WORKSHOP ON INCORPORATING DISCARDS INTO THE ASSESSMENTS AND ADVICE OF ELASMOBRANCH STOCKS (WKSHARK5, OUTPUTS FROM 2019 MEETING)

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i Executive summary

Background

Elasmobranchs are mainly species that are not targeted but appear in various amounts as by-catch. Although, the EU landing obligation requires all catches to be landed, skates and rays have a temporary exemption from this because of the expected high discard survival rate. At the same time, the data on elasmobranch stocks are often limited, and information on catches and discards is important to improve the assessment of these stocks. Between 25 February and 1 March 2019, WKSHARK5 met in Leeuwarden, The Netherlands to discuss the incorporation of discards into the assessments and advice of elasmobranch stocks. Eighteen experts from seven countries tackled the issues around raising methods, data sources, data quality and how to deal with species which have been under moratorium. Ultimately it is envisaged that an advice framework will be developed that incorporates data on discards.

The meeting was attended by ten members of Working Group on Elasmobranch Fishes (WGEF) and attracted experts from other groups such as the Working Group on Bycatch of Protected Species (WGBYC), the Working Group on Commercial Catches (WGCATCH), the Joint ICES/Probyfish Workshop on identification of target and bycatch species (WKTARGET), and the Working Group on Beam Trawl Surveys (WGBEAM).

The last plenary of each day Tuesday to Thursday was held with an open WebEx connection allowing extra participation in the workshop.

The objective of WKSHARK5 was to:

a) Investigate and propose a raising method for elasmobranch fishes when a species is mostly discarded, as standard raising procedures are not applicable;

b) Evaluate and define the data quality and onboard coverage; discard retention patterns between fleets and countries; discard survival, as well as the definition of acceptable types/sources of data required for advice;

c) propose how to include discard information into the advisory process for elasmobranch fishes;

d) Propose a method to provide fishing opportunities that ensure that exploitation is sustainable when a species has been under moratorium, as is the case with the undulate ray.

Jette Fredslund from the ICES Secretariat delivered a presentation on the ICES advisory process including the benchmark procedures and summarizing the special request for updated advice on undulate ray in 7.de and 8.ab, from 2018 (ICES, 2018). The background for the request was new catch and discard data available to France from a fisheries self-sampling programme. The outcome of the request was new catch advice for the first time, involving only onboard observer programme data, assuming 100% discard survivability. The process also involved a new assessment during the 2018 advice drafting group leading to a 77% increase in advised landings for one of the stocks and new catch advice after a "no targeted fisheries due to lack of data" on the other. The data from the self-sampling programme could not be used as it needed further validation.

Following recent join activities between WGEF and WGBYC, Bram Couperus from WGBYC presented the actual work form the group and preliminary results from the WGBYC data call with valuable data on elasmobranch bycatch, particularly on some of the prohibited species that WGEF have to assess in 2019, e.g., angel shark (*S. squatina*).

An OSPAR/NEAFC special request for deep sea sharks was presented by Inigo Martinez from the ICES Secretariat, together with a draft questionnaire for bycatch-mitigation measures that WGBYC will comment on during their following week meeting before being distributed to all WGEF experts.

Landing Obligation

It was acknowledged that there is a temporary exemption to the application of the EU Landing Obligation for skates and rays. See Annex 5 for the documentation from the EU. All stocks in all areas (North Sea, North-western waters and Southwestern waters) will be exempt from the Landing Obligation for a three year period (2019–2021). The exemption has been extended until 2023 in the North Sea. For the cuckoo ray the exemption is for a shorter period due to the expected low survival of this species.

Main outcomes

ToR a and b: Raising methods and data quality, discard retention and survival

During the meeting, the group looked at different observer data on discards and discussed raising procedures and developed scripts for these. The conclusion was that each country use different raising methods adjusted to their fleets and sampling programmes. This is also the case for round fish. Several case studies were presented:

- Ana Ribeiro Santos from the UK presented (by WebEx) the CEFAS catch sampling programmes;
- Claudia Junge from Norway on discard data from the Norwegian reference fleet from 2017 and raising to the coastal Norwegian fishery in ICES Division 4.a;
- Pascal Lorance from France on two new surveys in the western Channel and Bai St. Michel;
- Jurgen Batsleer from the Netherlands brought the group up to date on first results from a Dutch research programme looking at the automated counting of rays om the conveyor belt;
- Noemi van Bogaert from ILVO in Belgium gave a presentation on the collaborative project SUMARiS in which the survival of skates and rays in the demersal fishery will be determined. The project will look at factors influencing survival and possible management measures.

In order to explore the robustness of different raising procedures given different data source for ToR a) two case studies on thornback ray (*Raja clavata*) in the North Sea were carried out, using data from The Netherlands and Belgium. For the case study from The Netherlands three different raising methods were compared:

1. raising discards of the stock to fishing effort, hp-effort or total landings of all species;
2. raising discards of the stock including bootstrapping;
3. regression model

The conventional method (1) and bootstrapping method (2) result in similar estimates, those derived from the regression model give higher results. It is not possible to infer a general procedure for all countries based on these results.

In the Belgian case study, four methods were compared:

1. raising of raw discard data by effort
2. raising of raw discard data by effort × engine power
3. raising of raw discard data by landings
4. spatio-temporal modelling of discards per unit effort

In general, the different raising procedures result in similar outcomes in terms of estimated quantities and width of the confidence intervals. However, the spatio-temporal method showed a strong decline in discards per unit effort, which can be explained by the spatio-temporal dynamics of the observer programme. The comparison illustrated that this method seems to be more robust in situations where the spatio-temporal coverage of the observer programme is limited.

ToR b: Evaluate and define the data quality and onboard coverage; discard retention patterns between fleets and countries; discard survival, as well as the definition of acceptable types/sources of data required for advice.

For ToR b) a matrix was developed, based on work from WGCATCH, to characterize and record each source of data (Discards_gap_table[1]) including quality checks.

In terms of acceptable sources of data and self-sampling programmes, there is not any official ICES, nor expert group guidelines. However, minimum requirements used in other cases to accept industry collected data in assessments include:

- The time series must have a time-span of a minimum of five years.
- Normally new data always has to go through a benchmark (or interbenchmark) process before they can be included in the assessment. Generally, short updates are given each year on progress to the working groups (WGs) and the scientist involved publish a working document for the benchmark/WG.

WKSHARK5 recommends that the same matrix as for onboard programmes is filled in and entries compared before accepting any new data.

While observer data are available from many countries, not all métiers are sampled to a level that can allow patterns in discard/retention ratios to be observed. Similarly, few métiers have been intensively sampled enough to allow changes in pattern to be determined. Otter trawl-based métiers have the most number of samples for almost all examined species. These are most likely to be of use in stock assessments. Whilst some nations have large sample sizes for various gillnet métiers, the length-distributions are influenced greatly by mesh size, which would need to be considered in future evaluations of length-based indicators.

ToR c: Propose how to include discard information into the advisory process for elasmobranch fishes

The North Sea thornback ray (*Raja clavata*) was used as an example stock to test the raising procedure and advice method prepared in the other ToRs. Here the regular advice for 2018 and 2019 for *R. clavata* in Subarea 4 and divisions 3.a and 7.d based on previous landings is compared to an advice for 2018 and 2019 where catch data would have been used. The advice was recalculated using an estimated discard rate of 0.34. The landings corresponding to the catch advice are 30% lower when this discard rate is applied. Issues which could influence this estimate, such as survivability, discard retention and the length-frequency of catches and landings are discussed. It is recommended to develop a length-based model for future work on including discards in advice.

ToR d: species under a moratorium

In the ICES area, some elasmobranch stocks have been under highly restrictive management measures, including being included on the EU list of prohibited species, and/or have had null TACs for several years. As a direct consequence of these restrictive measures, there is a lack of

[1] Password required - to access Discard gap table, please contact the ICES Secretariat

fishery dependent data. Current ICES DLS methods recommend catches or landings based on the previous advice or catches and the variation of a biomass index (ICES, 2013). In the situation where there was no or very small landings for several years in order to rebuild a larger stock, there is no ICES procedure to set the advice at a sustainable level.

Pascal Lorance from France gave a presentation of the methodology he developed in 2018 in order to address the special request from France to revise the advice provided in 2016 on fishing opportunities for 2018 for the stocks of undulate ray (*Raja undulata*) in 7.de and in 8.ab.

Three different procedures were presented and their adequacy to provide scientific advice on sustainable catch when a species was under moratorium was discussed. These differ according to the sources and data availability, survey and/or fishery data (see report):

- No survey data but georeferenced catches derived from self-sampling programmes to derive acceptable mortality.
- Deriving advisable landings for a species under moratorium based on biomass indices from a reference species:

$$Adv(mor) = \left[\frac{B\ (mor)}{B\ (ref)}\right] \times \frac{r(mor)}{r(ref)} \times Adv(ref)$$

- Long-time series survey and reliable historical catch with contrasting biomass/mortality periods:

$$F_{proxy} = \text{Yield/Survey biomass.}$$

The value and potential use of self-sampling data that do not meet the requirement listed in the above have to be scrutinized case by case, as these data may also provide ancillary information about the stock of concern. For example the self-sampling data from French coastal vessels reported numbers of individuals and body lengths, even though this was only carried out during the first year of the programme.

Future work

When the workshop was held it was envisaged that the report would be ready for use by June 2019. Due to unforeseen circumstances there has been a considerable delay in finalising the report. Some of the results may be superannuated in this case.

The outcome of the workshop was discussed at the WGEF 2019 meeting in June. The group assessed whether the work done by WKSHARK5 on characterizing the discard and raising methods available and the application of data could be used for the 2019 assessments in WGEF 2019, but decided against it as there were still so many uncertainties (ICES, 2019). See the 2019 WG report for recommendations following the discussions at the meeting (ICES, 2019).

There should be a discussion with the ICES ACOM Leadership on a process to accept and apply the methods proposed on ToR d.

WGEF will engage with WGBYC on the use of elasmobranch bycatch data and the finalization of questionnaire to answer ToR on mitigation measures for the OSPAR-NEAFC request.

ii Expert group information

Expert group name	Workshop on incorporating discards into the assessments and advice of elasmobranch stocks (WKSHARK5)
Expert group cycle	Annual
Year cycle started	2019
Reporting year in cycle	1/1
Chair	Paddy Walker, The Netherlands
Meeting venue and dates	25 February – 1 March 2019, Leeuwarden, The Netherlands (19 participants)

1 Opening of the meeting

The meeting was opened at 14 h on Monday 25 February 2019 by the Chair (Paddy Walker) who welcomed the group to the Van Hall Larenstein University of Applied Sciences and the town of Leeuwarden.

2 Terms of Reference

WKSHARK5 - Workshop on incorporating discards into the assessments and advice of elasmobranch stocks (WKSHARK5)

The **Workshop on incorporating discards into the assessments and advice of elasmobranch stocks** (WKSHARK5), chaired by Paddy Walker (Netherlands) will meet in Leeuwarden, Netherlands from 25 February – 1 March 2019 to:

a) Investigate and propose a raising method for elasmobranch fishes when a species is mostly discarded, as standard raising procedures are not applicable;

b) Evaluate and define the data quality and onboard coverage; discard retention patterns between fleets and countries; discard survival, as well as the definition of acceptable types/sources of data required for advice;

c) propose how to include discard information into the advisory process for elasmobranch fishes;

d) Propose a method to provide fishing opportunities that ensure that exploitation is sustainable when a species has been under moratorium, as is the case with the undulate ray

It is envisaged that this workshop will be part of a process to ultimately develop an advice framework for elasmobranchs that incorporate DC-MAP data on discards as well as explore the use of fisheries dependant data.

It will investigate and propose options for advice on fishing opportunities of bycatch of elasmobranch fishes, when raising procedures and survivability greatly influence the estimates of catch and landings.

A subsequent Management Strategy Evaluation may be required in order to identify how possible changes in estimated stock biomass and associated catch advice might affect stocks.

Considering the scope of the meeting, it is recommended to invite experts from WGMEDS, WKLIFE, WGBIOP and WGBYC.

WKSHARK5 will report by 25 March 2019 for the attention of ACOM.

3 Introduction

In the past three years, the Working Group on Elasmobranch Fishes (WGEF) has explored how to incorporate data on discards into the stock assessments (ICES, 2017; ICES, 2018). In 2017, there was a dedicated workshop on this issue (WKSHARK3, ICES 2017). This workshop collated the information available as basis for further work. The executive summary of the meeting is shown below (WKSHARK3, ICES 2017):

ICES WKSHARK3 made an overview of the available discards information and the common procedures to calculate population level estimates of discards removals for different countries were described. The potential issues related to sampling procedures for elasmobranchs were collated for the different sampling programs in the different countries. The available discards information was used to determine discards retention, i.e. the lengths and species composition of discards compared to the total catches. The suitability of national programmes to inform on the by-catch of rare species was reviewed considering three demersal species that are rare throughout the ICES area (angel shark, white skate and guitarfish), three pelagic species that are uncommon in observer programmes (Basking shark, Porbeagle and Common thresher shark) and two demersal species that are locally rare (undulate ray in 7.bj and starry smoothhound in 9.a). These species were also given particular attention in terms of potential issues related to sampling plans and procedures. Finally, the available knowledge on the mortality caused by discarding of elasmobranchs depends on the survival of individuals in the catching process and the subsequent handling of the fish was reviewed.

Until now, discard data are not routinely included in the assessments as there is not a validated methodology. During the 2018 meeting of the WGEF, there was a special request from France to revise the advice provided in 2016 on fishing opportunities for 2018 for the stocks of undulate ray (*Raja undulata*) in 7.de and in 8.ab. For this, both observer and onboard sampling data were provided in order to estimate discard rates. During the meeting, it proved difficult to validate the approach. This led to a recommendation to explore the application of discard data in assessments further, also for species which had been under moratorium such as the undulate ray. The WKSHARK5 meeting is the result of this recommendation.

4 ToR a: Comparison of different raising procedures

Most exploited elasmobranch stocks have discard proportions that are estimated to range between 50% and 100%. Consequently, the total discards and the survival rate of discarded elasmobranch species are considered key parameters to make robust inferences about the exploitation rate of most elasmobranch stocks.

However, no guidelines for discard monitoring programmes, and raising procedures to estimate discard quantities of elasmobranch species are implemented within the ICES advice framework. Member States use different data sources and raising procedures often developed to estimate discard quantities of target species. Consequently, the precision and accuracy of the estimated discard quantities of elasmobranch stocks is poorly understood.

ToR a) addresses this knowledge gap by providing an assessment of different raising procedures. Two case studies on thornback ray (*Raja clavata*) in the North Sea (27.4.a; 27.4.b; 27.4.c) were used during WKSHARK5. The case studies presented below aim not at providing an exhaustive overview and review of all discard raising methods applied in different member states. Rather, the aim of the case studies is to explore the robustness of different raising procedures given different data sources, and as such provide insights and guidelines into how different data sources should be explored and analysed to improve the accuracy of discard estimates.

4.1 Case study: The Netherlands

4.1.1 Data

DCF monitoring programme

The collection of discards data has been enforced through the Data Collection Regulation (DCR) and subsequently the Data Collection Framework (DCF) of the European Commission (EC). To comply with this ruling, 6–18 active demersal fishing trips in the North Sea have been monitored annually since 2000 in the Netherlands by scientifically-trained observers (i.e. observer programme). Within a trip, operational- and catch data are collected by the observer each time the fishing gear is deployed. Furthermore >60% of the hauls is sampled by one or two observers in each trip. For each sampled haul, the total volume of the catch is estimated and a sample (ca. 40 kg) of the discards which is representative for the sampled haul is collected. From each sample all species are identified, numbers at length are recorded for all fish species, Norway lobster and edible crab, and numbers without length measurements are recorded for all remaining (benthos) species. Standard Data management software is used to enter and subsequently audit all data before the data is stored in the centralised WMR database.

In 2009, revisions to the DCF required member states to increase sampling intensity to improve the precision of their estimates and the number of sampled fishing fleets (métiers). In foresight of the expenses involved, an affordable self-sampling programme commenced in the Netherlands for the Dutch demersal fisheries in the North Sea in 2009. The sampling plan of the self-sampling programme is based on a demersal reference fleet consisting of 20–25 vessels with protocol-instructed fishers that collect discard samples according to a predefined schedule during their regular commercial operations. Within a trip operational- and catch data are collected by the crew each time the fishing gear is deployed. Furthermore, the crew is instructed to retain a sample (ca. 80 kg) of the discards which is representative for the sampled haul during two separate hauls. The samples are collected in large plastic bags which are sealed off, labelled and cool-stored until the vessel returns to the port. Back at port, the discard samples are collected by WMR staff and returned to the laboratory for analysis. From each sample all species are identified. Numbers at length are recorded for all fish species, Norway lobster and edible crab. Numbers without length measurements are recorded for all remaining (benthos) species. Standard data management software is used to enter and subsequently audit all data before the data is stored in the centralised WMR database.

The selection of the observer trips occurred in cooperation with the active demersal fleet up to 2011. From 2011 onwards, observers went onboard trips where self-sampling was also conducted. As such, hauls sampled during the self-sampling trips are verified using the observer data from the same haul from observer trips (Verkempynck *et al.*, 2018). In addition, the observer trips have proven to be of importance for training crew members in sampling of discards. Also, the observer trips are appreciated by the skipper and the members of the reference fleet, it bridges the gap between scientists and crew.

Discard data collected within the observer programme have been used by the ICES working groups up to and including 2010. Since 2011, discard data from the self-sampling programme are used, amongst others, by the ICES working groups for the assessment for stocks in the North Sea (WGNSSK).

Industry discards sampling programme

Between 2016 and 2018, the Dutch demersal industry run a study (Dutch) funded by the European Maritime and Fisheries Fund to gain knowledge on the quantity, composition and spatial distribution of discards of quota regulated species. In total, 15 pilot trips carried out by vessels in the pulse fishery (a subset of the beam trawl fleet) registered and retained all discards of all quota regulated species by haul on board. All discards collected during the trip were landed and sorted by species, measured and weighed.

Given the restrictive quota for rays, Producer Organisations often take measures including implementing a minimum landing size (>55 cm) as well as setting a maximum to the amount of rays that can be landed per trip. The latter can range from 40–275 kg per trip. Due to these PO-measures, only the largest individuals of the most valuable species are landed, while the remainder of the catch is discarded. In this context, by sorting, measuring and weighing each individual ray in the discards the studied provided a unique opportunity to gain insight in the species composition and quantity for each fishing location. Such detailed information is highly valuable in understanding discard patterns as well as to obtain the full size spectrum of the catch.

Exploratory analysis

The data set collated for the analysis covered the period 2012–2017. Within this period a total of 59 observer trips, covering six métiers, have been executed (Table 4.1). The majority of the observer trips took place on board larger beam trawl vessels fishing with 70–99 mm mesh (métier TBB_DEF_70-99_G300hp). In total, 1917 hauls were conducted of which 1896 hauls have been sampled by the onboard observers. More specifically, within 94 hauls during 25 trips covering 4 métiers, thornback ray was encountered.

Using self-sampling, a larger number of trips and métiers were sampled in the same period (2012–2017) compared to the observer trips. In total, 922 self-sampling trips, covering 11 métiers, have been executed (Table 4.1) whereby 28 643 hauls were conducted of which 1831 hauls have been sampled. As for the observer trips, the TBB_DEF_70-99_G300hp métier was the most sampled (429 sampled trips in 2012–2017). Thornback ray was observed within 232 hauls during 194 trips, covering 10 métiers.

Difference in the sampling methodologies results in a different spatial distribution of the hauls sampled, with samples collected within observer trips being usually more clustered in space than samples from the self-sampling programme (Figure 4.1). The industry discard trips only provide data since 2016. While the number of industry trips per year is lower than for the observer program, the number of hauls sampled per trip is higher as every haul of the entire trip has been sampled to obtain the maximum spatial resolution.

It should be noted that within our analysis, métiers for which the number of sampled trips was limited were merged. In this case the following métiers were merged:

i. OTB_DEF_100-119 and OTB_DEF_>=120 into OTB_DEF_>=100,
ii. SSC_DEF_100-119 and SSC_DEF_>=120 into SSC_DEF_>=100
iii. OTB_DEF_70-99 and OTB_MCD_70-99 into OTB_70-99.

In addition, two métiers for which no thornback ray discards were observed (TBB_DEF_>=120) or sampling was limited to three years or less within the period 2012-2017 (TBB_DEF_>=120 and SSC_DEF_70-99) were excluded from further raising.

Table 4.1: Overview of number of trips where thornback ray was observed / total sampled trips, by sampling programme (i.e. observer programme and self-sampling programme), year and métier.

