appendix table 2.a *– Estimated numbers of discard, weight of discard, discard rate (% of total catch) and total number of sales notes with cod in 2012, per annual quarter and statistical areas (00, 05 and 06) for vessels < 15 m total length using gillnets. Upscaled with total sales notes with cod, CIs calculated using two methods.*

Stratum	Estimator	Total no. Sales notes	Numbers discarded	Weight of discard (tonnes)	Discard rate (%)
00, 1	Arithmetic	7 158	45 269 [39 737, 50 802]	176 [154, 197]	1.23 [1.08, 1.38]
	Bootstrap	7 158	45 269 [34 825, 56 582]	176 [135, 220]	1.23 [0.94, 1.53]
05, 1	Arithmetic	6 644	13 661 [10 936, 16 385]	53 [42, 61]	0.29 [0.23, 0.33]
	Bootstrap	6 644	13 661 [9 254, 19 185]	53 [36, 74]	0.29 [0.20, 0.41]
06, 1	Arithmetic	3 622	8 504 [7 190, 9 818]	33 [28, 38]	1.20 [1.01, 1.38]
	Bootstrap	3 622	8 504 [6 063, 10 984]	33 [23, 43]	1.20 [0.85, 1.55]
06, 2	Arithmetic	2 486	2 387 [1 411, 3 362]	9 [5, 13]	1.11 [0.66, 1.57]
	Bootstrap	2 486	2 387 [796, 4 276]	9 [3, 17]	1.11 [0.37, 2.00]

Appendix table 2.b *– Estimated numbers of discard, weight of discard, discard rate (% of total catch) and total number of sales notes with cod in 2013, per annual quarter and statistical areas (00, 05 and 06) for vessels < 15 m total length using gillnets. Upscaled with total sales notes with cod, CIs calculated using two methods.*

Stratum	Estimator	Total no. Sales notes	Numbers discarded	Weight of discard (tonnes)	Discard rate (%)
00, 1	Arithmetic	6 989	28 990 [24 117, 33 862]	98 [82, 115]	0.64 [0.53, 0.74]
	Bootstrap	6 989	28 989 [19 983, 39 572]	98 [68, 134]	0.64 [0.44, 0.87]
00, 2	Arithmetic	3 405	11 960 [9 489, 14 431]	41 [32, 49]	0.60 [0.48, 0.73]
	Bootstrap	3 405	11 960 [7 322, 16 556]	41 [25, 56]	0.60 [0.37, 0.84]
00, 3	Arithmetic	429	759 [590, 928]	3 [2, 3]	3.83 [2.98, 4.69]
	Bootstrap	429	759 [429, 1089]	3 [2, 4]	3.83 [2.17, 5.50]
00, 4	Arithmetic	886	3 159 [2 651, 3 668]	11 [9, 13]	4.04 [3.39, 4.69]
	Bootstrap	886	3 159 [2 227, 4 162]	11 [8, 14]	4.04 [2.85, 5.32]
05, 1	Arithmetic	7 526	68 434 [45 696, 91 172]	232 [115, 310]	1.00 [0.67, 1.33]
	Bootstrap	7 526	68 434 [29 929, 113 586]	232 [102, 386]	1.00 [0.44, 1.66]
06, 1	Arithmetic	2 290	10 944 [8 756, 13 132]	37 [30, 45]	1.68 [1.34, 2.01]
	Bootstrap	2 290	10 944 [6 923, 15 710]	37 [23, 53]	1.68 [1.06, 2.40]
06, 2	Arithmetic	2 150	1 286 [966, 1 606]	4 [3, 5]	0.41 [0.30, 0.51]
	Bootstrap	2 150	1 286 [675, 1 960]	4 [2, 7]	0.41 [0.21, 0.62]
06, 3	Arithmetic	686	161 [68, 255]	1 [0, 1]	1.26 [0.53, 1.98]
	Bootstrap	686	161 [0, 363]	1 [0, 1]	1.26 [0.00, 2.83]
06, 4	Arithmetic	785	1 020 [853, 1 188]	3 [3, 4]	6.97 [5.82, 8.11]
	Bootstrap	785	1 020 [785, 1 334]	3 [3, 4]	6.97 [5.36, 9.11]