	2012	2013	2014	2015	2016	2017
Observer trips						
OTB_DEF_100-119		0/1	0/2	0/1		
OTB_DEF_70-99	0/1	0/1				
OTB_MCD_70-99	1/2	0/1	2/2		1/1	1/3
TBB_DEF_100-119	1/1				1/1	1/1
TBB_DEF_70-99_G300hp	2/4	2/6	3/4	0/6	3/6	3/5
TBB_DEF_70-99_S300hp	0/2	0/1	1/2	1/3	1/1	1/1
Self-sampling trips						
OTB_DEF_>=120	0/1		0/1	1/3	0/2	
OTB_DEF_100-119	3/10	2/13	2/16	4/13	3/8	0/2
OTB_DEF_70-99	2/13	2/8	0/8	3/20	0/6	2/11
OTB_MCD_70-99	1/16	0/19	4/19	0/17	4/23	1/27
SSC_DEF_>=120	0/2	0/5	0/3	1/4	0/3	
SSC_DEF_100-119	0/6	0/2	0/3	1/4	1/1	
SSC_DEF_70-99				3/10	0/2	
TBB_DEF_>=120		0/2		0/3		0/1
TBB_DEF_100-119	3/15	0/11	1/9	0/5	1/9	1/10
TBB_DEF_70-99_G300hp	12/63	8/55	30/80	18/66	24/80	35/85
TBB_DEF_70-99_S300hp	0/17	0/17	4/20	4/26	3/24	10/23

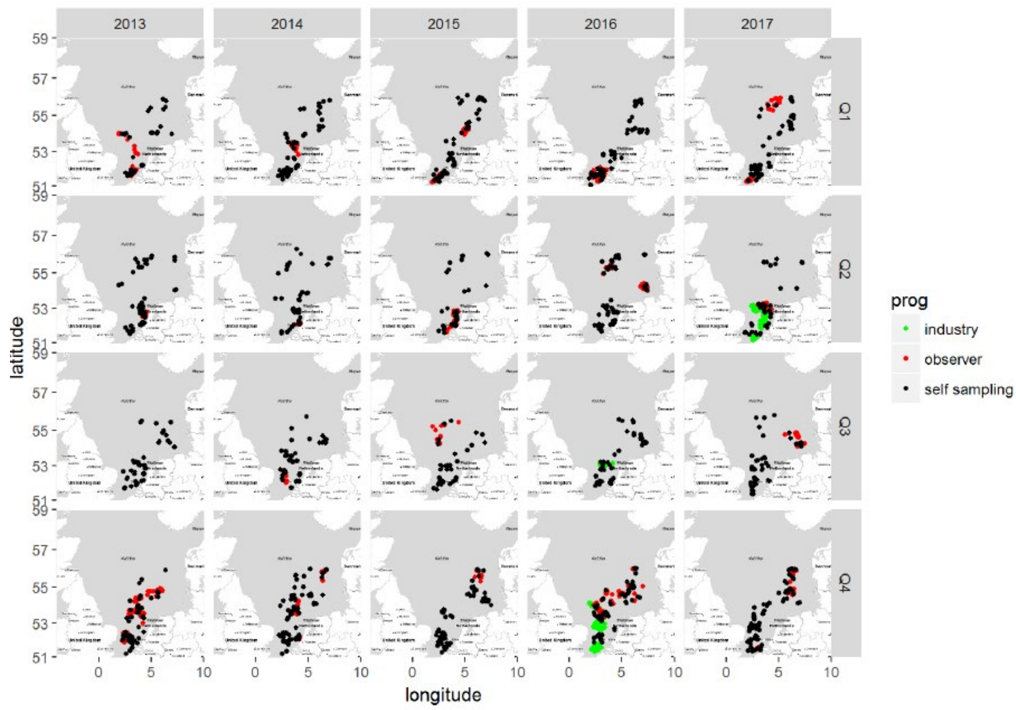


Figure 4.1: Distribution of the hauls sampled per year (2013–2017), quarter and data collection programme (From Brunel *et al*., 2018)

Length frequency distributions

The three programs use different sampling strategies to collect discard data. Difference in sampling strategies may result in a bias in the spectrum of length classes of discards of rays. In this context, the self-sampling programme collects only a fraction of the discards. These are bagged, sealed and brought to shore. Because the species are bagged, it is assumed the larger individuals will not be included in the sampling, creating a bias towards smaller species and specimens being observed within trips (ICES, 2017). This potential size bias is assumed to be lower with observer trips.

Here the length distribution of thornback ray (*Raja clavata*) caught in Subarea 4 for the three programs were analysed (Figure 4.2 and 4.3). The length frequency distributions show a comparable size range of thornback ray discards in all programs. The length distribution ranged between approx. 15 and 90 cm. The industry discards sampling programme, however, shows a lower mode (35 cm) but a larger number of discards of the larger length classes compared to the self-sampling and observer programmes.

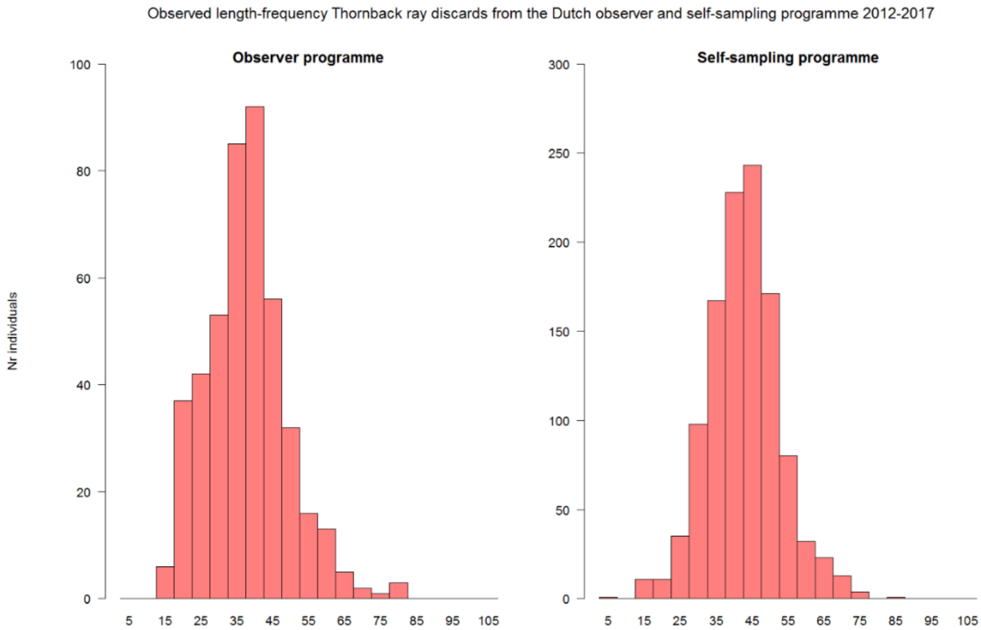


Figure 4.2: Histogram of observed lengths (bars) for the observer trips (left) and the self-sampling trips (right). Note that this concerns data on sample level (i.e. not raised data).

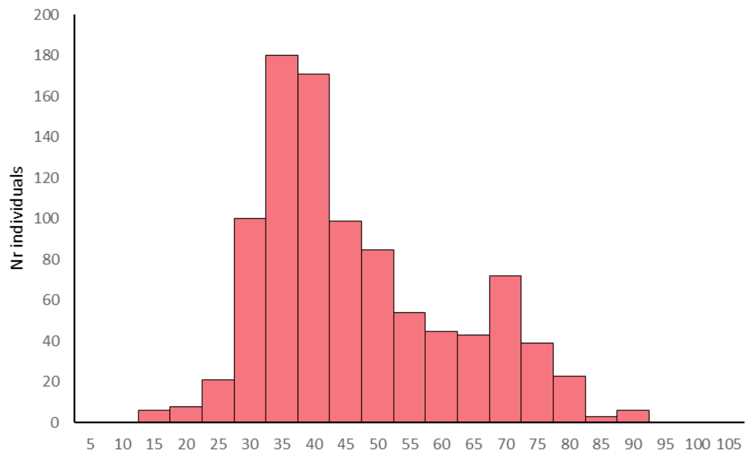


Figure 4.3: Histogram of observed lengths (bars) for the industry discard monitoring trips. Note that this concerns data on haul level (i.e. not raised data).

4.1.2 Methods for raising sampled trips to fleet level

A number of different methods are available to estimate how many elasmobranchs are removed from the population by métier or fishery. In general, discards estimates per haul, or per trip are raised to the population level using the fractions of fishing effort, landings of the same stock or total landings to their total within a métier or fishery. Different countries use different methods, generally determined by the methodology used for the commercial species in these fisheries.

In the Netherlands, thornback ray discards of the Dutch demersal fleet fishing in the North Sea have been estimated based on the data collected within the Dutch demersal discard programme in the period 2012–2017, where a distinction is made between data collected within the observer programme and data collected within the self-sampling programme. It should be noted that data from the Dutch industry discard monitoring programme are not used for raising discards for any of the stocks. These industry data consist of a short time-series (2016–2018) and cannot be used in our analysis. Here, three different methods have been used to estimate the total thornback ray discards in the Dutch demersal fleet:

- Method 1 : Raising discards of the stock to fishing effort, hp-effort or total landings of all species
- Method 2: Raising discards of the stock to fishing effort, hp-effort or total landing but include bootstrapping to assign a confidence interval
- Method 3: Raising discards of the stock to fishing effort using a regression model

Raising the samples to haul level

Numbers (at length) have been registered for all individuals (by species) for each sample. Whenever a species is very abundant within the sample, a sub-sample of this species has been counted. The numbers (at length) have been multiplied with the sub-sample fraction to estimate total numbers (at length) within the sample. The numbers (at length) in the samples have been multiplied with the volume ratio between discard sample and total discards to estimate total numbers (at length) within that haul. Thereafter, a length/weight-relationship has been applied to convert numbers at length to weight at length.

Next, weights for the sampled hauls are summed up by species. These weights have then been standardized into discards per unit effort (expressed in kg/hour) rates by dividing them by the deployment duration (i.e. fishing time). Total weights per fishing trip have been calculated by multiplying the standardized rate with the duration of all hauls. Doing this we assume that the sampled hauls per trip are representative in species composition and variance for all the other hauls in a trip.

Method 1: raising discards of the stock to fishing effort, hp-effort or total landings of all species

The first method can be described as the conventional raising procedure applied by most of the countries. This method uses the ratio between the sampled effort, hp-effort or total landings and the total effort, hp-effort, or total landings of all species by métier or fleet, respectively.

Effort (expressed in days at sea), hp-effort (expressed in hp per days at sea) and total landings (all species) per trip have been extracted from the WMR VISSTAT database containing the official Dutch logbook information. The total discards per fishing trip were then standardized into (i) thornback ray discards per fishing day, (ii) thornback ray discards per hp fishing day, and (iii) thornback ray discards per kg landings. The WMR VISSTAT database was used to assign all sampled trips to their respective métier based on the level 6 for the métier classification defined by the European Union (EU) definitions (2008/969/EC Appendix IV).

When using different raising factors, the resultant discard estimates will vary (Figure 4.4). If total landings of all species is used as a raising factor, discard estimates are highest while using hp-effort as a raising factor results in the lowest estimates. The differences in discard estimates, however, resulting from the three raising factors are negligible. In 2017, when discard estimates are highest, the differences are largest, with the estimate of hp-effort being 35 tonnes and 79 tonnes lower compared to effort and total landings, respectively. From this analysis we can only infer the difference in discard estimates, we cannot determine if the results are an over or under estimation of the actual thornback ray discards.

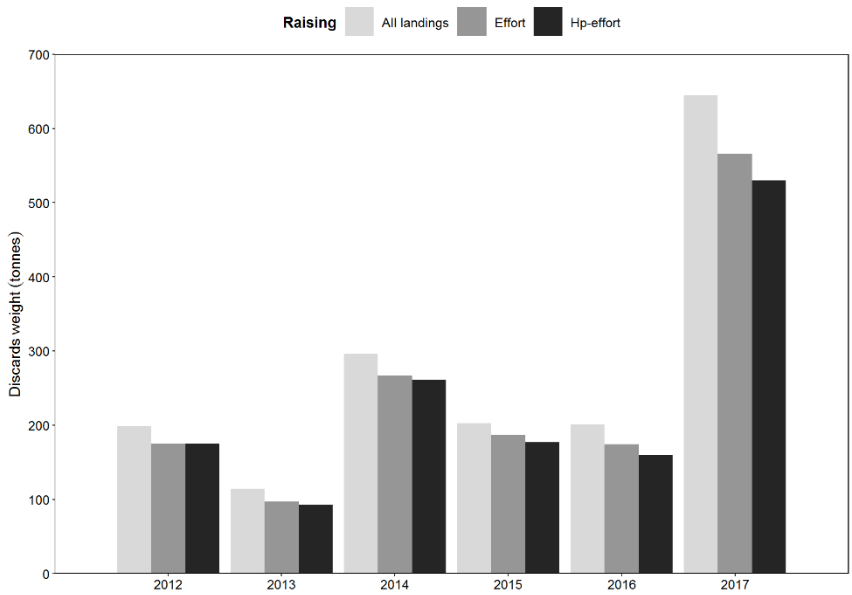


Figure 4.4: Discard estimates of the Dutch demersal fleet raised using three different raising factors.

Method 2: raising discards of the stock including bootstrapping

Discard sampling is often associated with a large amount of uncertainty. Method 1, however, results in a point estimate of the total discards of the fleet, providing no uncertainty over the discard estimates. To obtain confidence intervals over the discard estimates, bootstrapping was used. Bootstrapping is a statistical technique using random sampling with replacement from a single original sample, allowing the attribution of confidence intervals to the sample estimate (Davison and Hinkley, 1997). However, the technique requires a large enough sample size to be reasonably certain that the distribution of the random sample corresponds to that of the original sample.

Within the Dutch sampling programme, the number of sampled trips for certain métiers was very limited. To increase the number of samples per quarter per métier, métiers were merged and zeros were added to all zero catch samples. Bootstrapping was done per quarter per métier using the effort and hp-effort as raising factors.

Difference in discard estimates between both raising factors are negligible (Figure 4.5). Median discard estimate values and confidence intervals are almost equal within the time-period analysed. Only in 2017, a larger difference between the discard estimates for thornback ray were noted, i.e. a median discard estimate of 289 tonnes using effort compared to 450 tonnes using hp-effort as a raising factor. While median values may differ considerably, confidence intervals overlap and are very large. For example in 2017, the confidence interval ranges from 37 tonnes to 996 tonnes and 143 tonnes to 956 tonnes for effort and hp-effort, respectively. This large variance may be caused by large difference in catches among quarters in combination with a low sample size per quarter. As such, we cannot infer whether the use of one raising factor over another results in a better discard estimate.

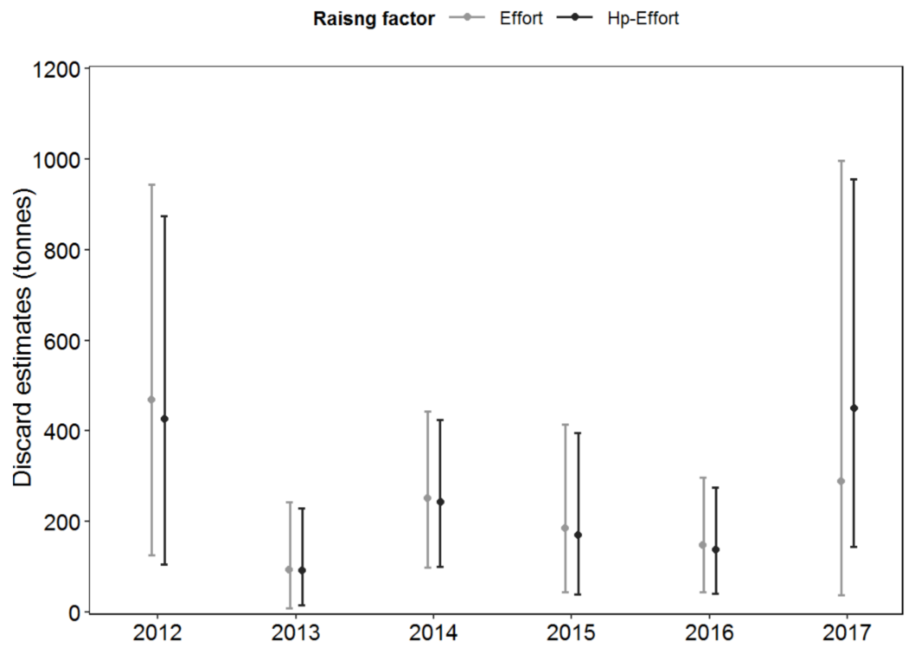


Figure 4.5: Discard estimates of the Dutch demersal fleet raised using effort and hp-effort. Bootstrapping was applied to get the median value and confidence intervals.

Method 3: regression model

The third method concerns a negative binomial Generalised Linear Model (GLM) which relates the thornback discards rate (expressed in kg/day) collected in the sampling period 2012–2017 on trip level to sampling programme, year and métier. The Akaike's Information Criterion (AIC) was used to determine the optimal model fit.

The results of the negative binomial GLM selection and corresponding AIC are shown in Table 4.2. The Akaike's Information Criterion (AIC) is lowest when sampling programme is not included. The parameter estimates of the selected model are shown in Table 4.3. The regression model predicts the thornback ray discard rate (expressed in kg/day) and corresponding uncertainty by year and métier. The predicted discard rate has been used to calculate the total thornback ray discards of the Dutch fleet (Figure 4.6):

$$RJC\ discards_{year,metier} = RJC\ discard\ rate_{year,metier} \times fleet\ effort_{year,metier}$$

where RJC discard rate is expressed in kg/day and fleet effort is expressed in total fishing days.

The outcomes of the regression model are expressed as annual mean discard estimates with a 95% confidence interval. The discard estimates follow the same trend as was seen under the first and second method with a low discard estimate in 2013, increasing towards the highest mean estimate in 2017. Also, confidence bands are large, which is probably caused by the low sample size and high variation in catches of thornback ray within the samples.

Table 4.2. Model selection table for the negative binomial GLM selection with response variable thornback ray (RJC) discards (expressed in kg/day). Model with the lowest AIC in bold.

Model name	AIC RJC Discards (kg/day)
GLM NB model prog, year, métier	3051.8
GLM NB model year, métier	**3050.7**
GLM NB model métier	3052.9

Table 4.3. Parameter estimates of selected catch model using thornback ray discard rate expressed in kg/day as response variable.

Effect	estimate	Std. error	z value	Pr(>|z|)
Intercept	0.7052	0.4492	1.570	0.1165
Year 2013	-1.1341	0.5140	-2.207	0.0273
Year 2014	0.4822	0.4871	0.990	0.3323
Year 2015	0.1592	0.4891	0.325	0.7449
Year 2016	0.1790	0.4901	0.365	0.7149
Year 2017	0.7450	0.4895	1.522	0.1280
Metier OTB_DEF_>=100	0.6890	0.6027	1.143	0.2530
Metier SSC_DEF_>=100	-0.4800	0.8378	-0.573	0.5667
Metier TBB_DEF_>=100	1.3466	0.6355	2.119	0.0341
Metier TBB_DEF_70-99_G300hp	2.2094	0.3719	5.941	<0.001
Metier TBB_DEF_70-99_S300hp	-0.3278	0.4891	-0.670	0.5027

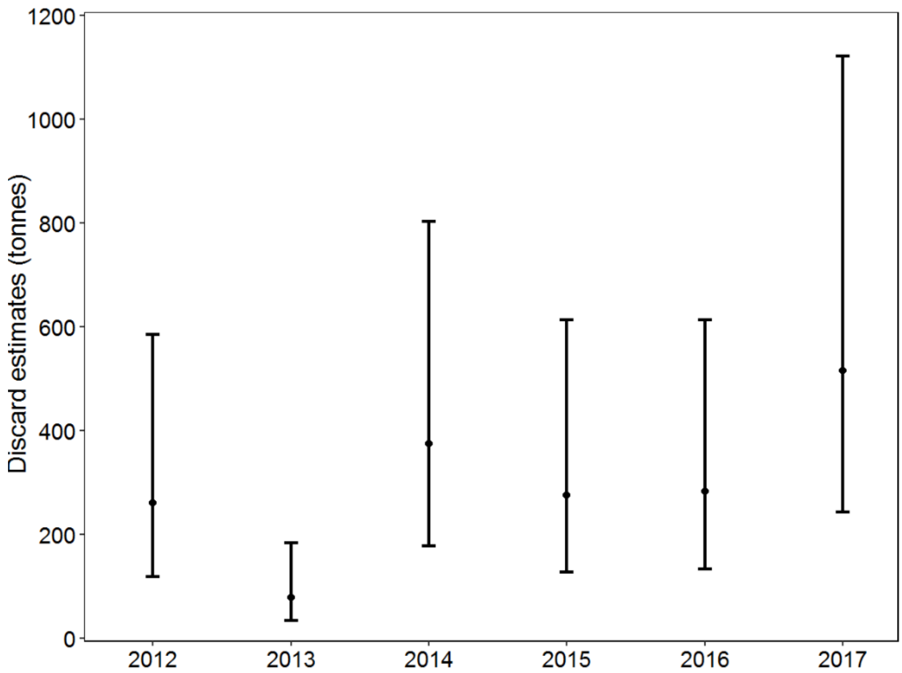


Figure 4.6: Discard estimates from the regression model expressed as annual mean discard estimates with a 95% confidence interval.

Comparison of raising procedures

Currently, countries are using different methods to raise their estimates per haul or sample to a population level. ToR a) was aimed at addressing the different raising factors and using different raising methods. To address ToR a) the outcomes of using different methods to raise discard estimates while using effort as a raising factor are graphically shown in Figure 4.7.

Discard estimates of thornback ray do vary by the raising methods used. Differences, however, are small with the exception of the estimates in 2012 and 2017. In both years, differences in the mean discard estimate can be substantial, whereby the highest and lowest estimate can vary by method followed. Overall, it seems, the conventional method (method 1) and bootstrapping (method 2) result in more similar estimates. Estimates from the regression model (method 3) are generally higher compared to the two other methods.

Given the similar discard estimates for thornback ray using different raising factors as well as raising method, a general procedure applicable by all countries cannot be inferred from these results.

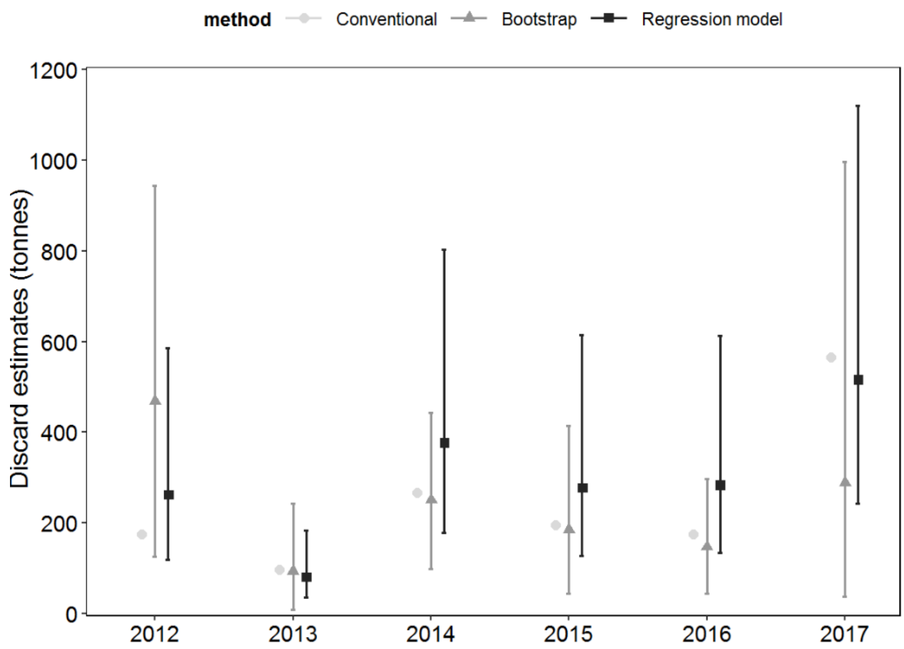


Figure 4.7: Comparison of annual discard estimates for thornback ray for three raising methods using effort as raising factor. The bootstrap method shows the annual median estimate with a 95% confidence interval. The regression model is expressed as annual mean discard estimates with a 95% confidence interval.

4.2 Case study: Belgium

4.2.1 Data sources

For the Belgian fisheries, information on discards is only available through a catch monitoring programme of commercial fishing vessels by onboard observers. This onboard observer programme is organized as such to meet the requirements as stated by the Data Collection Framework (DCF). Since the DCF has no specific requirements for elasmobranch species, data on elasmobranch species in Belgium has been collected in various ways from 2000 up to now.

Since 2000, data on the weight of discards and landings is available on haul level through catch registration of alternating hauls. Before 2013 however, ray species were not registered at the species level but grouped in a single category, *skates*, which obviously hampers discard estimation at the species level. This changed in 2013, when rays were reported at the species level. Length-frequency data has never been collected for ray catches because fishermen want to limit the exposure time of rays on deck, and minimize the physical impact caused by measuring. Length data is only available from a small number of hauls, but the low coverage impedes the estimation of discards per length-class.

The total annual observer coverage of landings of commercial Belgian fishing vessels is rather high (~1%). However, in terms of spatiotemporal and within fleet coverage, the current observer programme performs rather poor. On average, only ~0.4 trips per quarter and ICES division are observed which is significantly below the target of 2 trips per métier, quarter and ICES division as advised for onboard observer programs. This low coverage of the observer programme results from the practical constraints related to the commercial fishing fleet. Firstly, the Belgian fishing fleet is dominated by a single métier (TBB_DEF_70-99) which accounts for ~85% of the total annual landings. As a result of the importance of this métier, the onboard observer programme has been developed to monitor this métier as good as possible. Nevertheless, the spatiotemporal fishing effort allocation of this métier is characterized by strong seasonal patterns. This is related to the dynamics of the fleet: the majority of the fishers tend to organize fishing trips in campaigns to optimize quota uptake in each of the seven ICES divisions in which the fleet has fishing rights (Figure 4.8). During these campaigns, fishing effort is strongly concentrated in a specific ICES division causing a heterogeneous distribution of fishing effort between quarters and ICES divisions. Obviously, given the high number of 'ICES divisions x quarter x métier' combinations, the heterogeneous distribution of fishing effort among these combinations, and the constraint of the available number of onboard observers for the program, it is practically impossible to observe 2 trips per métier per quarter and ICES division with this program. In addition, the number of vessels that are able to host an onboard observer is limited. Most vessels have limited space meaning that data is only collected on a small subsample of the fleet, which is not necessarily representative for the entire fleet. Consequently, new ways of catch monitoring (e.g. self-sampling and electronic monitoring through cameras) are currently explored to improve the catch monitoring program, although not implemented yet.

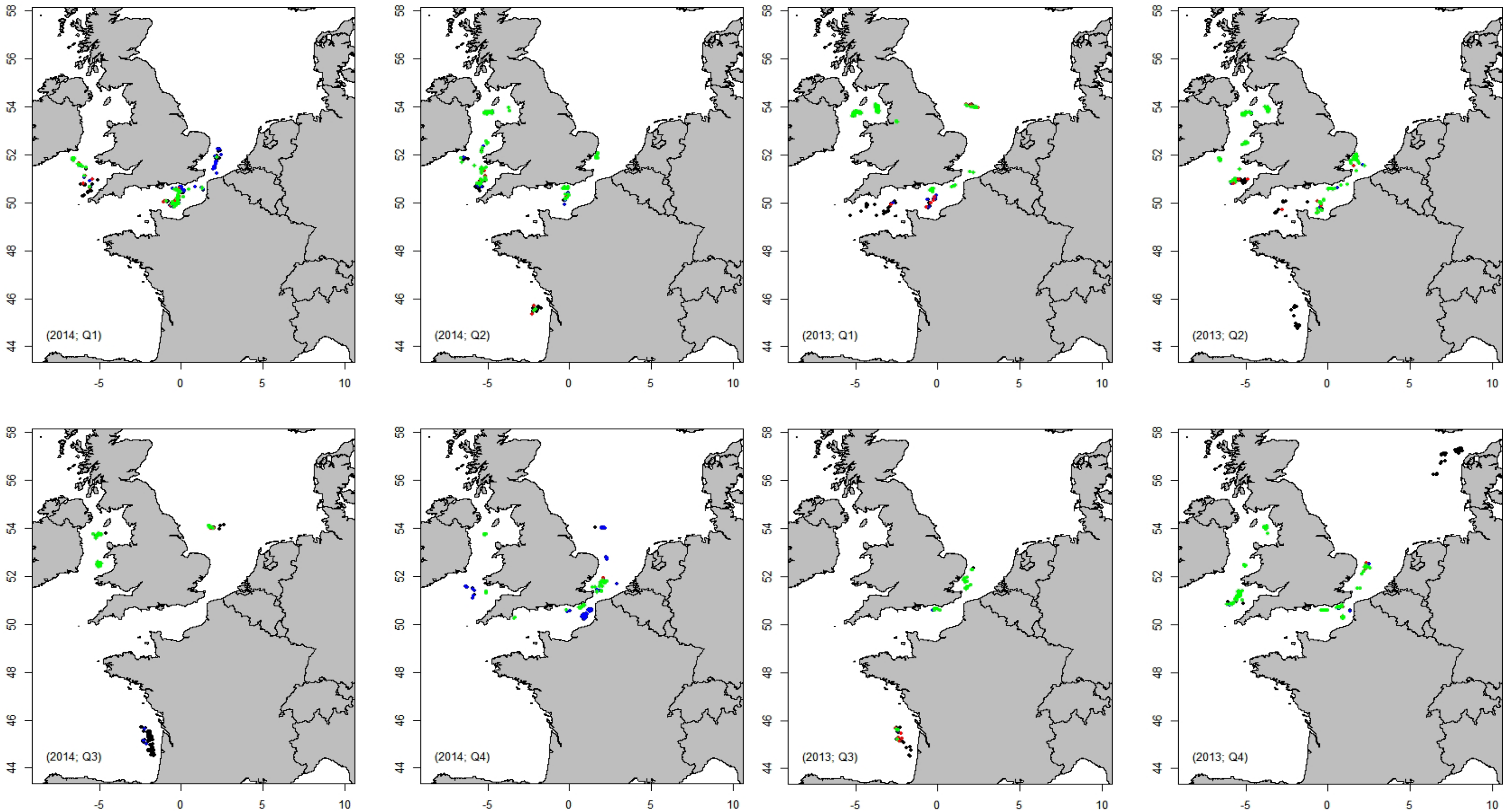


Figure 4.8: Spatio-temporal coverage of Belgian's onboard observer program. Each dot corresponds to an observed haul. Black, red, blue and green dots indicate that no catches, only landings, only discards, or both landings and discards of *Raja clavata* were observed.

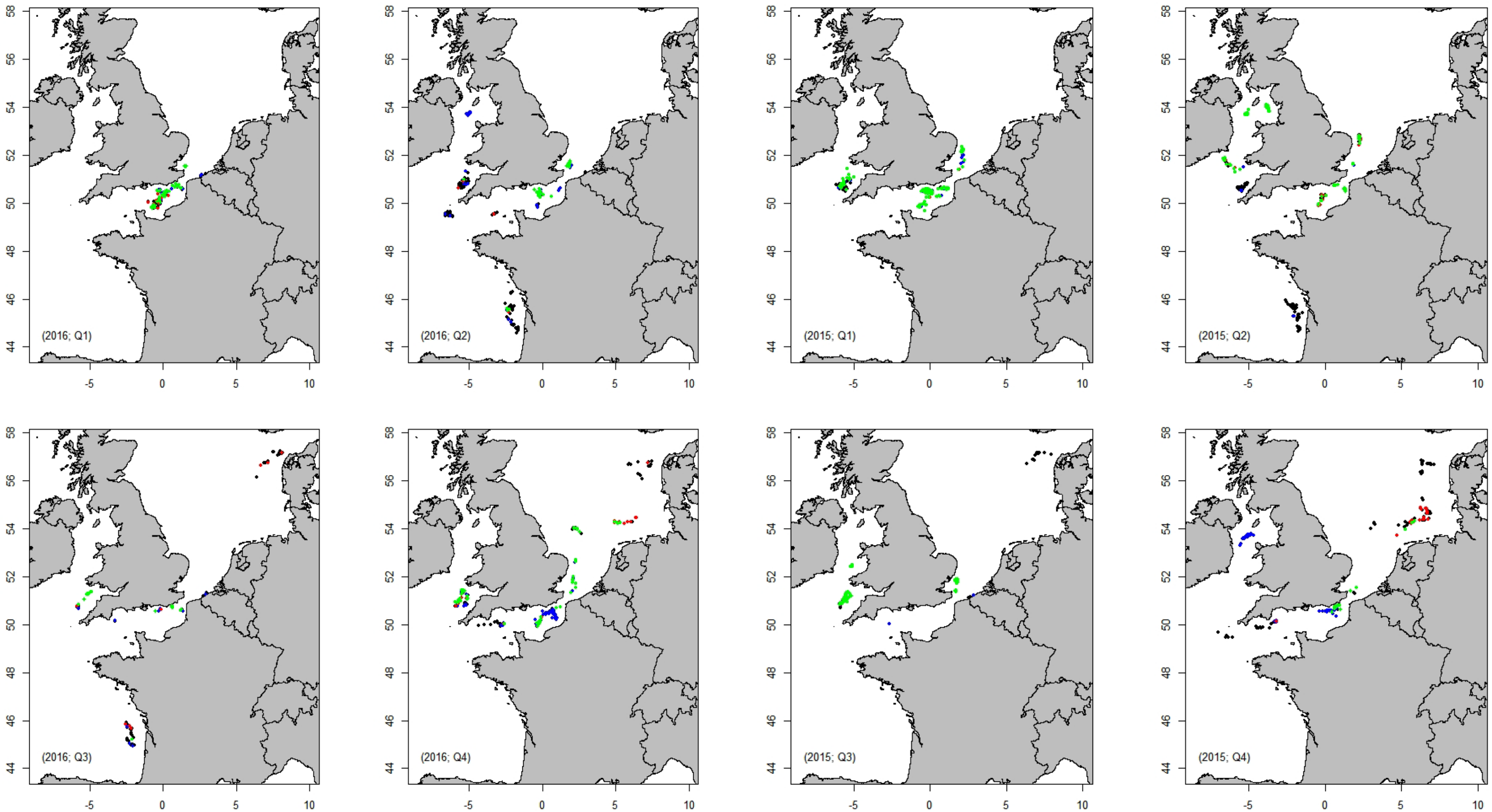


Figure 4.8 (cont'): Spatio-temporal coverage of Belgian's onboard observer program. Each dot corresponds to an observed haul. Black, red, blue and green dots indicate that no catches, only landings, only discards, or both landings and discards of *Raja clavata* were observed.

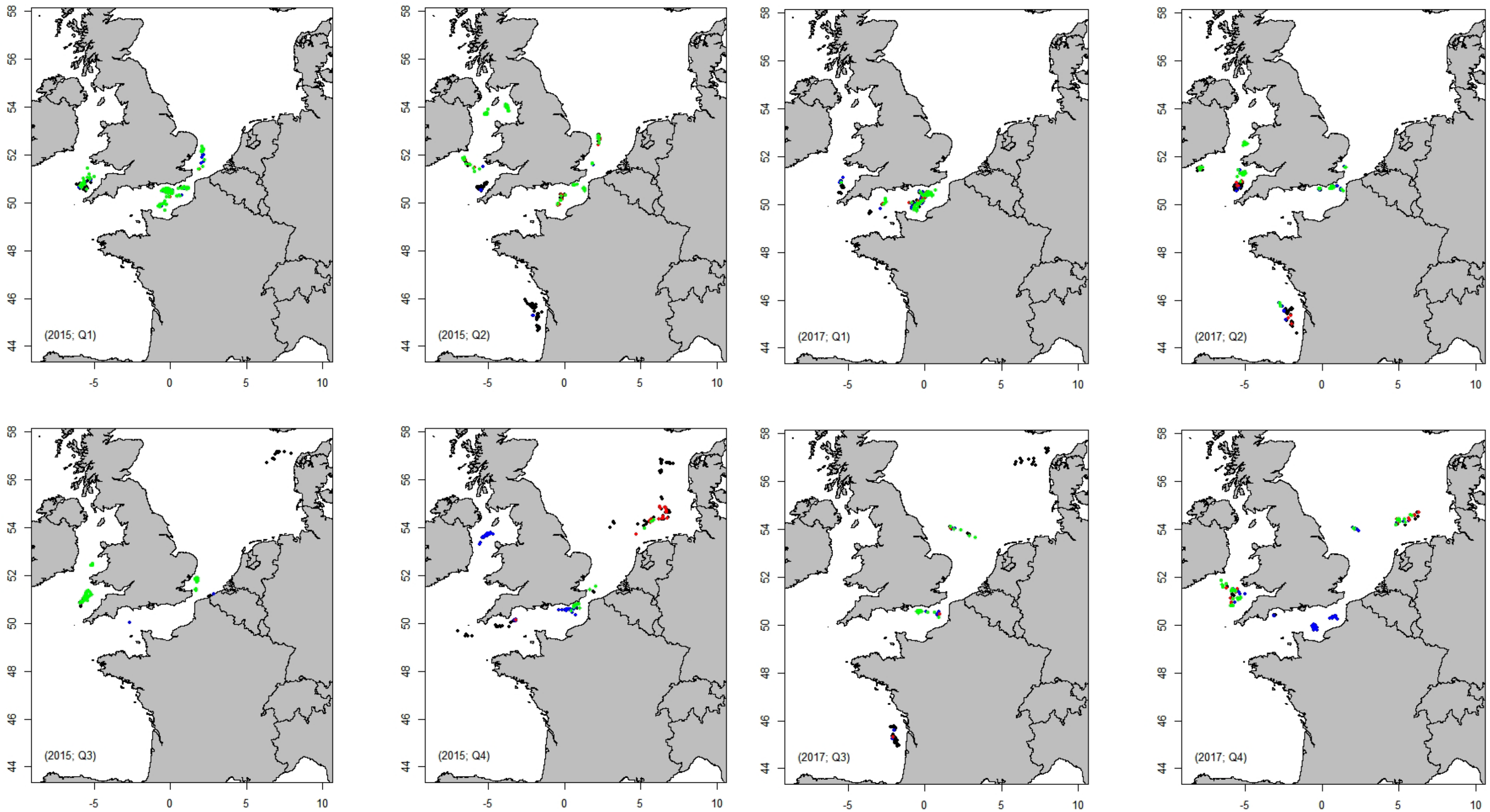


Figure 4.8 (cont'): Spatio-temporal coverage of Belgian's onboard observer program. Each dot corresponds to an observed haul. Black, red, blue and green dots indicate that no catches, only landings, only discards, or both landings and discards of *Raja clavata* were observed.

In the next part of this section, different discard estimation raising procedures are compared. In each of the methods, observer data, containing the discarded weight (kg) from *Raja clavata* per haul from 2013 until 2018 is used. Table 4.4 provides an overview of the data. Note that no data was collected in the Western English Channel during 2014, and also note the high number of zero observations in the Central part of the North Sea (27.4.b), Western English Channel (27.7.e), Celtic Sea (27.7.fg), and Bay of Biscay (27.8.ab).

Table 4.4: Summary statistics of the observer data. The mean and standard deviation refer to the non-zero discard observations of *Raja clavata*.

Year	Area	Nr hauls	Nr zeros	Mean (kg)	sd (kg)
2013	27.4.b	81	62	0.91	0.71
2014	27.4.b	34	20	6.14	8.99
2015	27.4.b	119	115	2.05	1.38
2016	27.4.b	73	60	3.46	2.98
2017	27.4.b	81	43	2.77	2.19
2013	27.4.c	137	13	17.08	16.42
2014	27.4.c	82	11	16.20	27.67
2015	27.4.c	90	26	11.13	19.30
2016	27.4.c	49	9	7.17	10.00
2017	27.4.c	8	4	6.38	2.72
2013	27.7.a	224	29	43.03	42.56
2014	27.7.a	143	7	31.69	38.84
2015	27.7.a	112	1	35.37	41.63
2016	27.7.a	11	0	56.07	23.66
2017	27.7.a	7	0	100.74	76.50
2013	27.7.d	159	42	8.11	9.55
2014	27.7.d	241	71	4.85	9.68
2015	27.7.d	224	34	12.59	19.14
2016	27.7.d	272	108	8.80	30.87
2017	27.7.d	271	63	15.29	40.69
2013	27.7.e	48	47	1.00	-
2015	27.7.e	21	17	0.65	0.44
2016	27.7.e	48	41	1.20	0.77
2017	27.7.e	32	21	18.03	18.92
2013	27.7.fg	91	32	6.39	7.51
2014	27.7.fg	141	72	6.79	9.02
2015	27.7.fg	145	73	4.40	4.36
2016	27.7.fg	151	97	17.05	29.17
2017	27.7.fg	176	107	8.19	8.91
2013	27.8.ab	60	54	0.70	0.33
2014	27.8.ab	105	99	0.88	0.54
2015	27.8.ab	56	54	1.00	0.85
2016	27.8.ab	95	85	1.40	1.33
2017	27.8.ab	83	72	1.25	0.74

4.2.2 A comparison of discard raising methods applied to *Raja clavata*

Method 1: Raising of raw discard data by effort

A straightforward method to estimate the total discard quantity is based on direct raising of the raw discard observations. This involves two steps, a raising step to calculate discards at the trip level, and a second raising step to estimate the total quantity at the métier level. In practice, the observed discards per haul are summed by trip, and subsequently raised by the proportion of observed fishing effort (duration of the observed hauls expressed in hours) to the total fishing hours (duration of all hauls in that trip). These discard estimates of the observed fishing trips are then raised in a similar way to obtain a total discard estimate at the fleet or métier level. The discards over the observed trips are summed by quarter (year, in the Belgian case) and divided by the proportion of observed fishing effort (hours) versus the total effort (hours) of all trips as registered in the vessel logbooks.

To quantify uncertainty of the estimated discard quantities, a bootstrap simulation study was conducted. This was done by resampling the observed hauls within a quarter with replacement. Subsequently, the raising procedure as described above, was applied to the simulated dataset to obtain a discard estimate. This procedure was repeated 1000 times. The 0.025 and 0.975 quantiles was calculated from the simulated discard estimate to calculate a 95% confidence interval. The results of this analysis are shown in Figure 4.9.