Appendix table 2.c *– Estimated numbers of discard, weight of discard, discard rate (% of total catch) and total number of sales notes with cod in 2014, per annual quarter and statistical areas (00, 05 and 06) for vessels < 15 m total length using gillnets. Upscaled with total sales notes with cod, CIs calculated using two methods.*

Stratum	Estimator	Total no. sales notes	Numbers discarded	Weight of discard (tonnes)	Discard rate (%)
00, 1	Arithmetic	7 583	28 566 [24 068, 33 064]	44 [37, 50]	0.26 [0.22, 0.30]
	Bootstrap	7 583	28 566 [20 256, 37 342]	44 [31, 57]	0.26 [0.18, 0.34]
00, 2	Arithmetic	2 796	22 767 [18 451, 27 084]	35 [28, 41]	0.54 [0.44, 0.65]
	Bootstrap	2 796	22 767 [14 379, 30 956]	35 [22, 47]	0.54 [0.34, 0.74]
05, 1	Arithmetic	9 390	45 877 [33 596, 58 158]	70 [51, 89]	0.23 [0.17, 0.29]
	Bootstrap	9 390	45 877 [23 073, 71 364]	70 [35, 109]	0.23 [0.11, 0.35]
05, 2	Arithmetic	957	1862 [1570, 2154]	3 [2, 3]	0.21 [0.18, 0.24]
	Bootstrap	957	1862 [1267, 2482]	3 [2, 4]	0.21 [0.14, 0.28]
05, 4	Arithmetic	3 002	7 204 [5 613, 8 796]	11 [9, 13]	0.70 [0.55, 0.86]
	Bootstrap	3 002	7 205 [4 289, 10 464]	11 [6, 16]	0.70 [0.42, 1.02]
06, 1	Arithmetic	2 378	13 694 [10 208, 17 180]	21 [16, 26]	0.90 [0.67, 1.13]
	Bootstrap	2 378	13 694 [7 708, 20 910]	21 [12, 32]	0.90 [0.51, 1.37]
06, 2	Arithmetic	1 719	1 910 [1 265, 2 554]	3 [2, 4]	0.42 [0.28, 0.58]
	Bootstrap	1 719	1 910 [828, 3 183]	3 [2, 5]	0.42 [0.18, 0.69]
06, 3	Arithmetic	702	2574 [758, 4390]	4 [1, 7]	6.52 [1.92, 11.12]
	Bootstrap	702	2574 [364, 6370]	4 [1, 10]	6.52 [0.92, 16.13]

Appendix table 2.d *– Estimated numbers of discard, weight of discard, discard rate (% of total catch) and total number of sales notes with cod in 2015, per annual quarter and statistical areas (00, 05 and 06) for vessels < 15 m total length using gillnets. Upscaled with total sales notes with cod, CIs calculated using two methods.*

Stratum	Estimator	Total no. sales notes	Numbers discarded	Weight of discard (tonnes)	Discard rate (%)
00, 1	Arithmetic	7 894	24 980 [19 010, 30 949]	58 [44, 72]	0.29 [0.22, 0.36]
	Bootstrap	7 894	24 980 [14 601, 38 170]	58 [34, 89]	0.29 [0.17, 0.44]
00, 2	Arithmetic	3 397	2 874 [1 901, 3 848]	7 [4, 9]	0.11 [0.07, 0.14]
	Bootstrap	3 397	2 874 [1 176, 4 965]	7 [3, 12]	0.11 [0.04, 0.19]
00, 4	Arithmetic	840	349 [177, 520]	1 [0, 1]	1.19 [0.61, 1.78]
	Bootstrap	840	349 [79, 729]	1 [0, 2]	1.19 [0.27, 2.50]
05, 4	Arithmetic	1 882	13 516 [11 767, 15 266]	31 [27, 35]	2.78 [2.42, 3.13]
	Bootstrap	1 882	13 516 [10 094, 16 767]	31 [23, 39]	2.78 [2.07, 3.44]
06, 1	Arithmetic	7 582	36 921 [26 694, 47 148]	86 [62, 110]	3.63 [2.63, 4.64]
	Bootstrap	7 582	36 921 [19 128, 57 681]	86 [44, 134]	3.63 [1.88, 5.68]
06, 2	Arithmetic	1 576	788 [448, 1 128]	2 [1, 3]	0.29 [0.16, 0.41]
	Bootstrap	1 576	788 [215, 1 504]	2 [0, 3]	0.29 [0.08, 0.55]