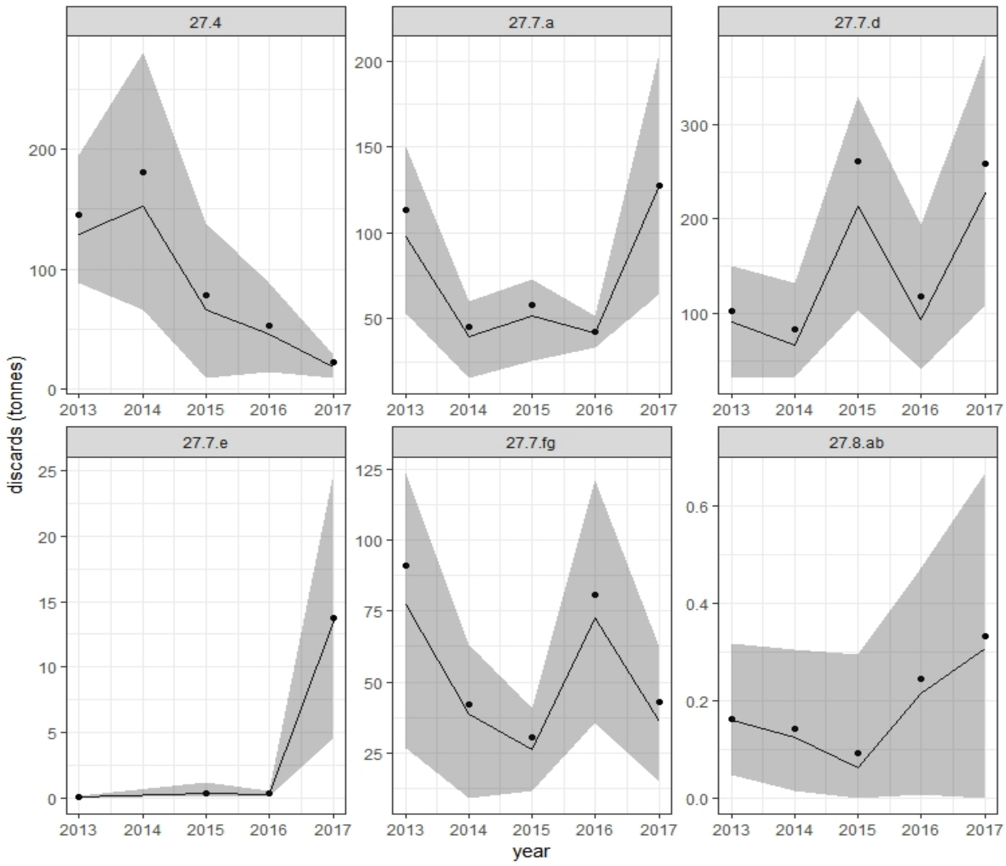


Figure 4.9: Discard estimates raised by effort, of the Belgian beam trawl fleet (métier TBB_DEF_70-99; TBB_DEF_>=120) in each ICES division per year. The black line shows the discard estimates calculated on the true data. The black dots and grey shade represent the median and 0.025-0.975 quantiles of the estimates obtained through bootstrap simulation, respectively.

Method 2: Raising of raw discard data by effort x engine power

The second approach differs from the previous method in the way how discards are raised from the trip to the fleet level. The first, within trip raising step is similar, but in the second raising step, the proportion of the kW x hours fished of the observed trips versus the total effort (in kW hours) is used to raise the discards from the trip level to the fleet level. As such, the total estimates are corrected for differences in engine power between fishing vessels. This may be of interest in case of e.g. a beam trawl fleet where a vessel's engine power is known to have a positive relationship with the catch rates of sole (*Solea solea*) and plaice (*Pleuronectes platessa*) which is mainly caused by the fact that more powerful vessels can increase fishing speed (and thus the swept area) and the number of tickler chains used in front of the gear (and thus penetration depth). Again, a bootstrap simulation was performed to construct a 95% confidence interval (Figure 4.10).

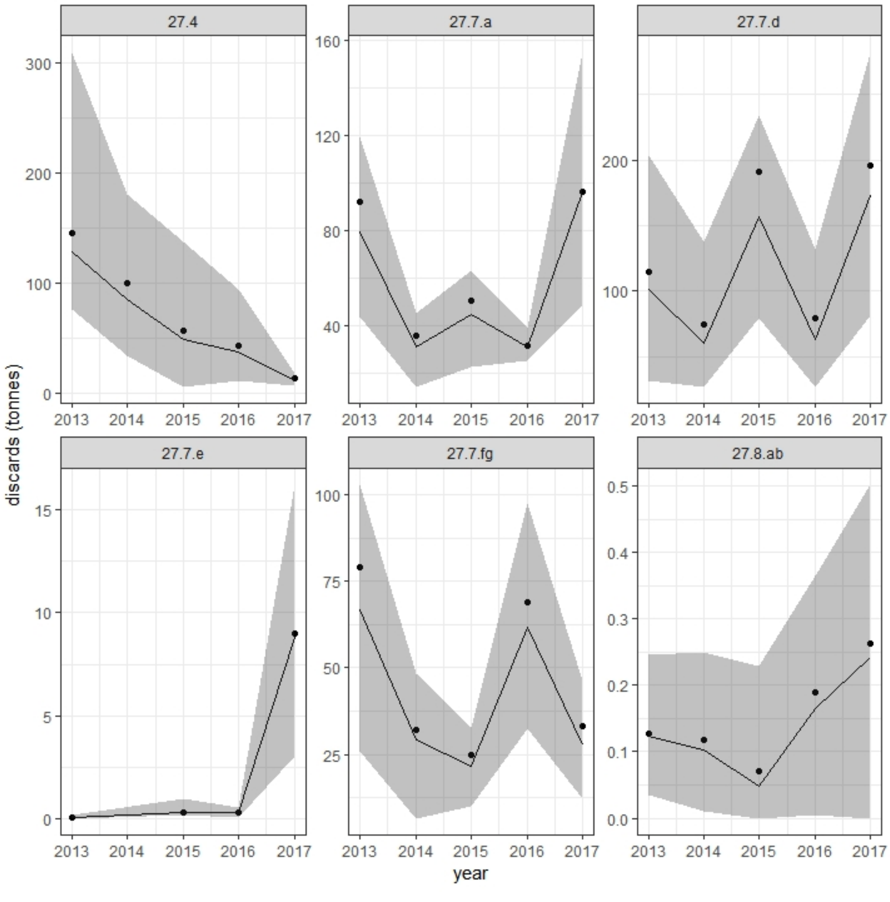


Figure 4.10: Discard estimates, raised by effort x engine power, of the Belgian beam trawl fleet (métier TBB_DEF_70-99; TBB_DEF_>=120) in each ICES division per year. The black line shows the discard estimates calculated on the true data. The black dots and grey shade represent the median and 0.025-0.975 quantiles of the estimates obtained through bootstrap simulation, respectively.

Method 3: Raising of raw discard data by landings

As an alternative to the previous methods, discards can be raised by the total landings. In this method, the proportion of the landings associated with the observed discards to the total landings of a trip is used to calculate the landings by trip. In the next step, the total discards and total landings from the observed trips are calculated, and finally the total discards of the observed trips is raised to the fleet level using the proportion of landings of the observed trips versus the total landings of the fleet (in a specific quarter and ICES subdivision) (Figure 4.11). As such, one avoids the use of effort data in the raising procedure. This is often considered to be more robust, as comparing different sources of fishing effort (haul duration as registered in observer trips, fishing hours as registered in vessel logbooks, and VMS based effort estimates) may induce an important bias, while landing data is generally more reliable.

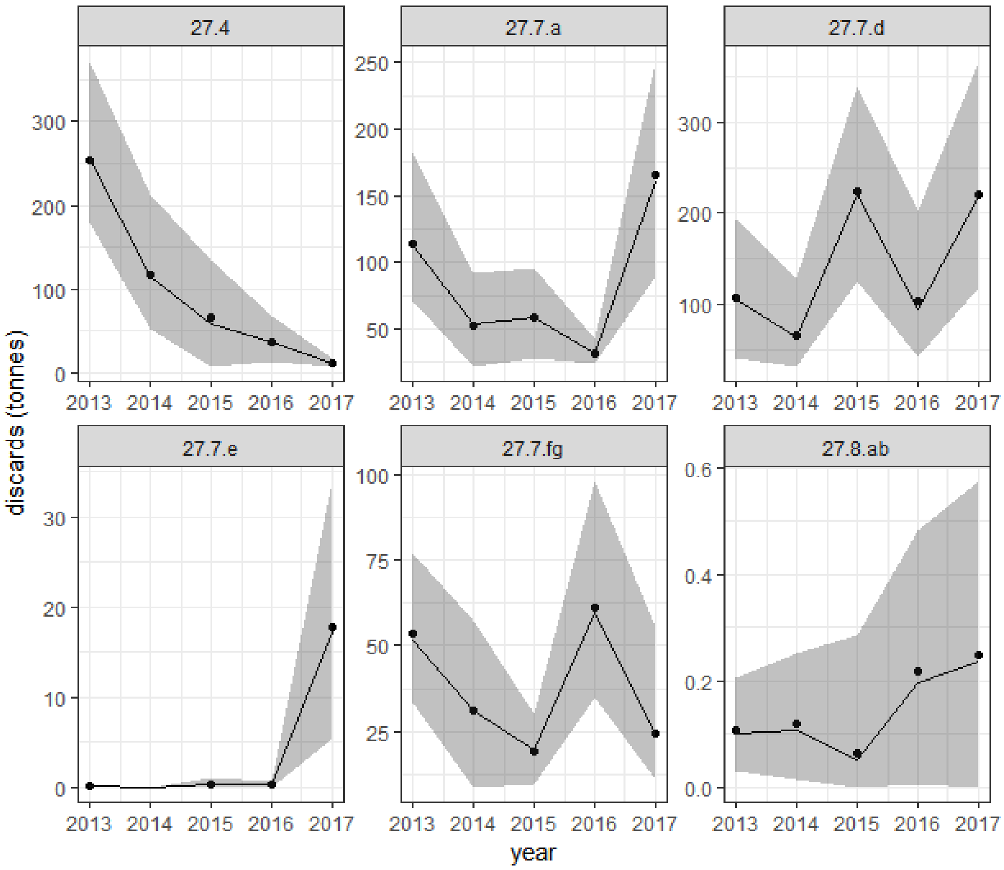


Figure 4.11: Discard estimates, raised by effort x engine power, of the Belgian beam trawl fleet (métier TBB_DEF_70-99; TBB_DEF_>=120) in each ICES division per year. The black line shows the discard estimates calculated on the true data. The black dots and grey shade represent the median and 0.025–0.975 quantiles of the estimates obtained through bootstrap simulation, respectively.

Method 4: Spatio-temporal modelling of discards per unit of effort

As a final approach, the observed discards per haul were standardized in a spatio-temporal regression model. This approach is similar to the standardization procedures applied to catch/landings per unit effort data in order to obtain an index of abundance used in stock assessment models. The idea is to standardize the discards per unit effort in order to remove all effects that are not related to abundance. Obviously, these effects are dependent on the characteristics of a fishery, and the availability of data. For instance, in a trawl fishery one would typically use a vessel's engine power as a fixed effect, and/or other covariates that influence the efficiency of the gear (e.g. mesh size, gear configuration). Besides the technical characteristics of the fishery, standardization should also aim to account for the spatio-temporal dynamics of the fleet and fish stock. Depending on the resolution, ICES statistical rectangles can be used as categorical variables in a model eventually in interaction with a temporal variable (e.g. catch quarter/month or date). Finally, other effects such as depth, temperature or habitat information can be included in the models, and hierarchical structures (e.g. hauls that belong to the same trip, and different trips from the same vessel) can be modelled through the use of random effects, thereby accounting for the sampling design of the data.

In the case of the Belgian observer data, each record contains information on the trip and vessel (métier code level 7, engine power, and vessel code), a time stamp (dd/mm/yy – hh/ss), and spatial point information (coordinates of shooting and hauling of the net) is available. In theory, this would allow to fit a model to the data that includes métier and engine power as fixed effects, the vessel and trip code as random effects, and a spatial field that changes over time. However, since data is only available since 2013, few contrasts are present in the fixed effects covariates (one métier level in all areas, except the North Sea, and a small range of engine powers across the data). Consequently, engine power was not included in the models, but if appropriate, the fleet category (small segment: engine power <= 221 kW; or large segment: engine power >221 kW) was included as a categorical variable in the model. In all models, the observation error was assumed to follow a negative binomial distribution with a logarithmic link function between the response variable and the linear predictor.

Furthermore, we did not include the trip and/or vessel reference number as random effects in the model. Including these effects would account for the intra-class correlation between observations of the same vessel and/or trip and as such correct for the sampling design. In general, this would enlarge the confidence bounds on the estimated parameters. However, to keep the models simple, and to allow better comparison with the previous raising procedures, we opted not to do so.

A spatial field was estimated to account for the spatial correlation structure caused by the migratory behaviour of most fish stocks, and the dynamics of the fleet. In fact, the spatial field was approximated through a Gaussian Markov Random Field with a Matern correlation structure. This allowed to use the routines of R-INLA, being the SPDE (Stochastic Partial Differential Equations) approach and Laplace approximation to estimate the latent effects at each node in the mesh. Subsequently, the posterior means and standard deviation of each latent effect can be used to interpolate and visualize the spatial field at a high spatial resolution (Figure 4.12). Due to the limited number of data points and the short time-series, no spatiotemporal models were fitted to the data. Instead, a random walk model of the second order was used to model the annual trend in discards per unit effort except for the Western English Channel and Bay of Biscay, where no temporal trend was included in the model.

The spatial fields in Figure 4.12 show how the sampling locations influence the estimates of the spatial field. For instance, in the North Sea, no hauls have been monitored in the north-western part which results in the estimate of the field being 0 in this part of the North Sea with a high uncertainty that increases to the north-western direction. In contrast, in the southern part of the

North Sea, a clear spatial pattern is observed with, as expected, the highest discard rates in the Estuary of the Thames.

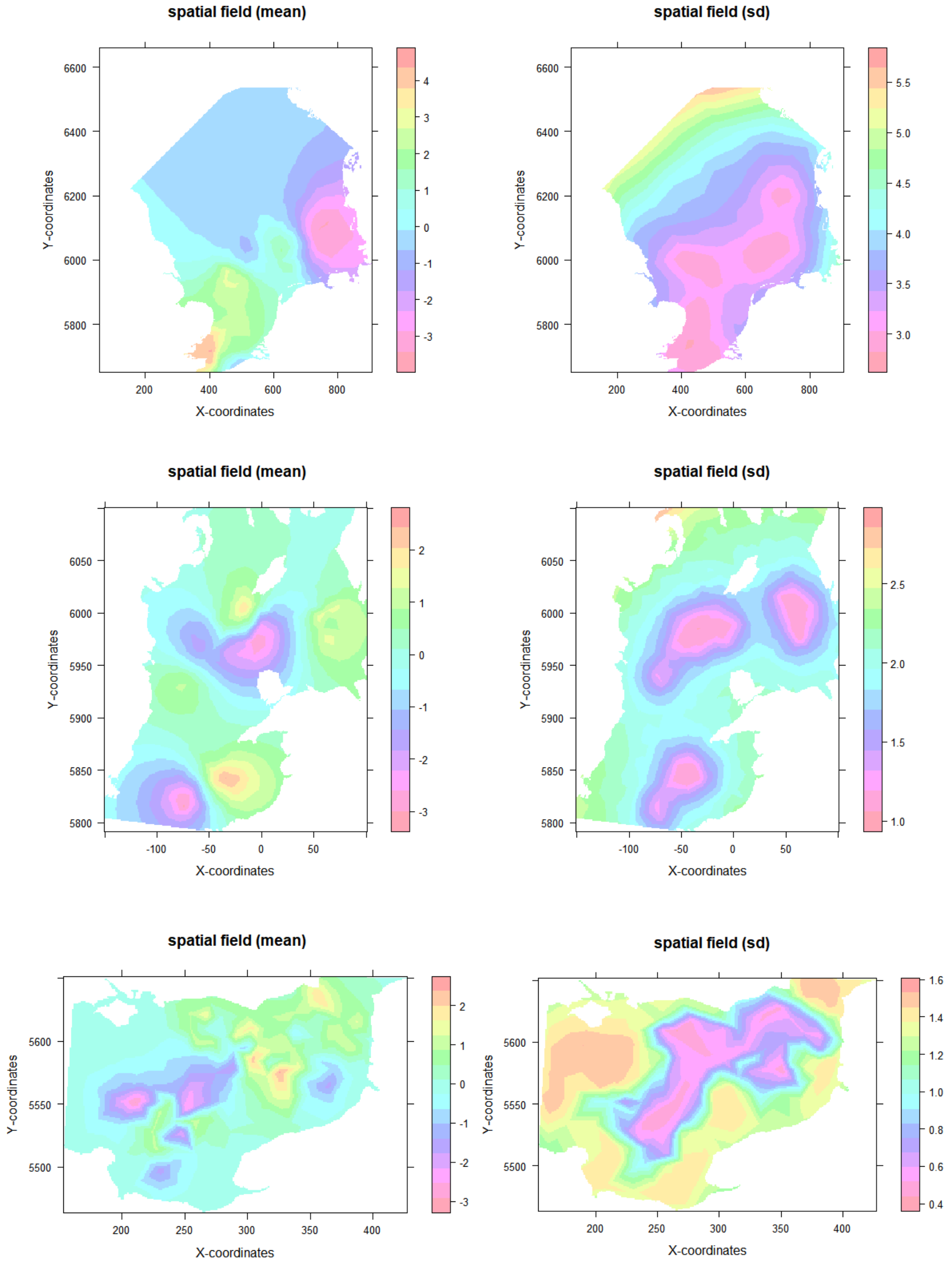


Figure 4.12: Mean and standard deviation of the estimated spatial fields in each ICES division. The panels show the North Sea, Irish Sea, Eastern English Channel, Western English Channel, Celtic Sea and Bay of Biscay from top to bottom. Remark that the panels display the logarithm of the spatial field.

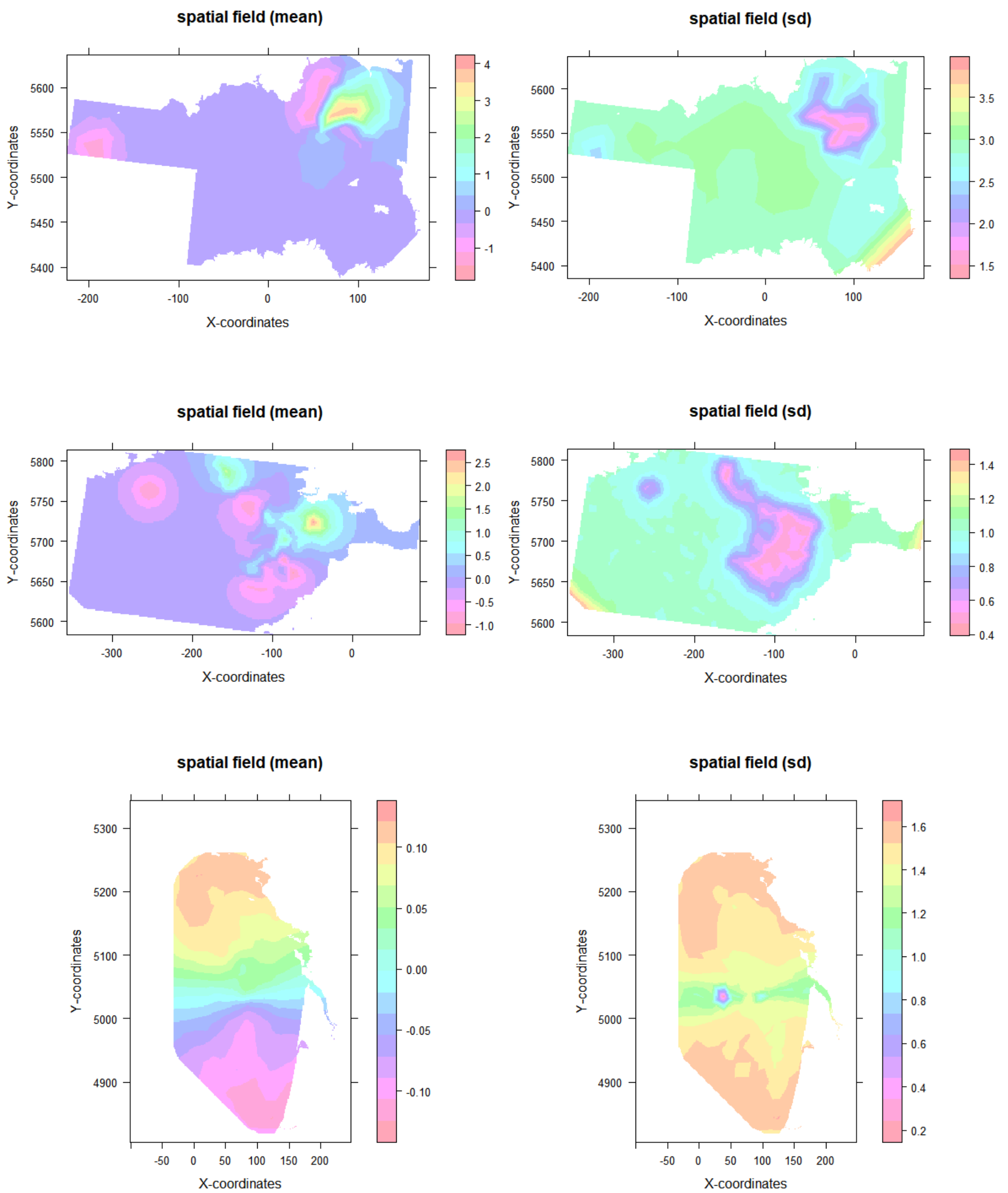


Figure 4.12 (cont'): Mean and standard deviation of the estimated spatial fields in each ICES division. The panels show the North Sea, Irish Sea, Eastern English Channel, Western English Channel, Celtic Sea and Bay of Biscay from top to bottom. Remark that the panels display the logarithm of the spatial field.