Appendix table 2.e *– Estimated numbers of discard, weight of discard, discard rate (% of total catch) and total number of sales notes with cod in 2016, per annual quarter and statistical areas (00, 05 and 06) for vessels < 15 m total length using gillnets. Upscaled with total sales notes with cod, CIs calculated using two methods.*

Stratum	Estimator	Total no. sales notes	Numbers discarded	Weight of discard (tonnes)	Discard rate (%)
00, 1	Arithmetic	10 059	8 876 [7 577, 10 174]	27 [23, 31]	0.15 [0.13, 0.17]
	Bootstrap	10 059	8 876 [6 401, 11 404]	27 [19, 34]	0.15 [0.11, 0.19]
00, 2	Arithmetic	2 152	2 827 [2 336, 3 319]	9 [7, 10]	0.36 [0.30, 0.43]
	Bootstrap	2 152	2 827 [1 899, 3 755]	9 [6, 11]	0.36 [0.24, 0.48]
00, 3	Arithmetic	417	1001 [808, 1193]	3 [2, 4]	6.19 [5.00, 7.38]
	Bootstrap	417	1001 [634, 1401]	3 [2, 4]	6.19 [3.92, 8.67]
00, 4	Arithmetic	773	185 [119, 251]	1 [0, 1]	1.13 [0.73, 1.54]
	Bootstrap	773	185 [72, 322]	1 [0, 1]	1.13 [0.44, 1.97]
05, 1	Arithmetic	9 219	18 400 [15 614,21 186]	56 [47, 64]	0.24 [0.20, 0.28]
	Bootstrap	9 219	18 400 [13 376, 23 991]	56 [40, 73]	0.24 [0.17, 0.31]
06, 1	Arithmetic	2 566	20 679 [12 528, 30 490]	63 [49, 76]	2.72 [2.12, 3.31]
	Bootstrap	2 566	20 679 [12 528, 30 490]	63 [38, 92]	2.72 [1.65, 4.00]
06, 3	Arithmetic	904	1 537 [862, 2 211]	5 [3, 7]	7.03 [3.95, 10.12]
	Bootstrap	904	1 537 [452, 2 893]	5 [1, 9]	7.03 [2.07, 13.24]

Appendix table 2.f *– Estimated numbers of discard, weight of discard, discard rate (% of total catch) and total number of sales notes with cod in 2017, per annual quarter and statistical areas (00, 05 and 06) for vessels < 15 m total length using gillnets. Upscaled with total sales notes with cod, CIs calculated using two methods.*