To model the discards in the Celtic Sea, Western English Channel, and Bay of Biscay, a zero-inflated model was fitted to the data to account for the high number of hauls without discards encountered in the data. In fact, the zero-inflated negative binomial model combines a binomial regression on all data, with presence (1)-absence (0) as response variable, and a negative binomial regression model on the positive discard rates. For both models, the same structure of the spatial field was used.

For this exercise, model validation was kept simple: visual inspection of the residuals and biological sense were used to reject or accept the models. Obviously, it is recommended to use other tools such as information criteria, posterior predictive checks, and simulation for appropriate model validation.

Finally, the models were used to predict discards from VMS data. Fishing pings and effort were estimated from VMS data using the vmstools package. To validate this procedure, we compared the estimated effort with the effort as registered by fishers in their logbooks, and eventually corrected to match this effort. Subsequently, the coordinates of the identified VMS fishing pings were used to predict discards with the regression models (Figure 4.13).

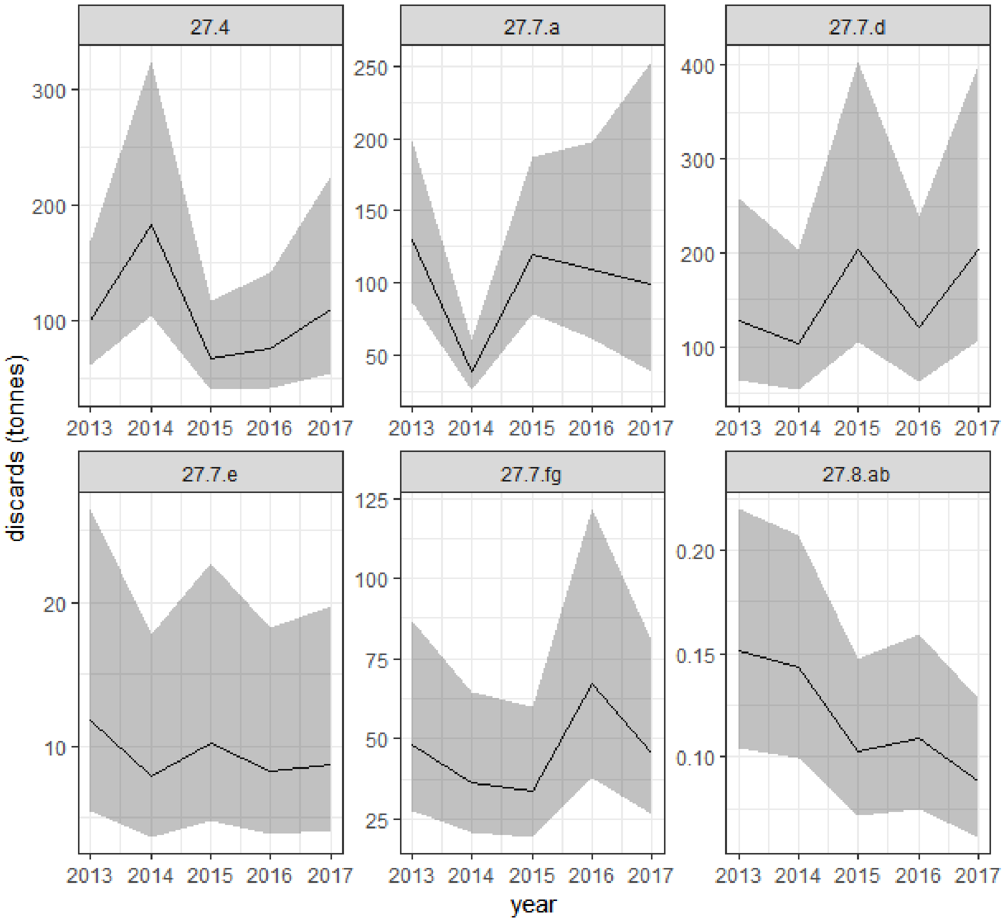


Figure 4.13: Estimated discard quantities obtained by predicting discards per VMS fishing ping with a spatiotemporal regression. The black line indicates the mean value while the grey shades indicate the 95% confidence interval.

4.2.3 Discussion

In general, the different raising procedures result in similar outcomes in terms of estimated quantities and width of the confidence intervals (Figure 4.13). This is especially the case for the first three discard raising procedures described in this case study. Nevertheless, some remarkable differences are found in the North Sea, Irish Sea and Western English Channel between the direct raising procedures and the spatio-temporal model-derived discard estimates.

The trend of the *spatio-temporal* discard estimate in the North Sea strongly differs from the trend obtained with the alternative discard raising procedures that indicate a strong decline in discards per unit effort. Inspecting the observer data shows that this can be explained by the spatio-temporal dynamics of the observer program. As shown in Figure 4.8, since 2016, the number of observation in the Thames Estuary dropped while more observations in the southern part of the

North Sea occurred between 52° and 54° latitude where abundance of *Raja clavata* is limited. Obviously, ignoring the spatial shift of the observer programme in the raising procedure is likely to result in a biased discard estimate if the discards per unit effort have an irregular spatial pattern. In contrast, the spatial model enables to deal with such a shift in the observer program, as the model will still assign higher discard quantities of *Raja clavata* to fishing pings in the Estuary of the Thames (Figure 4.13). The same issue is observed in the Irish Sea: the total discard quantity of the non-spatial raising procedures are strongly dependent on the number of observed hauls in the Cardigan Bay which is a known hotspot of *Raja clavata* in the Irish Sea.

Another advantage of the modelling approach is its ability to provide a discard estimate for years without observations. In the case of the Belgian onboard observer program, this happened in the Western English Channel in 2014. Similar to spatial interpolation based on the latent effects of a two dimensional spatial mesh, temporal interpolation can be done on a one dimensional mesh that may be applied to model irregular time series. Equally, temporal interpolation could also be applied to provide discard estimates per quarter when the temporal coverage of the data is too low.

The ability to model presence/absence of discards seems also to improve the accuracy of estimated discard quantities compared to the direct raising procedures. This is illustrated by the discard estimates from 2013–2016 in the Western English Channel. As shown in Table 4.4, from 2013–2016, no discards of *Raja clavata* were registered in approximately 90% of the observed hauls, while the proportion of zero discard catches dropped in 2017 to ~66%. In the direct raising procedures, this translates to the absence of discards from 2013–2016, and a strong increase in 2017. In contrast, the modelling approach enables to estimate the process of presence-absence of discards in space and time which results in a less erratic total discard pattern in the case of the Western English Channel.

This comparison illustrated that the spatio-temporal modelling approach to estimate discards seems more robust in situations where the spatio-temporal coverage of the observer programme is limited and the discard per unit effort has strong spatio-temporal patterns. The modelling approach allows to use all the data from the start of the observer program, and as such provide better estimates that are likely to improve if more data is collected. In addition, a statistical model allows a good quantification of uncertainty. However, one drawback is that a model that fits all does not exist. Therefore, deliberate choices (e.g. statistical distribution, fixed effects, spatial resolution, priors), supported through extensive model validation, should be made when developing models.

5 ToR B: Evaluate and define the data quality and onboard coverage; discard retention patterns between fleets and countries; discard survival, as well as the definition of acceptable types/sources of data required for advice.

5.1 ToR b description:

ToR b: "Evaluate and define the data quality and onboard coverage; discard retention patterns between fleets and countries; discard survival, as well as the definition of acceptable types/sources of data required for advice."

WKSHARK5 participants of this subgroup:

- Claudia Junge (IMR, Norway)
- Noémi Van Bogaert (ILVO, Belgium)
- Loes Vandecasteele (ILVO, Belgium)
- Barbara Serra-Pereira (IPMA, Portugal)
- Paddy Walker (chair, the Netherlands)
- Harriet van Overzee (WUR, the Netherlands)

Main discussion points and questions:

- Can we identify ICES-areas where we have no discard data at all?
- Are there national programs that we might be missing?
- What are the different types of programs (e.g. industry vs. self-sampling)?
- What will be the main goal of the metadata table?
- Are there any general guidelines or objective criteria if acceptable types/sources of data?

5.2 Output

For ToR b, we identified four main tasks:

1. A metadata table template showing the main gaps in discard data per ICES-area, métier ((Discards_gap_table[2]))
2. A species-specific table, which can be linked to the metadata table using a unique ID, with more detailed info per species, including survival rate estimates (if present), Section 5.2.2.
3. R-plots of the discards per gear/areas and more detailed table of the same information with areas split in divisions (based on R-code and excel files provided by WGEF chair Sam Shepherd), Section 5.2.3.
4. Summary of discard retention patterns, based on previous WKSHARK and WGEF reports, Annex 2.

[2] Password required - to access Discard gap table, please contact the ICES Secretariat

5.2.1 Metadata table

The main goal of this table is to provide an overview of the main gaps in Elasmobranch discard data per ICES-area. This table is not meant as a template for a data call, but for our own understanding. The metadata table has been adapted based on Table 3.1. and Table 3.2. of the WKSHARK3 report and the Table "DC_Annex 7.8.1. WGCATCHDataQualQuant" provided by CEFAS. For each column header a definition is provided in a separate sheet of the Excel (sheet 1).
The table contains the following data on sheet 2:

ID code	ICES sub-area	Country	Name program	DCF (yes/no)	Pro-gramme type	Temporal resolution	Quarter	Highest métier level	Metier	Start year

End year	#Trips Sampled	#Hauls Sampled	%Fleet Coverage	Estimator	Threshold	# sharks	# rays and skates	# chime-ras	Contact

The table contains the following data on sheet 3:

ID code	ICES-area	Genus	Species	Data type	Survival estimate?	Survival reference	Quality score

5.2.2 Species specific table with survival rate estimates (and references)

The species-specific table provides a more detailed overview of discard data on species-level. The table can be linked to the metadata table using a unique ID (first column). Survival estimates (if available) can be added to this table. An overview of survival estimates per species and gear were obtained from Rihan *et al*. (2019). However, some of the listed studies in the Rihan *et al*. (2019) table do not meet all criteria defined by WGMEDS to obtain reliable and robust survival estimates. For example, some studies did not allow for mortality to asymptote. Hence, if survival estimates are going to be used in stock assessments, a careful evaluation should be made on whether these estimates are robust enough based on the information provided in the study. Besides this problem, there are still many gaps for different species x gear combinations. At the moment, different survival studies are ongoing in Europe, so new, robust estimates should be available soon.

Table 5.1: Overview table of peer-reviewed elasmobranch survival studies (from: Rihan *et al*. 2019 Requirements for Documentation, Data Collection and Scientific Evaluations)

Common name	Latin name	Gear	ICES area	min%	max%	Mindays	Maxdays	N	Treatment	Reference	Delegated Regulation (EU) No	WGMEDS guidelines ok?
Blonde ray	*R. brachyura*	Beam trawl	7.e	25	74	2	3	26	Tow duration	Ellis *et al.* 2012	2018/2034	Yes
Blonde ray	*R. brachyura*	Beam trawl	7.e	41	44	2	3	26	Modelled results to asymp-tote from Ellis *et al.* 2012	Catchpole *et al.* 2017	2018/2034	Yes
Blonde ray	*R. brachyura*	Otter trawl	7.f	NA	92	20	111	25	DST tags, across vitality classes A,B, and D	Catchpole *et al.* 2017	2018/2034	Yes
Blonde ray	*R. brachyura*	Otter trawl	7.f	55	67	0	<2	11	Survival was not monitored until asymptote	Enever *et al.* 2009	2018/2034	No
Cuckoo ray	*L. naevus*	Beam trawl	Western Eng-lish Channel (7.e)	34 %	35 %	n/a	n/a	26	Modelled results to ass-ymptote from Ellis *et al.* 2012	Catchpole *et al.* 2017	2018/2034	Yes
Cuckoo ray	*L. naevus*	Beam trawl	Western Eng-lish Channel (7.e)	25 %	83 %	2	3	26	Tow duration	Ellis *et al.* 2012	2018/2034	Yes
Cuckoo ray	*L. naevus*	Trammel nets	Bristol Channel (7.f)	n/a	33 %	0	<2	6	Survival was not monitored until asymptote	Enever *et al.* 2009	2018/2034	No
Cuckoo ray	*L. naevus*	Beam trawl	Irish Sea (7.a)	n/a	59 %	0	6	32	Survival was not monitored until asymptote, no con-trols were used	Kaiser and Spencer 1995	2018/2034	No
Cuckoo ray	*L. naevus*	Trammel nets	Balearic Islands	60	71 %	7	7	296	n/a	Catanese *et al.*, 2018	2018/2036	No
Small-eyed ray	*R. microcellata*	Trammel nets	Bristol Channel (7.f)	55 %	67 %	2	2	278	Mesh size	Enever *et al.* 2010	2018/2034	No
Small-eyed ray	*R. microcellata*	Trammel nets	Bristol Channel (7.f)	n/a	51 %	0	<3	39	Survival was not monitored until asymptote	Enever *et al.* 2009	2018/2034	No
Small-eyed ray	*R. microcellata*	Beam trawl	Western Eng-lish Channel (7.e)	0	1	n/a	n/a	n/a	23% Excellent/Good, 72% Moderate/Poor, 5% dead	Ellis *et al.* 2012; Bird *et al.* 2018	2018/2034	No

Common name	Latin name	Gear	ICES area	min%	max%	Mindays	Maxdays	N	Treatment	Reference	Delegated Regulation (EU) No	WGMEDS guidelines ok?
Spotted ray	*R. montagui*	Beam trawl	Western English Channel (7.e)	0.4	0.67	2	3	14	Tow duration	Ellis *et al.* 2012	2018/2034	Yes
Spotted ray	*R. montagui*	Trammel nets	n/a	n/a	n/a	n/a	n/a	457	13% Excellent/Good, 74% Moderate/Poor, 14% dead	Bird *et al.* 2018	2018/2034; 2018/2035	No
Spotted ray	*R. montagui*	Gillnets	n/a	n/a	n/a	n/a	n/a	47	66% Excellent/Good, 26% Moderate/Poor, 6% dead	Bird *et al.* 2018	2018/2034; 2018/2035	No
Spotted ray	*R. montagui*	Pulse trawl	North Sea (4.c)	21	67	21	21	9	Gear deployment duration	Schram and Molenaar 2018b	2018/2035	Not yet reviewed
Thornback ray	*R. clavata*	Otter trawl	Bristol Channel (7.f)	0.57	0.69	3	3	47	Commercial hauls (2.7-4.3 h)	Catchpole *et al.* 2017	2018/2035	Yes
Thornback ray	*R. clavata*	Otter trawl	Bristol Channel (7.f)	0.77	0.79	3	3	34	Short hauls (0.75-2.0 h)	Catchpole *et al.* 2017	2018/2035	Yes
Thornback ray	*R. clavata*	Trammel nets	Bristol Channel (7.f)	0.57	0.69	n/a	n/a	162	Enever *et al.* 2009 estimates modelled to asymptote	Catchpole *et al.* 2017	2018/2035	Yes
Thornback ray	*R. clavata*	Trammel nets	Bristol Channel (7.f)	0.54	0.87	0	<3	162	Not monitored to asymptote; survival rate overestimated; 78% Excellent/Good, 11% Moderate/Poor, 1% dead	Enever *et al.* 2009; Bird *et al.* 2018	2018/2035	No
Thornback ray	*R. clavata*	Trammel nets	North Sea and English Channel (4.c, 7.d)	0	0.96	3	317	60	DST tags, across vitality classes A,B, and D	Catchpole *et al.* 2017	2018/2035	Yes
Thornback ray	*R. clavata*	Beam trawl	North Sea (4.c)	0.72	0.77	1	2.5	249	Research beam trawls, mixed ray species	Depestele *et al.*, 2014	2018/2035	No
Thornback ray	*R. clavata*	Trammel nets	North Sea (4.c)	0.59	0.87	0	<3	162	Survival was not monitored until asymptote	Enever *et al.*, 2009	2018/2035	No
Thornback ray	*R. clavata*	Trammel nets	North Sea (4.c)	0.61	0.93	n/a	n/a	n/a	n/a	Bird *et al.* 2018	2018/2035	No

Common name	Latin name	Gear	ICES area	min%	max%	Mindays	Maxdays	N	Treatment	Reference	Delegated Regulation (EU) No	WGMEDS guidelines ok?
Thornback ray	*R. clavata*	Otter trawl	North Sea (4.c)	n/a	n/a	n/a	n/a	537	Vitality data only and tagging	Randall *et al.* 2018	2018/2035	No
Thornback ray	*R. clavata*	Beam trawl	North Sea (4.c)	0	0.82	14	180	95	Gear deployment duration	Schram and Molenaar 2018b	2018/2035	Not yet reviewed
Thornback ray	*R. clavata*	Trammel nets	Balearic Islands	0.08	0.16	7	7	224	n/a	Catanese *et al.*, 2018	2018/2036	No
Thornback ray	*R. clavata*	Otter trawl	Mediterranean Sea	0.44	0.92	0	<2	120	Survival was not monitored until asymptote	Saygu and Deval 2014	2018/2036	No

5.2.3 Discard plots per gear/area

The R-script provided by Sam Shepherd (chair WGEF) was adapted in order to produce ICES-area x species grid plots showing the reported discards for each of the gear types GNS, OTB, PTB, TBB and other bottom trawls for the years 2009–2017. The different data sources (i.e. countries) were plotted as separate bar charts with different colours, since the method used for raising the data differs per country. To generate the plots, the discard data from different ICES divisions were summed to the higher level of ICES areas.

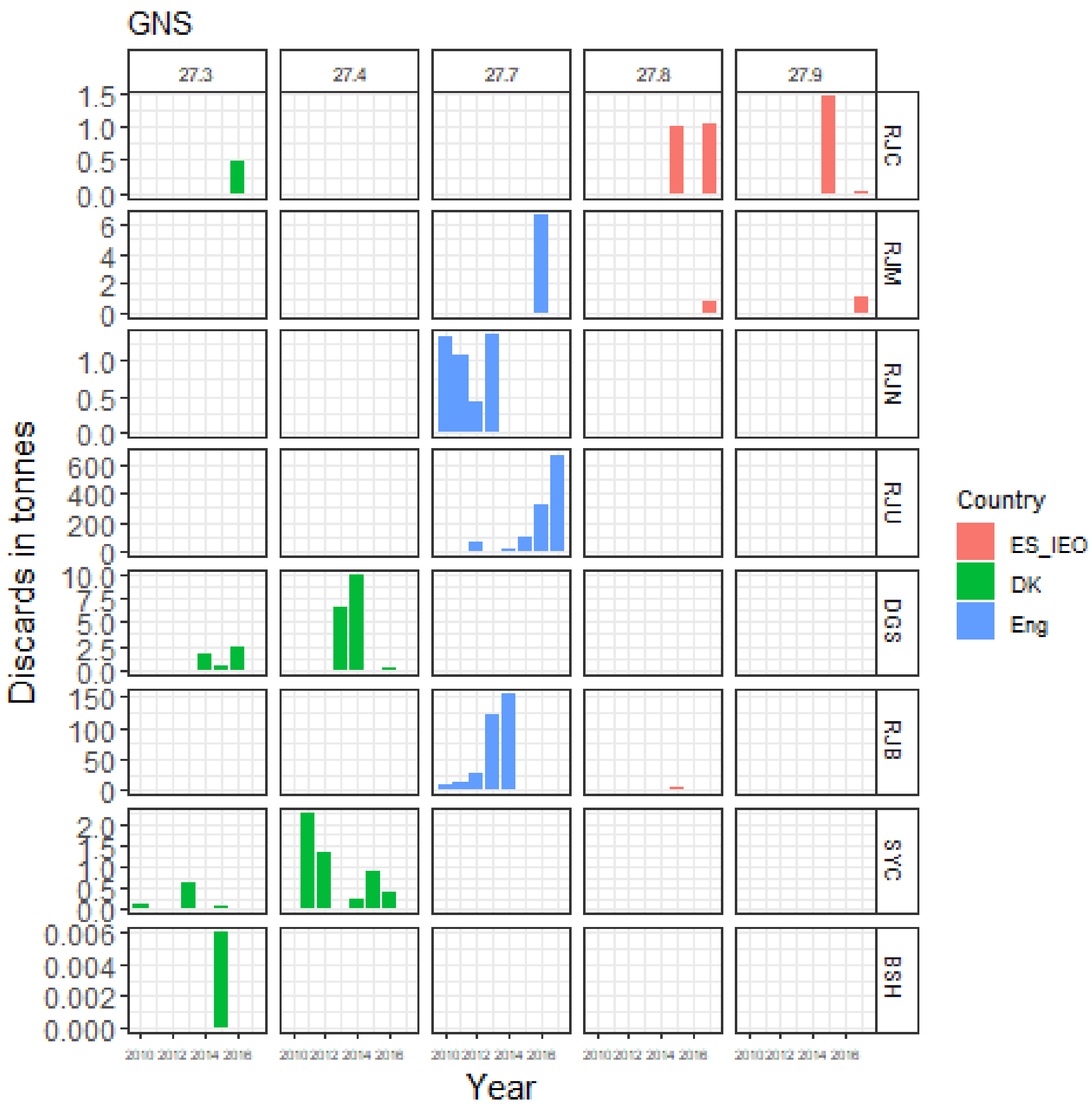


Figure 5.1: Discard data per ICES Division for gillnets (GNS). BSH = *Prionace glauca* ; SYC = *Scyliorhinus canicula*; RJB = common skate complex; DGS = *Squalus acanthias* ; RJU = *Raja undulata*; RJN = *Leucoraja naevus*; RJM = *Raja montagui*; RJC = *Raja clavata*.

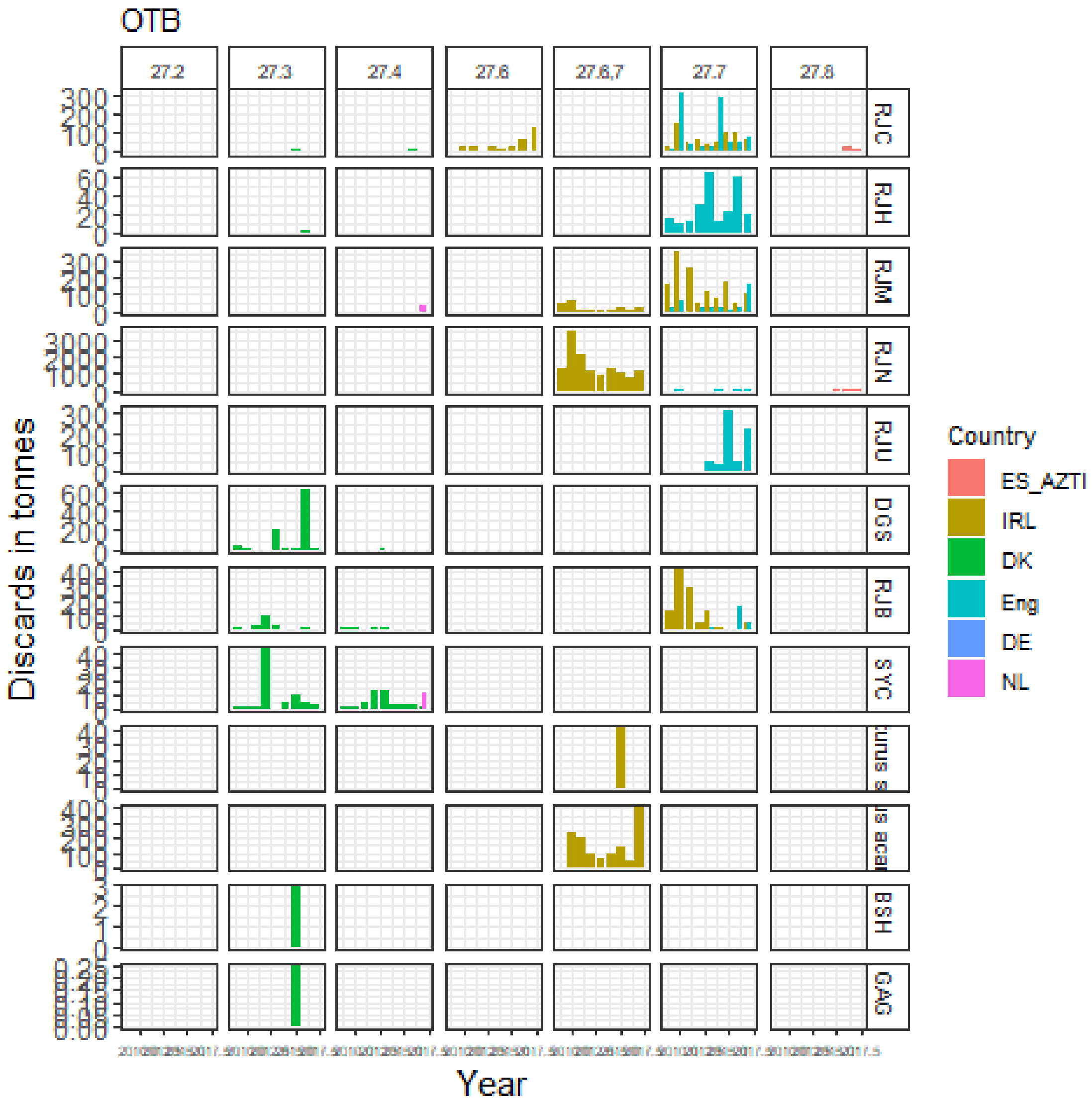


Figure 5.2: Discard data per ICES Division for otter trawls (OTB). GAG = *Galeorhinus galeus*; BSH = *Prionace glauca* ; SYC = *Scyliorhinus canicula*; RJB = common skate complex; DGS = *Squalus acanthias*; RJU = *Raja undulata*; RJN = *Leucoraja naevus*; RJM = *Raja montagui*; RJH = *Raja brachyuran*; RJC = *Raja clavata*.

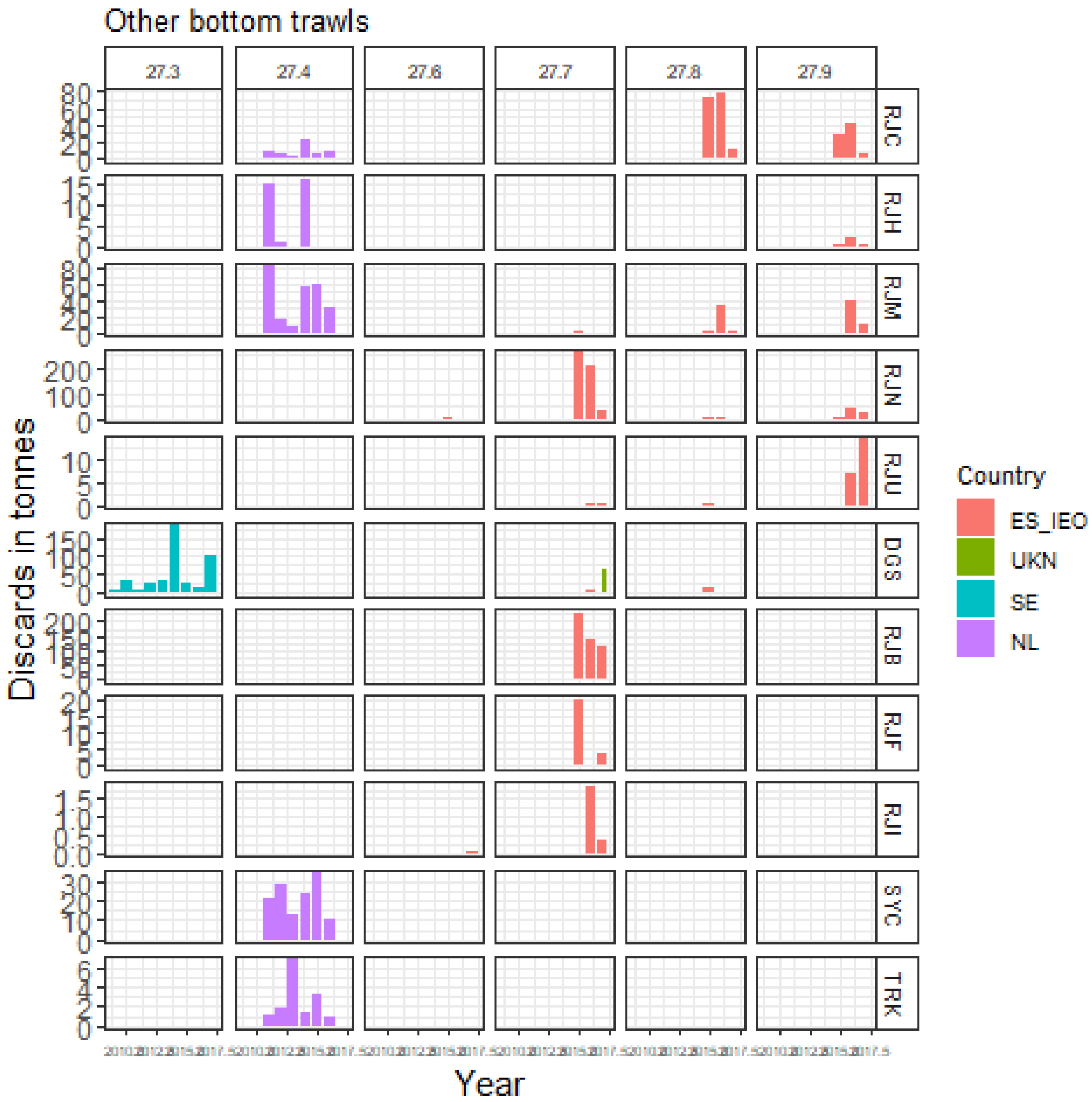


Figure 5.3: Discard data per ICES Division for bottom trawls other than those in figures 5.2-5.5 etc TRK = Triakidae (smoothhounds); SYC = *Scyliorhinus canicula*; RJI = *Leucoraja circularis* ; RJF = *Leucoraja fullonica*; RJB = common skate complex; DGS = *Squalus acanthias* ; RJU = *Raja undulata*; RJN = *Leucoraja naevus*; RJM = *Raja montagui*; RJH = *Raja brachyura*; RJC = *Raja clavata*.

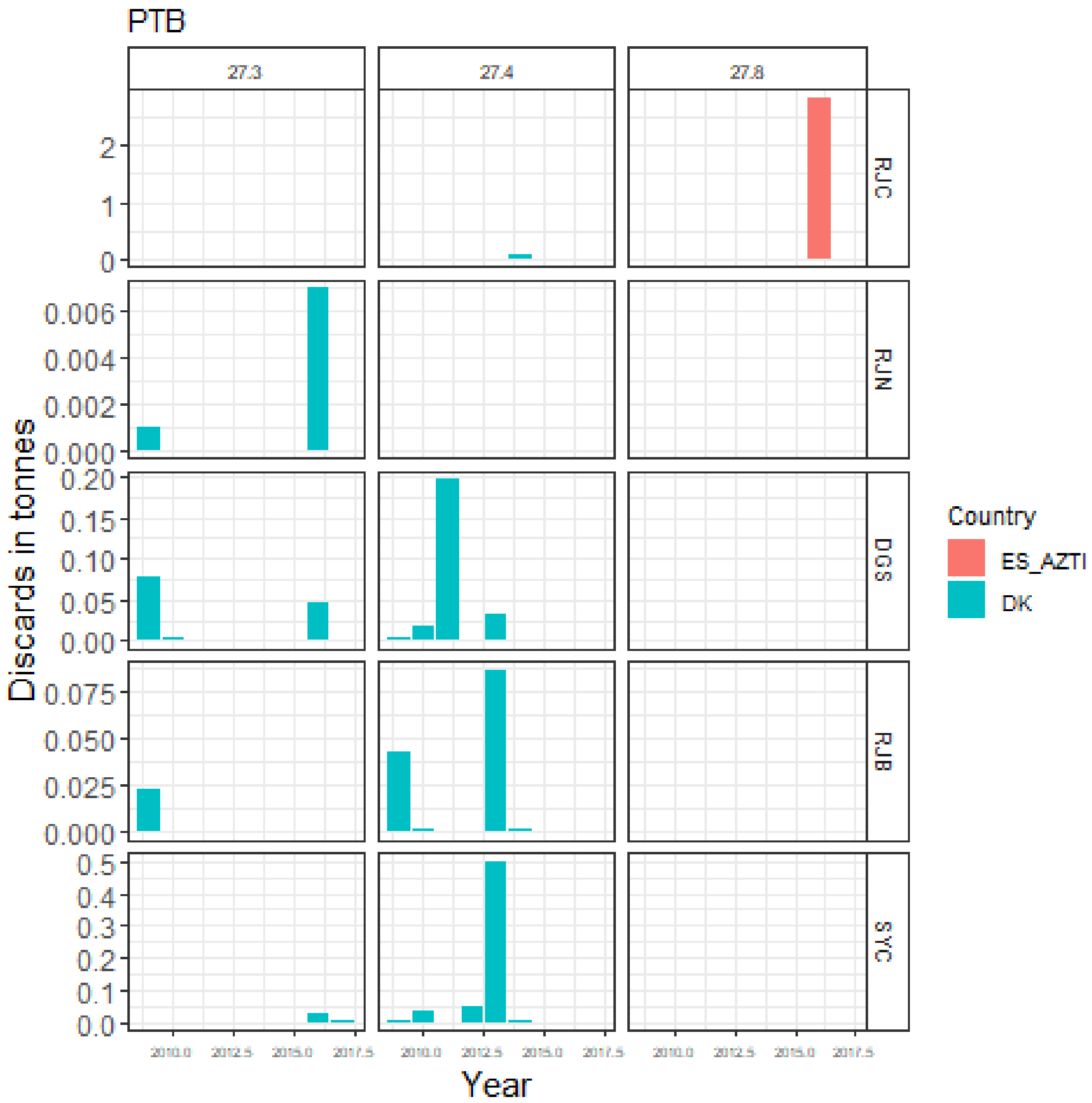


Figure 5.4: Discard data per ICES Division for bottom pair trawls (PTB). SYC = *Scyliorhinus canicula*; RJB = common skate complex; DGS = *Squalus acanthias*; RJN = *Leucoraja naevus*; RJC = *Raja clavata*.

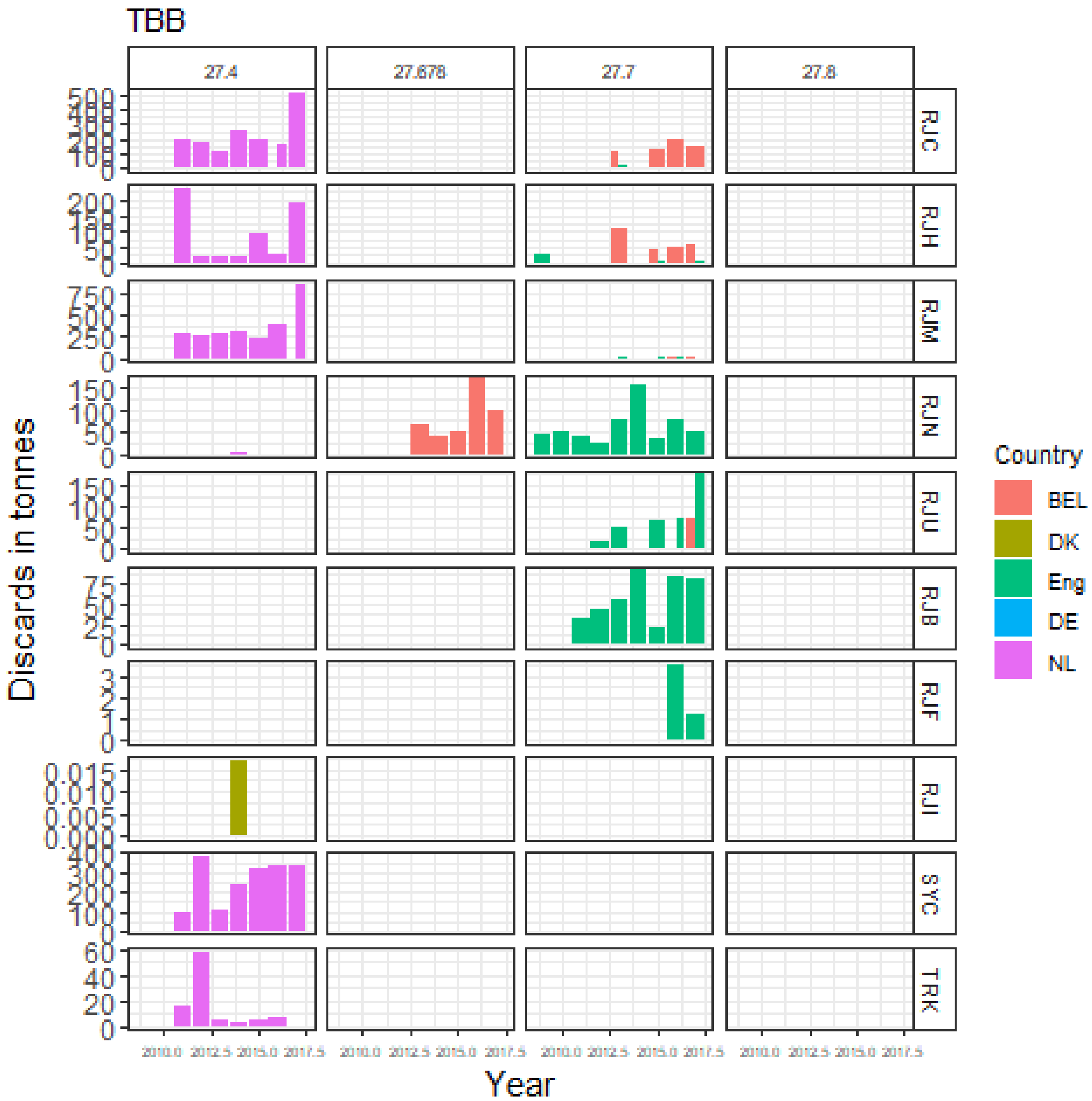


Figure 5.5: Discard data per ICES Division for beam trawls (TBB). TRK = Triakidae (smoothhounds); SYC = *Scyliorhinus canicula*; RJI = *Leucoraja circularis* ; RJF = *Leucoraja fullonica* ; RJB = common skate complex; RJU = *Raja undulata*; RJN = *Leucoraja naevus*; RJM = *Raja montagui*; ; RJH = *Raja brachyura*; RJC = *Raja clavata*.

5.2.4 Discard retention patterns for chondrichthyan species in the Northeast Atlantic (ICES Area 27)

The discard-retention patterns of fish are a function of the capture-gear (i.e. catchability and selectivity), regulations (e.g. size restrictions, quota availability), marketability (e.g. species, size and quality of fish, market price) and individual fisher behaviour (e.g. some vessels may retain fish for bait in pot fisheries; some vessels may only land lower value species if they are in a sufficient quantity). Consequently, there are a range of different discard-retention patterns between various species, across fleets and over time (Silva *et al.*, 2012, 2013; WKSHARK3, WKSHARK4, WGEF 2018 ToR k).

The rationale of this work was to summarize all available information on discard retention patterns of chondrichthyans in the NE Atlantic (ICES Area 27) and update data where possible, which will complement the overall effort of this ToR b) to collate available discard information across species, ICES areas, gear and data collection programmes. This will allow for the identification of data and knowledge gaps to be addressed in future working group meetings and data calls.

All summarised data can be found in Annex 2 of this document.

5.2.5 Conclusions

While observer data are available from many countries, not all métiers are sampled to a level that can allow patterns in discard/retention ratios to be observed. Similarly, few métiers have been intensively sampled enough to allow changes in pattern to be determined. Otter trawl-based métiers have the most number of samples for almost all examined species. These are most likely to be of use in stock assessments. Whilst some nations have large sample sizes for various gillnet métiers, the length-distributions are influenced greatly by mesh size, which would need to be considered in future evaluations of length-based indicators.

6 ToR c: Propose how to include discard information into the advisory process for elasmobranch fishes;

Most elasmobranch stocks are classified as category 3 stocks, i.e. advice is based on an indicative trend of fishery-independent survey data such as the International Beam Trawl Survey (IBTS), demersal Beam Trawl Survey (BTS) as well as long-line surveys (primarily off Iberia). For most stocks the overall index of stock development (stock size indicator) is based on the biomass index of multiple surveys combined (Figure 6.1). Subsequently, the actual advice is derived by multiplying the previously advised landings with the ratio between the two latest index values and the five preceding index values (Table 6.1).

From 2008 onwards, species-specific landings data for the major skate and ray species have been required and have been reported and presented in the advice (Figure 6.2). In addition, several Member States have been collecting information on discards in different demersal fisheries. Both landing and discard data are crucial in providing catch advice, which is gaining an increased focus within the ICES advisory process. Yet, to date, catch data have not been used within the assessment of elasmobranch stocks. There are several reasons why such data have not been utilised, including issues of data quality in terms of species identification as well as size spectrum of the catch and raising procedures. While issues on catch composition have already been discussed within WKSHARK4 (ICES, 2018a), issues with the raising procedures have been taken up in Section 4 (ToR a) of this report.