Stratum	Estimator	Total no. sales notes	Numbers discarded	Weight of discard (tonnes)	Discard rate (%)
00, 1	Arithmetic	9 868	17 804 [13 414, 22 194]	61 [46, 76]	0.30 [0.23, 0.38]
	Bootstrap	9 868	17 804 [10 107, 27 344]	61 [35, 94]	0.30 [0.17, 0.47]
00, 2	Arithmetic	2 216	2 908 [1 903, 3 914]	10 [7, 13]	0.30 [0.20, 0.40]
	Bootstrap	2 216	2 908 [1 246, 5 124]	10 [4, 18]	0.30 [0.13, 0.53]
00, 3	Arithmetic	543	989 [614, 1 364]	3 [2, 5]	8.06 [5.00, 11.11]
	Bootstrap	543	989 [368, 1 823]	3 [1, 6]	8.06 [3.00, 14.85]
00, 4	Arithmetic	716	609 [354, 863]	2 [1, 3]	4.87 [2.83, 6.90]
	Bootstrap	716	609 [215, 1 163]	2 [1, 4]	4.87 [1.72, 9.30]
05, 1	Arithmetic	6 881	20 805 [18 116, 23 494]	72 [62, 81]	0.34 [0.30, 0.38]
	Bootstrap	6 881	20 805 [15 775, 26 257]	72 [54, 90]	0.34 [0.26, 0.43]
06, 1	Arithmetic	2 455	7 949 [4 736, 11 163]	27 [16, 38]	1.91 [1.14, 2.68]
	Bootstrap	2 455	7 949 [3 156, 15 198]	27 [11, 52]	1.91 [0.76, 3.64]
06, 2	Arithmetic	1 507	937 [649, 1 225]	3 [2, 4]	0.71 [0.49, 0.93]
	Bootstrap	1 507	937 [448, 1 548]	3 [1, 5]	0.71 [0.34, 1.18]

Appendix table 2.g *– Estimated numbers of discard, weight of discard, discard rate (% of total catch) and total number of sales notes with cod in 2018, per annual quarter and statistical areas (00, 05 and 06) for vessels < 15 m total length using gillnets. Upscaled with total sales notes with cod, CIs calculated using two methods.*

Stratum	Estimator	Total no. sales notes	Numbers discarded	Weight of discard (tonnes)	Discard rate (%)
00, 1	Arithmetic	9 938	11 364 [9 726, 13 002]	32 [27, 37]	0.16 [0.14, 0.19]
	Bootstrap	9 938	11 364 [8 447, 14 885]	32 [24, 42]	0.16 [0.12, 0.21]
00, 2	Arithmetic	1 484	599 [460, 737]	2 [1, 2]	0.09 [0.07, 0.11]
	Bootstrap	1 484	599 [338, 885]	2 [1, 2]	0.09 [0.05, 0.13]
00, 3	Arithmetic	413	706 [576, 836]	2 [2, 2]	6.90 [5.63, 8.18]
	Bootstrap	413	706 [480, 986]	2 [1, 3]	6.90 [4.69, 9.64]
00, 4	Arithmetic	855	641 [528, 755]	2 [1, 2]	3.41 [2.81, 4.01]
	Bootstrap	855	641 [437, 874]	2 [1, 2]	3.41 [2.32, 4.65]
05, 1	Arithmetic	8 326	21 349 [17 624, 25 073]	60 [50, 71]	0.26 [0.22, 0.31]
	Bootstrap	8 326	21 349 [15 030, 29 519]	60 [42, 83]	0.26 [0.18, 0.36]
06, 1	Arithmetic	2 639	8 172 [7 103, 9 242]	23 [20, 26]	1.58 [1.37, 1.78]
	Bootstrap	2 639	8 172 [6 300, 10 386]	23 [18, 29]	1.58 [1.22, 2.01]
06, 2	Arithmetic	1 959	1 331 [850, 1 811]	4 [2, 5]	0.63 [0.41, 0.86]
	Bootstrap	1 959	1 331 [517, 2 255]	4 [1, 6]	0.63 [0.25, 1.07]

7.3 DISCARD RATES, PER STATISTICAL AREA AND ANNUAL QUARTER

Appendix table 3.a *– Estimated discard rates (% of total catch of cod) for cod per stratum (statistical area, annual quarter) when upscaling with total weight from 2012-2018, for vessels < 15 m total length, using gillnets. CIs were calculated using the Ratio Estimator*

Stratum							
	2012	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
00, 1	0.47 [0.26, 0.69]	0.27 [0.19, 0.35]	0.13 [0.09, 0.17]	0.18 [0.12, 0.24]	0.16 [0.11, 0.20]	0.30 [0.18, 0.41]	0.23 [0.16, 0.30]
00, 2		0.49 [0.30, 0.67]	0.31 [0.18, 0.45]	1.48 [0.40, 2.57]	2.98 [1.48, 4.48]	6.08 [3.77, 8.39]	0.23 [0.08, 0.37]
00, 3	4.26 [1.09, 7.42]	18.65 [2.18, 35.11]			9.65 [6.86, 12.44]	17.63 [10.65, 24.60]	14.80 [11.46, 18.14]
00, 4	21.00 [1.84, 40.15]	23.03 [11.55, 34.51]	0.00	3.63 [0.98, 6.28]	11.35 [6.75, 15.95]	22.56 [4.25, 40.87]	12.83 [9.67, 15.99]
05, 1	0.15 [0.08, 0.21]	0.90 [0.47, 1.32]	0.28 [0.14, 0.45]		0.29 [0.22, 0.37]	0.46 [0.33, 0.60]	0.28 [0.17, 0.40]
05, 2		13.20 [9.85, 16.55]	0.46 [0.24, 0.68]		0.07 [-0.02, 0.17]	0.17 [0.12, 0.22]	
05, 4			0.33 [0.21, 0.46]	1.94 [1.07, 2.80]			
06, 1	0.48 [0.27, 0.68]	0.63 [0.37, 0.89]	0.33 [0.15, 0.52]	0.37 [0.16, 0.58]	0.55 [0.22, 0.88]	0.36 [0.08, 0.64]	0.43 [0.23, 0.63]
06, 2	1.53 [0.38, 2.68]	0.45 [0.21, 0.70]	0.66 [0.15, 1.18]	0.41 [0.08, 0.75]	3.05 [1.82, 4.28]	1.96 [0.69, 3.23]	0.70 [0.37, 1.03]
06, 3		4.60 [-0.99, 10.19]	5.41 [-2.17, 13.00]		8.32 [2.08, 14.55]		
06, 4	6.08 [1.86, 10.31]	22.93 [15.12, 30.71]					

Appendix table 3.b *– Estimated discard rates (% of total catch of cod) for cod per stratum (statistical area, annual quarter) when upscaling with total weight from 2012-2018, for vessels < 15 m total length, using gillnets. CIs were calculated using the Bootstrap method.*

Stratum							
	2012	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
00, 1	0.47 [0.30, 0.76]	0.27 [0.19, 0.36]	0.13 [0.09, 0.17]	0.18 [0.13, 0.24]	0.16 [0.12, 0.21]	0.30 [0.19, 0.42]	0.23 [0.16, 0.31]
00, 2		0.49 [0.30, 0.67]	0.31 [0.19, 0.45]	1.48 [0.60, 2.95]	2.98 [1.78, 4.90]	6.08 [4.03, 8.42]	0.23 [0.12, 0.44]
00, 3	4.26 [1.90, 8.88]	18.65 [8.23, 46.59]			9.65 [6.78, 12.49]	17.63 [11.39, 25.52]	14.80 [11.51, 18.55]
00, 4	21.00 [11.54, 58.99]	23.03 [14.64, 39.51]	0.00	11.35 [6.84, 16.20]	12.17 [7.55, 17.78]	22.56 [14.28, 33.10]	12.83 [9.64, 16.47]
05, 1	0.15 [0.09, 0.23]	0.90 [0.52, 1.35]	0.33 [0.15, 0.52]		0.49 [0.37, 0.61]	0.46 [0.34, 0.62]	0.28 [0.19, 0.43]
05, 2		13.20 [10.19, 16.42]	0.46 [0.30, 0.81]		0.07 [0.00, 0.21]	0.17 [0.11, 0.21]	
05, 4			0.33 [0.21, 0.46]	1.94 [1.27, 3.03]			
06, 1	0.48 [0.31, 0.71]	0.63 [0.39, 0.92]	0.33 [0.19, 0.55]	0.37 [0.16, 0.62]	0.55 [0.32, 1.05]	0.36 [0.15, 0.69]	0.43 [0.28, 0.71]
06, 2	1.53 [0.58, 2.89]	0.45 [0.23, 0.74]	0.66 [0.28, 1.39]	0.41 [0.15, 0.80]	3.05 [1.97, 4.36]	1.96 [0.86, 3.34]	0.70 [0.35, 1.02]
06, 3		4.60 [0.00, 11.29]	5.41 [0.74, 14.97]		8.32 [3.86, 16.74]		
06, 4	6.08 [3.10, 12.45]	22.93 [16.41, 30.92]					