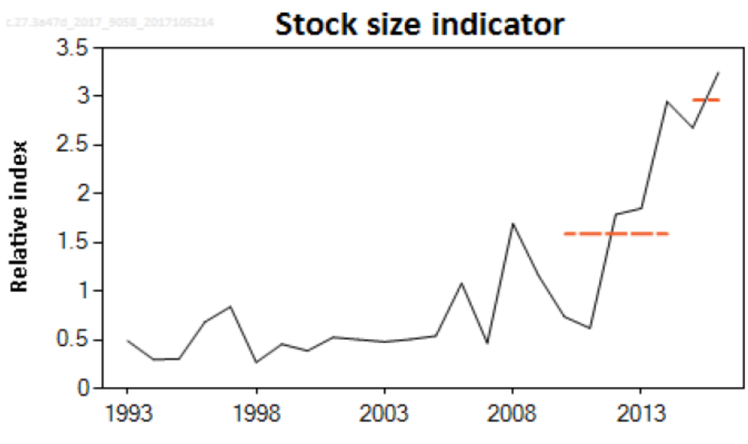


Figure 6.1: Stock size indicator for thornback ray in Subarea 4 and in division 3.a and 7.d. The indicator denotes the annual mean of four fishery-independent surveys, IBTS-Q1, IBTS-Q3, CGFS-Q4 and BTS-ENG-Q3, after results from each survey had been normalized by their long-term means and based on individuals of ≥50 cm total length.

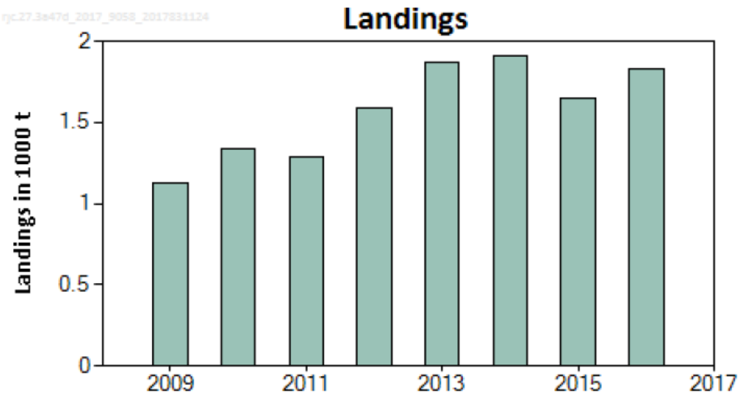


Figure 6.2: ICES estimates of species-specific landings of thornback ray in Subarea 4 and in division 3.a and 7.d since 2009.

Table 6.1: The conventional basis for the catch options of thornback ray in Subarea 4 and divisions 3.a and 7.d.*

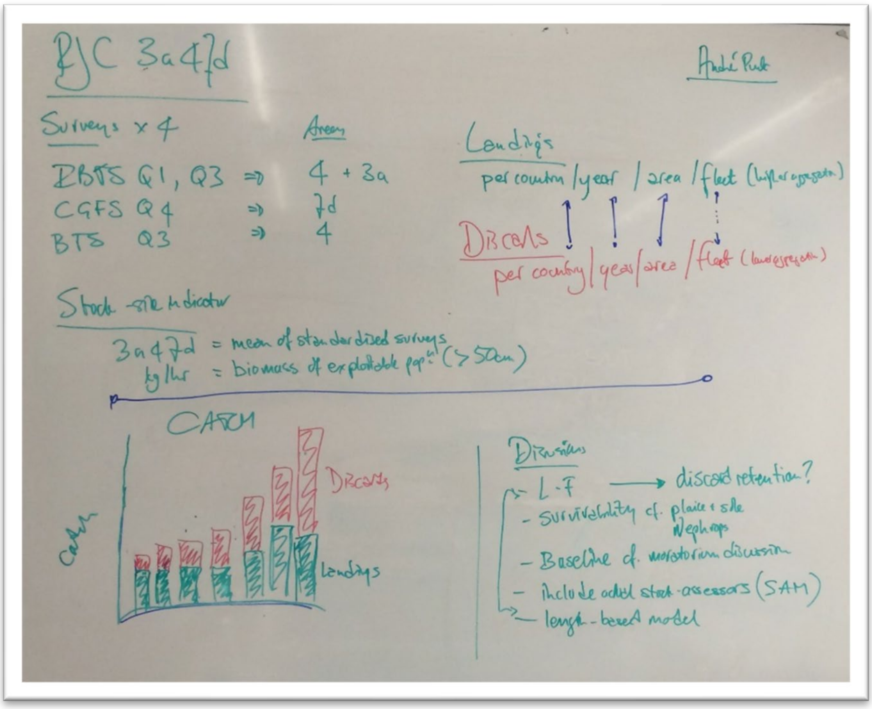
Index A (2015–2016)		2.96
Index B (2010–2014)		1.59
Index ratio (A/B)		1.87
Uncertainty cap	Applied	1.2
Advised landings (2016, 2017)		2145 tonnes
Discard rate		Unknown
Precautionary buffer	Not applied	-
Landings advice **		2743 tonnes

*** Figures in the table are rounded. Calculations were done with unrounded inputs and computed values may not match exactly when calculated using the rounded figures in the table.**

**** (Advised landings × uncertainty cap).**

6.1 Advice 2018–2019 based on survey trend and catch

ToR c) considers the potential of using catch information in providing advice on thornback ray (*Raja clavata*) in the North Sea. Here, the regular advice for 2018 and 2019 based on previous landings is compared with an advice for 2018 and 2019 where catch data would have been used. The 2017 ICES data call requested Member States to make species-specific landings and discard information for elasmobranchs available. As such, landing data of thornback ray in Subarea 4 and divisions 3.a and 7.d from 2009 to 2016 were obtained. Discard data (2011–2016), however, were not available for all Member States. In the cases where discard data were not available, these were requested during the meeting. With the exception of the UK, thornback ray discard data from all Member States were obtained.



Brainstorm on including discards in the advice

Following discussions in the group the ICES framework for category 3 stocks was applied (ICES, 2012). Biomass indices derived from four surveys (IBTS-Q1, IBTS-Q3, CGFS-Q4, and BTS-Eng-Q3) were used to provide an overall index of stock development (stock size indicator).The advice is based on a comparison of the two latest index values (index A) with the five preceding values (index B), multiplied by advised landings.

To provide catch advice and the corresponding landings, catches over the period 2011 and 2016 were calculated. The discards are considered to be adequately estimated, although there are some uncertainties due to issues of raising similar to that for other stocks. This allowed to derive estimates of total catch (Figure 6.3). Also here, the ICES framework for category 3 stocks was applied using the annual mean of four surveys (IBTS-Q1, IBTS-Q3, CGFS-Q4 and BTS-ENG-Q3). The advice is based on a comparison of the two latest index values (index A) with the five preceding values (index B), multiplied by the average catches (2011–2016), a period in which both landings and discard estimates are available (Table 6.2). Since the stock size indicator is estimated to have increased by more than 20% when comparing the index A with index B value, the uncertainty cap was applied.

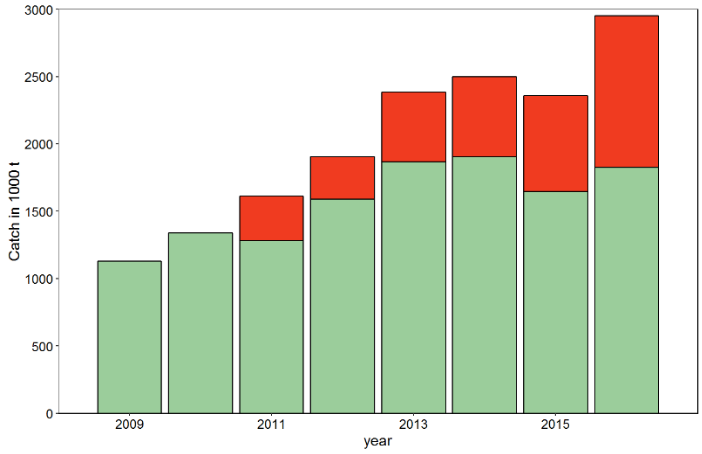


Figure 6.3: ICES estimates of species-specific landings and discards of thornback ray in Subarea 4 and in divisions 3.a and 7.d since 2009. Note that UK discard data are not included.

The advised landings for 2018 and 2019 using catch estimates (1811 tonnes) is 30% lower compared to the advised landings when the index ratio is multiplied by the advised landings of 2016 and 2017 (2574 tonnes). Again note that the discard rate is an underestimate as UK discard data are not included. If the UK data had been included, then the landings corresponding to the catch advice would be lower.

Table 6.2: Catch options table based on catch information (landings and discards) of thornback ray in Subarea 4 and divisions 3.a and 7.d.*

Index A (2015–2016)		2.96
Index B (2010–2014)		1.59
Index ratio (A/B)		1.87
Uncertainty cap	Applied	1.2
Average catches (2011–2016)		2286 tonnes
Average discard rate (2015–2016)		0.34
Precautionary buffer	Not applied	
Catch advice **		2743 tonnes
Landings corresponding to the catch advice ***		1811 tonnes
% advice change ^		

*** Figures in the table are rounded. Calculations were done with unrounded inputs and computed values may not match exactly when calculated using the rounded figures in the table.**

**** (Average catches × uncertainty cap).**

***** (Average catches × uncertainty cap) × (1-discard rate)**

^ Catch-based advised landings value for 2018 and 2019 relative to official ICES landings advice for 2018 and 2019.

6.2 Discussion

6.2.1 Landings corresponding to catch advice

The landings corresponding to catch advice are 30% lower than they are when a discard rate is not taken into account and would be even lower if UK discard data had been available and used in the calculation of the discard rate.

6.2.2 Survivability

While discard estimates are available, the group did not quantify the corresponding dead catch. As such, the advice did not take survival of discarded thornback rays into account. However, there are species-specific survival studies for thornback ray available. For example, a survival rate of 53% (95%-CI 40-65%) for thornback ray in the Dutch pulse trawl fishery was noted (Schram and Molenaar, 2018). Before taking survival into account in the assessment, survivability of the species in multiple fisheries should be initiated. Work carried out by Verkempynck *et al*. (2018) on the effect of discard survival on North Sea sole and plaice shows that for these stocks, taking discard survivability into consideration is dependent on the characteristics of the stock such as age at maturity and the extent to which the part of the stock is being discarded. Management measures such as minimum landing size, as described below, will have to be taken into account when applying survival rates.

6.2.3 Discard retention and the length-frequency of catches and landings

Because of the restrictive quota for rays, the Dutch Producer Organisations have implemented a minimum landing size (>55 cm) as well as a maximum to the amount of rays that can be landed per trip. The latter can range from 40–275 kg per trip. Due to these PO-measures, only the largest individuals of the most valuable species are landed, while the remainder of the catch is discarded. For example, a study on discards of the Dutch industry funded by the European Maritime and Fisheries Fund (2016–2018) demonstrated that up to 90% of the catches of rays in the pulse fishery were discarded and includes marketable (>55 cm) individuals. From all ray discards, almost 19% were of marketable size; more specifically for thornback ray, the proportion of marketable rays in the discards is almost 30%. In this context, PO-measures may influence discard decisions of the fleet, especially in the context of the Landing Obligation, and discards may include a reasonable amount of large marketable individuals. As such, these measures will influence landing statistics in terms of potential landings of marketable rays which we do not account for in the landings advice.

6.2.4 Develop a length-based model

Combining the results of the current workshop (WKSHARK5) with those of the work done at WKSHARK4 would provide a strong background from which to build a length-based model. It was suggested at the meeting that this work could be started intersessionally and further developed at WGEF 2020. It was recommended by the participants of WKSHARK5 that if WGEF/ICES envisages using this approach, then it should consider inviting experts with experience of stock-assessment of other species to join WGEF in 2020.

7 Tor d): Propose a method to provide fishing opportunities that ensure that exploitation is sustainable when a species has been under moratorium, as is the case with the undulate ray.

7.1 Introduction

Elasmobranchs are slow-growing, late maturing and have low fecundity, leading to longer generation time. These biological characteristics result in a moderate to low biological productivity. Further, as a consequence of their size at birth, elasmobranchs are usually vulnerable to fishing gear from birth or from their first year of life. They are therefore easily overexploited, unless stock status is adequately monitored and catches are managed so that fishing mortality does not exceed sustainable levels.

In the ICES area, some elasmobranch stocks have been under highly restrictive management measures, including being included on the EU list of prohibited species, as in the case of some stocks of undulate ray while others have had null TACs for several years. As a direct consequence of these restrictive measures, there is a lack of fishery dependent data for stocks such as undulate ray. Further, in cases where no or only a short time series of independent fishery data are available, the evaluation of stock status can only be in relative terms. Consequently, the ICES advice on the possible sustainable catches cannot be defined using the current ICES methods for Data Limited Stocks (ICES DLS), where recommended catches or landings are calculated based on the previous advice and the variation of a biomass index. In the situation where there are no or a very small amount of landings for several years, in order to rebuild a larger stock, there is no ICES approach to set the advice at a sustainable level.

Particularly in the case of species under moratorium, as it was the case of some undulate ray stocks in the ICES area, ICES considered "*that by-catch allowance as a step to collect the necessary information to future inform on the stock status and in consequence on the formulation of scientific advice with CFP should be considered and that the by-catch levels should be adopted under precautionary principle and taking into account the sampling effort required by the scientific pre-assessed close-fishery monitoring program in course.*"(ICES, 2018b).

During WKSHARK5, different approaches were presented and their adequacy to provide scientific advice on sustainable catch when a species was under moratorium was discussed.

Three different approaches were evaluated. These differ among themselves according to the sources and data availability, survey and/or fishery data.

7.2 No survey data, but georeferenced catches derived from self-sampling programs

A N-mixture model was proposed to be used to estimate species abundance by integrating temporally and spatially replicated counts (Kéry *et al*., 2005). Under the N-mixture model, the site-specific abundance is admitted to be a random effect, and the marginal likelihood of the counts is obtained by integrating the binomial likelihood for the observed counts over possible values of abundance at each location (Royle, 2004).

In the model, N_i is the random variable of the unknown number of *R. undulata* specimens vulnerable to the fishing gear at the i^{th} location ($i = 1, \dots ,m$) and p is the detection probability parameter (Royle, 2004), i.e., the probability of a specimen be caught at the fishing haul.

The model further assumes that the population under analysis is closed and so the number of specimens caught (n_{it}) at the i^{th} location in t^{th} time is a i.i.d. (independent and Identically Distributed variables) binomial random variable, i.e., $n_{it} \sim Binomial \quad (N_i p)$.

The estimation of model parameters is done by considering the distribution of specimens in each region as a homogeneous Poisson point process, expressed by:

$$N_i \sim Poisson \quad (\lambda_i a_i)$$

where λ_i is the expected density of specimens vulnerable to the fishing gear (number of specimens per km^2) and a_i is the average area fished per haul (in km^2) at i^{th} location. The average area fished per haul corresponds to the mean of area fished by the different fishing hauls, which in turn is considered as, the product of the length of the fishing gear trammel net by 100 m. The latter corresponds to the mean distance, usually adopted by Portuguese fishermen to set the fishing gear between consecutive hauls. The relationship between the expected density and spatially varying predictors influencing the density (x_i) at the i^{th} sample location was introduced in the model through a logarithmic link function, $\log(\lambda_i) = x_i\beta$. Several predictors were initially tested, seafloor type and depth were the ones which gave the best model fits. The estimates of the model's parameters (β and p) were obtained through the maximization of the marginal likelihood function.

The model parameters maximum likelihood estimates (MLEs) obtained were then used to predict the *R. undulata* density of specimens vulnerable to the fishing gear given the values of bottom sediment type and depth.

Spatial polygons comprising the areas where the species is likely to occur were drawn and considered as the prediction spatial domain. The abundance of *R. undulata* vulnerable to the fishing gear for an entire area was calculated by integrating the predicted density over the whole prediction spatial domain. The species biomass was then estimated as the product of the abundance estimate in number and the mean individual weight.

In order to calculate which fishing mortality could be applied to the stock for which the biomass was derived as described above, fishing mortality was estimated based on the knowledge available on species biology and dynamics by using a Beverton-Holt yield per recruit (Y/R) model which was adjusted for different potential spawning ratios.

Based on the estimated biomass and fishing mortality, it was proposed that the advised Catch for year + 1 (C_{y+1}) will be calculated by following the Harvest Control Rule method proposed for ICES DLS category 2 stocks (ICES, 2012).

Annex 3 presents the results of the application of the approach to 2017 self-sampling data for rju.27.9a stock.

7.3 Landings advice once the moratorium is lifted (LAEM approach). Deriving advisable landings for a species under moratorium based on biomass indices

The approach proposed for calculating a landings advice after a period of moratorium for a stock, relies upon relating the advice to that given for a reference stock which is already subject to a landings advice. This level of landings advised at exit of moratorium is further referred to as LAEM (Landings Advice at Exit Moratorium). The biomass indices for the moratorium and reference stocks are assumed to have similar relationship to actual species biomasses. If the moratorium and reference stocks occur in the same area, the calculation is done by multiplying the advised landings of the reference species by the ratio of biomass indices of the two species and the ratio of their productivities (Eq. 1).

$$LAEM(mor) = \left[\frac{B\ (mor)}{B\ (ref)}\right] \times \frac{r(mor)}{r(ref)} \times Adv(ref) \qquad \text{(Eq. 1)}$$

Where *mor* stands for moratorium species and *ref* for the reference species. *B()* is biomass index and *r* is biological productivity, in the sense of intrinsic population growth rate in a production model, or a proxy of it. *Adv(ref)* is the level of landings advised for the reference species, *LAEM(mor)* is the level of landings to advise for the moratorium species, brackets (ref) and (mor) are kept for clarity. If no estimate of productivity is available, there are methods to derive it or a distribution of it from life history traits (e.g. McAllister *et al.*, 2001). Productivity can also be assumed proportional to some life history trait of species such as *Lmax* or L_∞.(Le Quesne and Jennings, 2012). Biomass indices are typically from surveys. However, in the lack of relevant survey data, the use of catches from observer data can be considered.

If stock areas for the moratorium stock and for the reference stock differ, which is the case for ray stocks, LAEM can be calculated separately for every area where the moratorium stock occurs, possibly using different reference stocks and then summing up over all areas of the moratorium stock. The LAEM in an area (typically an ICES Division) where the two stocks occur is calculated by including the ratio of the biomass index of the reference stock in that Division to that for the whole stock area (Eq. 2):

$$LAEM(mor, div) = \left[\frac{B\ (mor,div)}{B\ (ref,div)}\right] \times \frac{r(mor)}{r(ref)} \times \frac{B(ref,div)}{B(ref,.)} \times Adv(ref) \qquad \text{(Eq. 2)}$$

Where $B(ref, div)$ is an index of biomass of the reference species in the Division where the moratorium stock occurs and $B(ref, .)$ an index of biomass for the whole reference stock. These indices must be related to the absolute biomass, ideally swept area estimates of the biomass. For example, indices standardised to the long term mean are not suitable here. Alternatively, if available indices are kg h^{-1}, these should be multiplied by the surveyed area. Where such indices are not available, catch in the division and the whole stock area of the reference species may be used as surrogates. This latter option is only suitable if catches are considered proportional to biomasses.

Lastly, Eq. 2 simplifies as Eq. 3:

$$LAEM(mor, div) = \left[\frac{B\ (mor,div)}{B(ref,.)}\right] \times \frac{r(mor)}{r(ref)} \times Adv(ref) \qquad \text{(Eq. 3)}$$

The LAEM for the whole moratorium stock is the sum over divisions where it occurs:

$$LAEM(mor) = \sum^{div} LAEM(mor, div)$$

Following the ICES DLS approach, the advised landings are calculated in the year of assessment (*y*) for which only data until the previous year (*y-1*) are available and used to advise on the following one (*y+1*) or two years (*y+1* and *y+2*). Therefore, for an assessment in year *y*, biomass indices (*B*) are from year *y-1* and advised landings *Adv(ref)* and *LAEM(mor)* are for year *y+1* (or years *y+1* and *y+2* in the case of biennial advice as done for elasmobranch stocks). However, because biomass indices may have large confidence intervals, the calculation of *LAEM(mor)* may also be based upon the average of e.g. the last five years. Three examples of these calculations are given in Annex 4 of this report for undulate ray in the English Channel (rju.27.de).

When the LAEM approach has been applied once to set the advisable landings after the moratorium period, the stock is regularly assessed under the ICES method for Category 3 stocks.

For most ray stocks, recent advice are landings advice so this approach applies directly. However, it could be applied in the same way if the reference stock was subject to a catch advice instead of a landings advice. In this case, the level of catches instead of that of landings is derived for the moratorium stock. As a proportion of discarded elasmobranchs survive, the landings corresponding to the catch for the moratorium species could be calculated as the same proportion of the advised catch as for the reference species, or corrected based on the ratio of survival rates.

7.4 Long time-series of survey data and reliable historical catch data

The catch and survey biomass data are used to construct a time-series F_{proxy} (as total catch divided by survey biomass):

F_{proxy} = Yield/Survey biomass.