Appendix table 3.c *– Estimated discard rates (% of total catch of cod) for cod per stratum (statistical area, annual quarter) when upscaling with sales notes, from 2012-2018, for vessels < 15 m total length, using gillnets. CIs were calculated arithmetically (SE).*

Stratum							
	2012	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
00, 1	1.23 [1.08, 1.38]	0.64 [0.53, 0.74]	0.26 [0.22, 0.30]	0.29 [0.22, 0.36]	0.15 [0.13, 0.17]	0.30 [0.23, 0.38]	0.16 [0.14, 0.19]
00, 2		0.60 [0.48, 0.73]	0.54 [0.44, 0.65]	0.11 [0.07, 0.14]	0.36 [0.30, 0.43]	0.30 [0.20, 0.40]	0.09 [0.07, 0.11]
00, 3		3.83 [2.98, 4.69]			6.19 [5.00, 7.38]	8.06 [5.00, 11.11]	6.90 [5.63, 8.18]
00, 4		4.04 [3.39, 4.69]		1.19 [0.61, 1.78]	1.13 [0.73, 1.54]	4.87 [2.83, 6.90]	3.41 [2.81, 4.01]
05, 1	0.29 [0.23, 0.33]	1.00 [0.67, 1.33]	0.23 [0.17, 0.29]		0.24 [0.20, 0.28]	0.34 [0.30, 0.38]	0.26 [0.22, 0.31]
05, 2			0.21 [0.18, 0.24]				
05, 4			0.70 [0.55, 0.86]	2.78 [2.42, 3.13]			
06, 1	1.20 [1.01, 1.38]	1.68 [1.34, 2.85]	0.90 [0.67, 1.13]	3.63 [2.26, 4.64]	2.72 [2.12, 3.31]	1.91 [1.14, 2.68]	1.58 [1.37, 1.78]
06, 2	1.11 [0.66, 1.57]	0.41 [0.30, 0.51]	0.42 [0.28, 0.58]	0.29 [0.16, 0.41]		0.71 [0.49, 0.93]	0.63 [0.41, 0.86]
06, 3		1.26 [0.53, 1.98]	6.52 [1.92, 11.12]		7.03 [3.95, 10.12]		
06, 4		6.97 [5.82, 8.11]					

Appendix table 3.d *– Estimated discard rates (% of total catch of cod) for cod per stratum (statistical area, annual quarter) when upscaling with sales notes, from 2012-2018, for vessels < 15 m total length, using gillnets. CIs were calculated using the Bootstrap method*

Stratum							
	2012	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
00, 1	1.23 [0.94, 1.53]	0.64 [0.44, 0.87]	0.26 [0.18, 0.34]	0.29 [0.17, 0.44]	0.15 [0.11, 0.19]	0.30 [0.17, 0.47]	0.16 [0.12, 0.21]
00, 2		0.60 [0.37, 0.84]	0.54 [0.34, 0.74]	0.11 [0.04, 0.19]	0.36 [0.24, 0.48]	0.30 [0.13, 0.53]	0.09 [0.05, 0.13]
00, 3		3.83 [2.17, 5.50]			6.19 [3.92, 8.67]	8.06 [3.00, 14.85]	6.90 [4.69, 9.64]
00, 4		4.04 [2.85, 5.32]		1.19 [0.27, 2.50]	1.13 [0.44, 1.97]	4.87 [1.72, 9.30]	3.41 [2.32, 4.65]
05, 1	0.29 [0.20, 0.41]	1.00 [0.44, 1.66]	0.23 [0.11, 0.35]		0.24 [0.17, 0.31]	0.34 [0.26, 0.43]	0.26 [0.18, 0.36]
05, 2			0.21 [0.14, 0.28]				
05, 4			0.70 [0.42, 1.02]	2.78 [2.07, 3.44]			
06, 1	1.20 [0.85, 1.55]	1.68 [1.06, 2.40]	0.90 [0.51, 1.37]	3.63 [1.88, 5.68]	2.72 [1.65, 4.00]	1.91 [0.76, 3.64]	1.58 [1.22, 2.01]
06, 2	1.11 [0.37, 2.00]	0.41 [0.21, 0.62]	0.42 [0.18, 0.69]	0.29 [0.08, 0.55]		0.71 [0.34, 1.18]	0.63 [0.25, 1.07]
06, 3			6.52 [0.92, 16.13]		7.03 [2.07, 13.24]		
06, 4		6.97 [5.36, 9.11]					

7.4 ANNUAL ESTIMATES OF DISCARD

Appendix table 4.a *– p-values from a poisson regression: Relationship between number of discarded cod and size of catch of cod in the statistical area 00, 05 and 06 for vessels < 15 m total length, using gillnets.*

Year	p-value	Average no. discards per catch	Average weight of catch (tonnes)
2012	0.55	2.43	2.87
2013	< 0.001	3.71	2.02
2014	< 0.001	3.05	1.90
2015	< 0.001	2.49	1.88
2016	< 0.001	1.56	1.20
2017	< 0.001	1.88	1.39
2018	0.09	1.28	1.04

Appendix table 4.b *– Annual estimated numbers of discard, mean individual weight of discard, total weight of discard and discard rate (%) of cod in the statistical areas 00, 05 and 06 for vessels < 15 m total length using gillnets from 2012-2018. Discard upscaled with the total weight of landed cod, and CIs established using the Ratio Estimator and the Bootstrap-method.*

Year	Estimator	No. Discard	Mean weight of individual discard (kg)	Total weight of discard (tonnes)	Total weight of landed cod (tonnes)	Discard rate for cod (%)
2012	Ratio Estimator	37 686 [27 827, 47 545]	3.88	146 [108, 184]	44 549	0.33 [0.24, 0.41]
	Bootstrap	37 686 [29 221, 48 647]	3.88	146 [113, 189]	44 549	0.33 [0.25, 0.42]
2013	Ratio Estimator	97 915 [76 727, 119 102]	3.40	333 [261, 405]	53 147	0.62 [0.49, 0.76]
	Bootstrap	97 915 [79 532, 119 829]	3.40	333 [270, 407]	53 147	0.62 [0.51, 0.76]
2014	Ratio Estimator	96 823 [76 020, 117 626]	1.53	148 [116, 180]	60 207	0.24 [0.19, 0.30]
	Bootstrap	96 823 [77 581, 119 922]	1.53	148 [119, 183]	60 207	0.24 [0.20, 0.30]
2015	Ratio Estimator	72 467 [56 810, 88 125]	2.33	169 [132, 205]	54 654	0.31 [0.24, 0.37]
	Bootstrap	72 467 [58 251, 89 627]	2.33	169 [136, 209]	54 654	0.31 [0.25, 0.38]
2016	Ratio Estimator	61 086 [50 7812, 71 391]	3.03	185 [154, 216]	48 399	0.38 [0.32, 0.44]
	Bootstrap	61 086 [51 796, 71 860]	3.03	185 [157, 218]	48 399	0.38 [0.32, 0.45]
2017	Ratio Estimator	66 252 [53 601, 78 904]	3.45	228 [185, 272]	49 082	0.46 [0.37, 0.55]
	Bootstrap	66 252 [54 714, 80 158]	3.45	228 [189, 276]	49 082	0.46 [0.38, 0.56]
2018	Ratio Estimator	60 116 [49 020, 71 212]	2.81	169 [138, 200]	48 739	0.35 [0.28, 0.41]
	Bootstrap	60 116 [49 868, 71 934]	2.81	169 [140, 202]	48 739	0.35 [0.29, 0.41]

Appendix table 4.c *– Annual estimated numbers of discard, mean individual weight of discard, total number of sales notes and discard rate for cod in the statistical areas 00, 05 and 06, for vessels < 15 m total length using gillnets, from 2012-2018. Discard upscaled using total number of sales notes and CIs established using standard deviation.*

Year	Total no. sales notes	No. discard	Mean weight of individual discard (kg)	Total weight of discard (tonnes)	Discard rate for cod (%)
2012	32 256	84 270 ± 242 114	3.88	327 ± 940	0.73 ± 2.09
2013	29 952	111 919 ± 508 038	3.40	380 ± 1 726	0.71 ± 3.22
2014	31 663	108 260 ± 405 194	1.53	165 ± 619	0.27 ± 1.03
2015	29 684	74 210 ± 295 161	2.33	173 ± 687	0.31 ± 1.25
2016	31 907	48 743 ± 188 071	3.03	148 ± 569	0.30 ± 1.17
2017	29 500	58 294 ± 270 676	3.45	201 ± 933	0.41 ± 1.90
2018	30 898	39 318 ±148 719	2.81	111 ± 419	0.23 ± 0.86

Appendix table 4.d *– Annual estimated numbers of discard, mean individual weight of discard, total number of sales notes and discard rate (%) for cod in the statistical areas 00, 05 and 06, for vessels < 15 m total length using gillnets, from 2012-2018. Discard upscaled using total number of sales notes and CIs calculated arithmetically (SE = sd/(sqrt(n))).*

Year	Total no. sales notes	No. discard	Mean individual weight of discard (kg)	Total weight of discard (tonnes)	Discard rate (% weight of total catch of cod)
2012	32 256	84 270 [76 306, 92 235]	3.88	327 [296, 358]	0.73 [0.66, 0.80]
2013	29 952	111 919 [95 980, 127 857]	3.40	380 [326, 434]	0.71 [0.61, 0.81]
2014	31 663	108 260 [96 621, 119 899]	1.53	165 [148, 183]	0.27 [0.24, 0.30]
2015	29 684	74 210 [64 436, 83 984]	2.33	173 [150, 195]	0.31 [0.27, 0.36]
2016	31 907	48 743 [44 405, 53 081]	3.03	148 [134, 161]	0.30 [0.28, 0.33]
2017	29 500	58 294 [51 675, 64 913]	3.45	201 [178, 224]	0.41 [0.36, 0.45]
2018	30 898	39 318 [36 085, 42 552]	2.81	111 [102, 120]	0.23 [0.21, 0.24]

Appendix table 4.e *– Annual estimated numbers of discard, mean individual weight of discard, total number of sales notes and discard rate (%) for cod in the statistical areas 00, 05 and 06, for vessels < 15 m total length using gillnets, from 2012-2018. Discard upscaled using total number of sales notes and CIs calculated using the Bootstrap method.*

Year	Total no. sales notes	No. discard	Mean individual weight of discard (kg)	Total weight of discard (tonnes)	Discard rate (% weight of total catch of cod)
2012	32 256	84 270 [69 399, 100 257]	3.88	327 [269, 389]	0.73 [0.60, 0.87]
2013	29 952	111 919 [86 606, 142 402]	3.40	380 [294, 484]	0.71 [0.55, 0.90]
2014	31 663	108 260 [87 623, 133 026]	1.53	165 [134, 203]	0.27 [0.22, 0.34]
2015	29 684	74 210 [55 853, 94 520]	2.33	173 [130, 220]	0.31 [0.2 4, 0.40]
2016	31 907	48 743 [40 801, 57 499]	3.03	148[123, 174]	0.30 [0.25, 0.36]
2017	29 500	58 294 [46 229, 71 702]	3.45	201 [159, 247]	0.41 [0.32, 0.50]
2018	30 898	39 318 [33 624, 45 743]	2.81	111 [95, 129]	0.23 [0.19, 0.26]