Based on the analysis of the F_{proxy} time series together with the abundance/biomass index time series, a reference F-proxy can be identified, under the constraint that the selected value adopted did not hinder the growth of the population.

The scientific catch advice is given following the following steps:

1. Multiply the F_{proxy} by abundance indices of the year -1 (Iy-1);
2. Apply the 20% Uncertainty Cap to the catch advice (i.e., "change limit" (ICES, 2013, Section 1.2.2.3). The change limit is relative to the reference on which it is based and may be e.g. recent average catches or a projection of a trend);
3. Apply the Precautionary Buffer to the catch advice (i.e., "precautionary margin". A precautionary margin of -20% is applied for those cases when the stock status relative to candidate reference points for stock size or exploitation is unknown).

7.5 Final comments

The approaches proposed were defined according to the differences in the data sources available and were designed to be applied to species that have been under moratorium for several years and for which ICES DLS methods are not adequate. Table 7.1 summarizes the main assumption of each approach and identifies the potential caveats.

Table 7.1. The main assumption of each approach and the potential caveats.

	Main assumptions	Main requirements
Section 7.2. No survey data but georeferenced catch rates are available	Closed population within the studied area and during the estimation period.	i) A good spatial coverage of the species distribution area. ii) The regular collection of length data from the exploited population.
Section 7.3. Deriving advisable landings for a species under *moratorium* based on biomass indices	The ratio of indices of the reference and moratorium species reflects the ratio of their stock biomasses.	i) Survey data or other data correlated to stock biomass.
Section 7.4. Long time-series of survey data and historical catch		i) Historical catches available at species level.

The value and potential use of self-sampling data that do not meet the requirement listed in the above have to be scrutinized case by case, as these data may also provide ancillary information about the stock of concern. For example the self-sampling data from French coastal vessels reported numbers of individuals and body lengths, even though this was only carried out during the first year of the programme.

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Annex 2: Summary of discard retention patterns, based on previous WKSHARK and WGEF reports

Background documents

- Report of the Workshop to Compile and Refine Catch and Landings of Elasmobranchs (WKSHARK3), (ICES, 2017):

In 2017, WKSHARK3 investigated distinct case studies, addressing some of the stocks to be examined by WGEF. The species included: *G. galeus, Mustelus spp., S. canicula, R. clavate, R. brachyura, L. naevus, A. radiata*. The rationale for the work in WKSHARK3 was: i) To identify which data sets may provide suitable data for further length-based analyses; ii) To examine existing data to determine where the direct or indirect effects of management measures may have led to changes in discard-retention patterns; iii) To identify where there are relatively higher levels of discarding (e.g. in relation to discard survival). In addition, several reasons why fish may be discarded were outlined, which should be considered when interpreting discards data. All detailed data can be found in the WKSHARK3 report (ICES, 2017).

- Report of the Workshop on Length-Based Indicators and Reference Points for Elasmobranchs (WKSHARK4), (ICES, 2018):

The overall objective was to analyse the appropriateness of length-based indicators (LBIs) for assessment of the status of elasmobranch stocks. To analyse the assumption of asymptotic fishing gear selectivity (part of WKSHARK4's ToR a) the length distribution of several elasmobranch species in the commercial catch of French and Dutch demersal fisheries, as well as the IBTS survey were compared. The species included: thornback ray (*Raja clavata*), blonde ray (*Raja brachyura*), spotted ray (*Raja montagui*), cuckoo ray (*Leucoraja naevus*), small-spotted catshark (*Scyliorhinus canicula*) and smooth-hounds (Triakidae).

A.2.1 Sharks

Tope *Galeorhinus galeus*

ICES 27 Subareas (no information)
Data: National observer programmes in UK (England), Ireland, France (figures 5.6–5.8)
Full results in: WKSHARK3 report (ToR a), 2017
Result summary:
There are insufficient data to interpret any trends in discard/retention patterns in these fisheries. There were no clear length-based differences in retention in UK data, which may reflect national measures in place. NOTE: Tope is not caught in large numbers, and it is possible that data for smaller tope and smooth-hounds may be confounded.

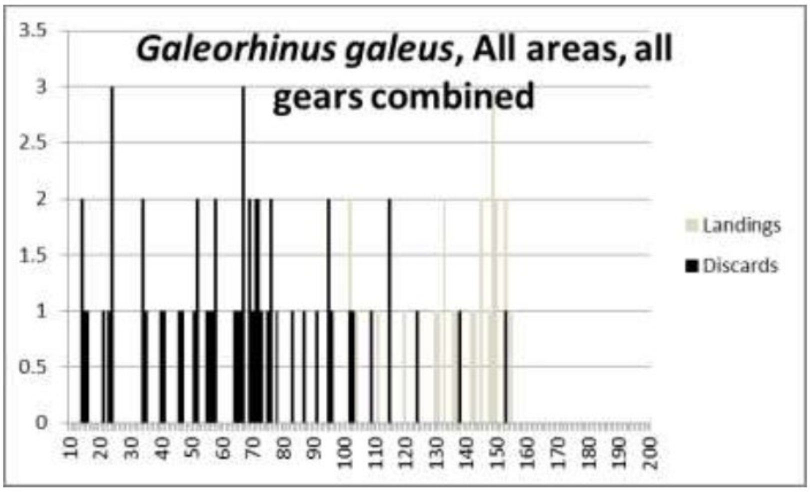

Figure 5.6: ***G. galeus*****. Discard/landing records from Irish observers.**

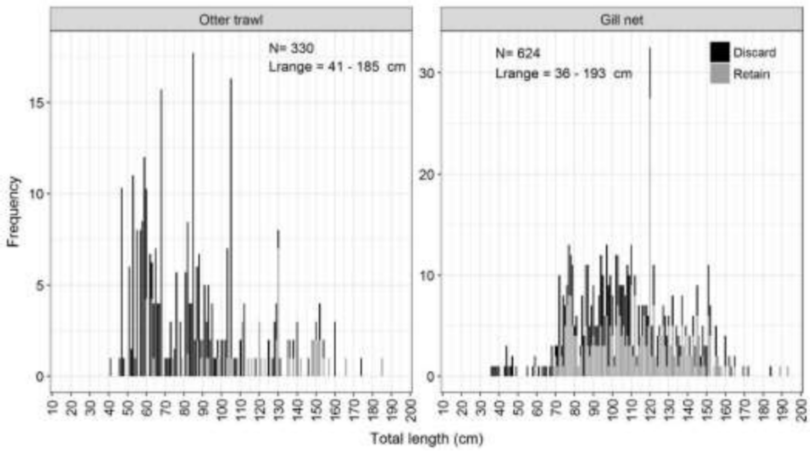

Figure 5.7: Length-based discard-retention pattern of tope *G. galeus* for otter trawl (left) and gill net (right), as recorded during the UK (English) observer programme (data combined for the years 2002–2016).

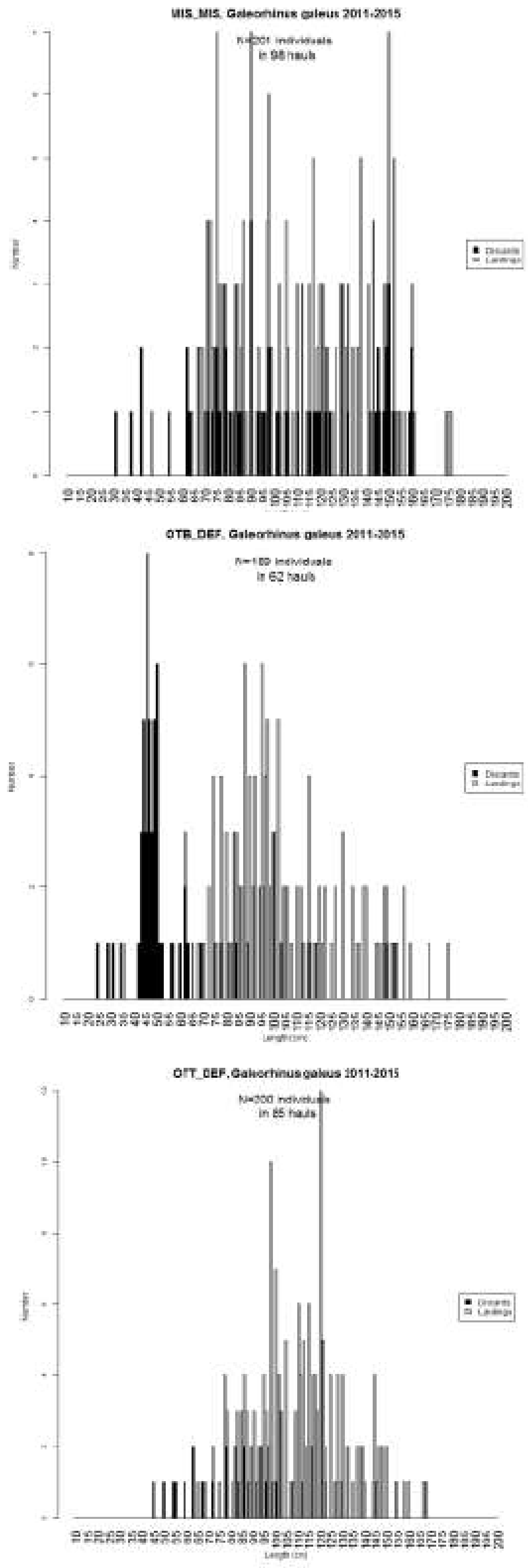

Figure 5.8: Length-based discard-retention pattern of tope, *G. galeus*, by métier, as recorded during the French observer programme (data combined for the years 2011–2016).

Smooth-hounds *Mustelus* spp.

ICES 27 Subareas (no information)
Data: National observer programmes in UK (England) and France (figures 5.9–5.10)
Full results in: WKSHARK3 report (ToR a), 2017
Result summary:
Beam trawls generally take a greater proportion of smaller specimens (ca. <70 cm), whilst a broader length range are taken by otter trawl, and gill nets generally take larger specimens (ca. >70 cm). Otter trawls tend to sample the broadest length range, with the smaller individuals tending to be discarded. The utility of the overall length composition (discard and retained) from these fleets for the development of LBI should be investigated by WGEF.

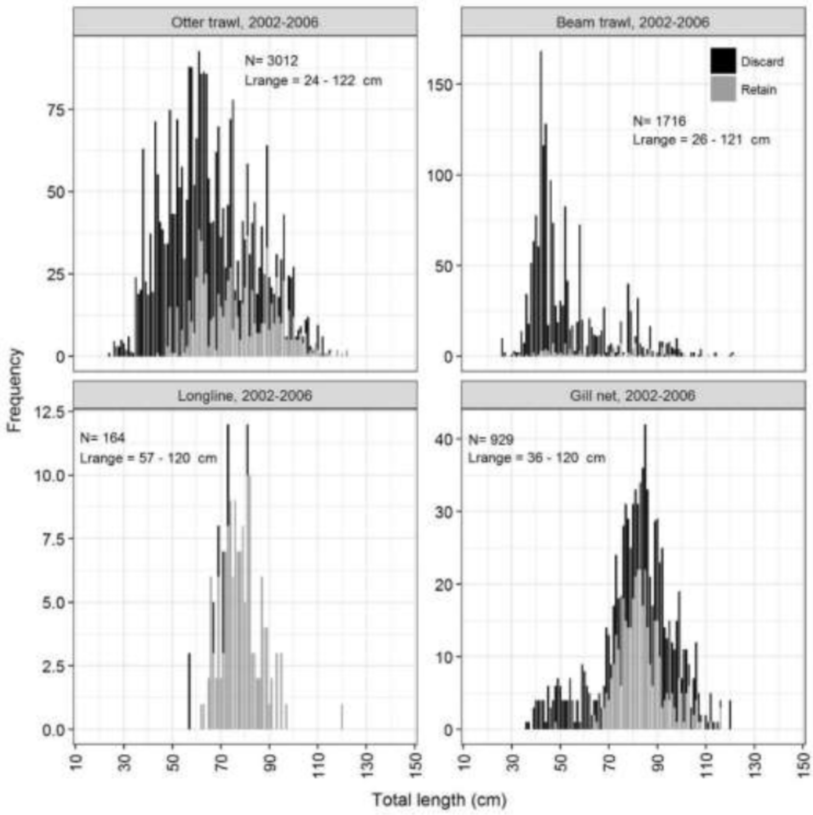

Figure 5.9a: Length-based discard-retention pattern of smooth-hounds *Mustelus* spp. for otter trawl (top left), beam trawl (top right), longline (bottom left) and gill net (bottom right) as recorded during the UK (English) observer programme (2002–2006).

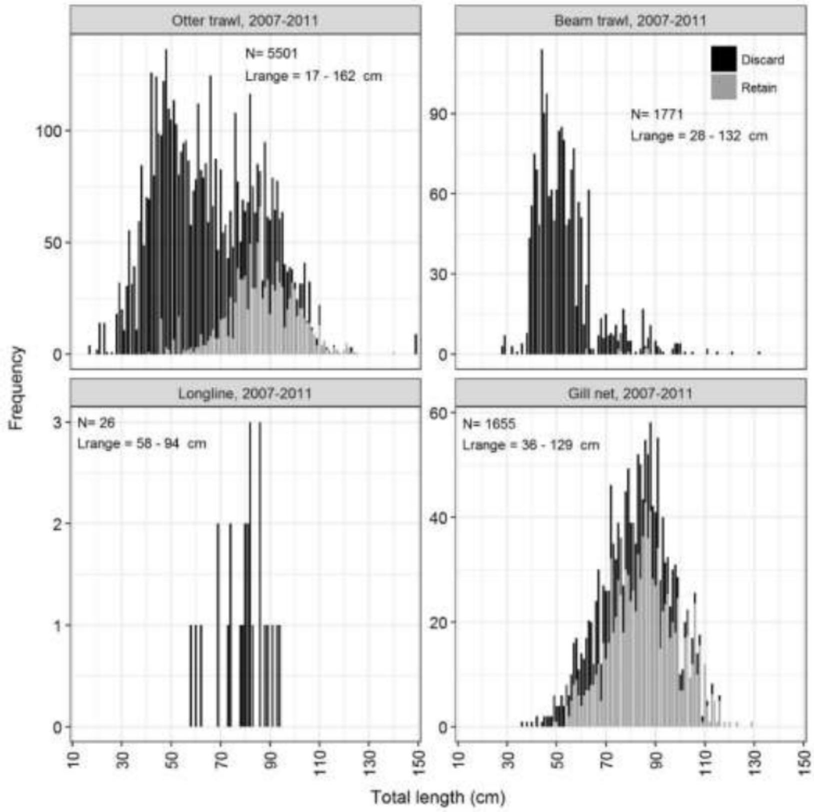

Figure 5.9b: Length-based discard-retention pattern of smooth-hounds *Mustelus* spp. for otter trawl (top left), beam trawl (top right), longline (bottom left) and gill net (bottom right) as recorded during the UK (English) observer programme (2007–2011).

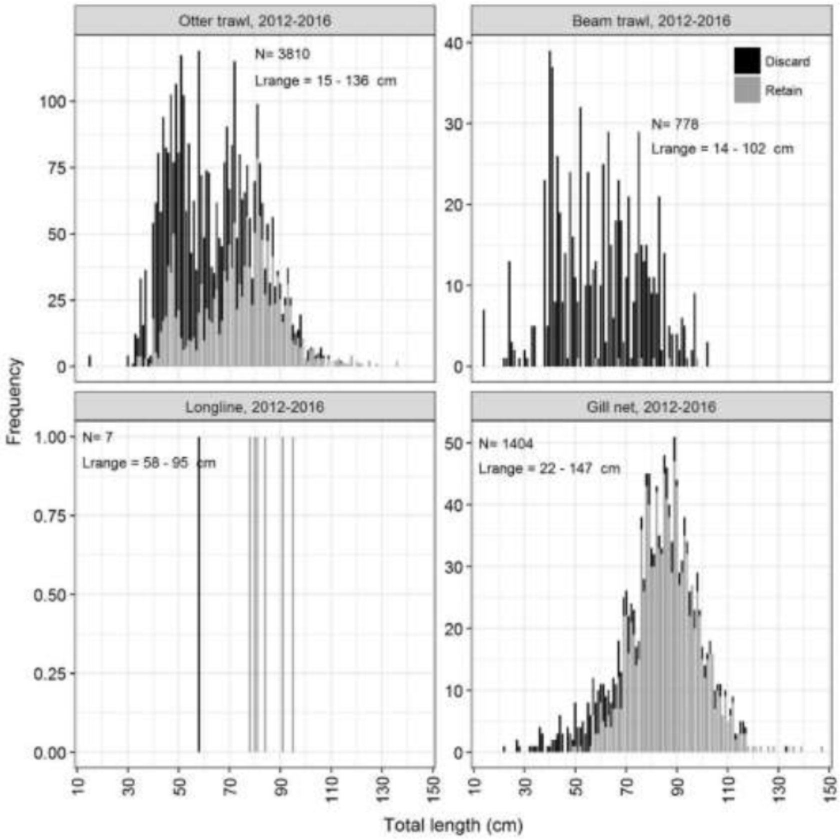

Figure 5.9c: Length-based discard-retention pattern of smooth-hounds *Mustelus* spp. for otter trawl (top left), beam trawl (top right), longline (bottom left) and gill net (bottom right) as recorded during the UK (English) observer programme (2012–2016).

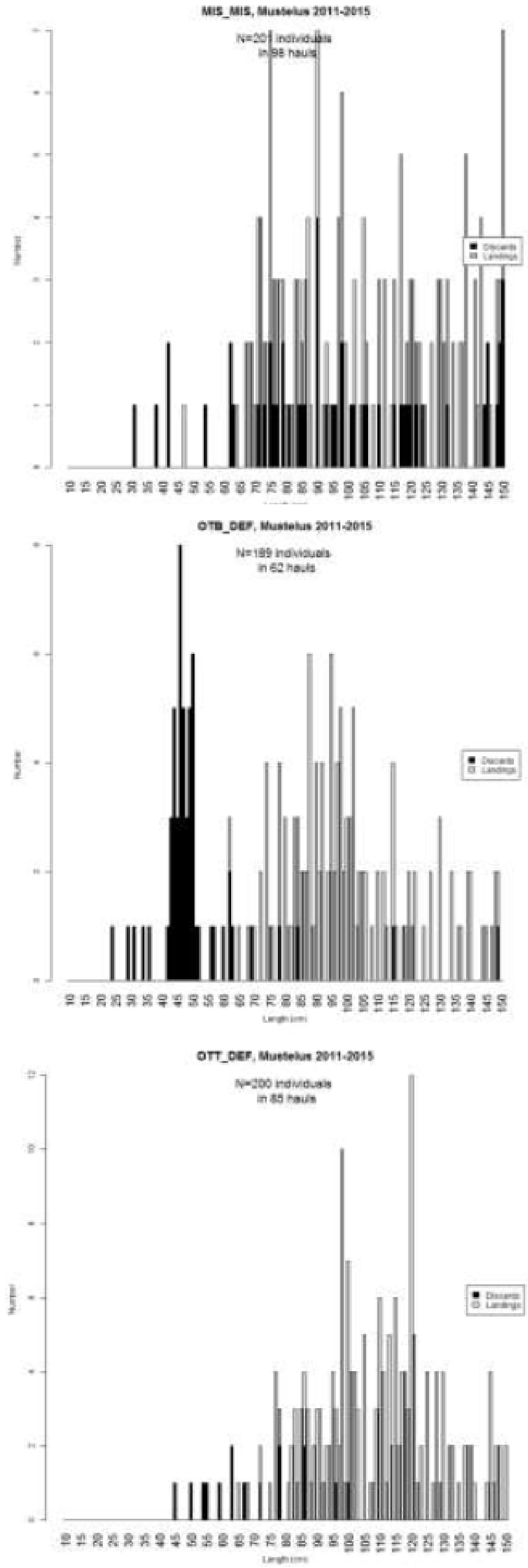

Figure 5.10: Length-based discard-retention pattern of Smooth-hounds, *Mustelus* spp. by métier as recorded during the French observer programme (data combined for the years 2011–2016).

Lesser-spotted dogfish *Scyliorhinus canicula*

There are likely to be a succession of stocks or meta-populations of this species, with ICES providing advice on the species by ecoregion.

Result summary:
Lesser-spotted dogfish is probably the most caught elasmobranch in European waters. However, it is rarely a target species. This is shown in the discard-retention patterns of the examined fleets where in most fleets and nations, the vast majority of specimen are discarded rather than retained, regardless of size. However, the UK otter-trawl fishery shows a higher retention pattern than other gears or similar gears from other countries. The Dutch beam-trawl fishery in Subarea 4 appeared to have a larger spectrum of length classes in their discards compared to other gear groups.

ICES 27 Subarea 4
Data: Dutch self-sampling programme (2011–2016)
Full results in: WKSHARK4 report (ToR a), 2018)

ICES 27 Subarea 4 and divisions 4.b.c and 7.d – combined data
Data: National observer programmes in UK (England Figure 5.11) and France (Figure 5.12)
Full results in: WKSHARK3 report (ToR a), 2017

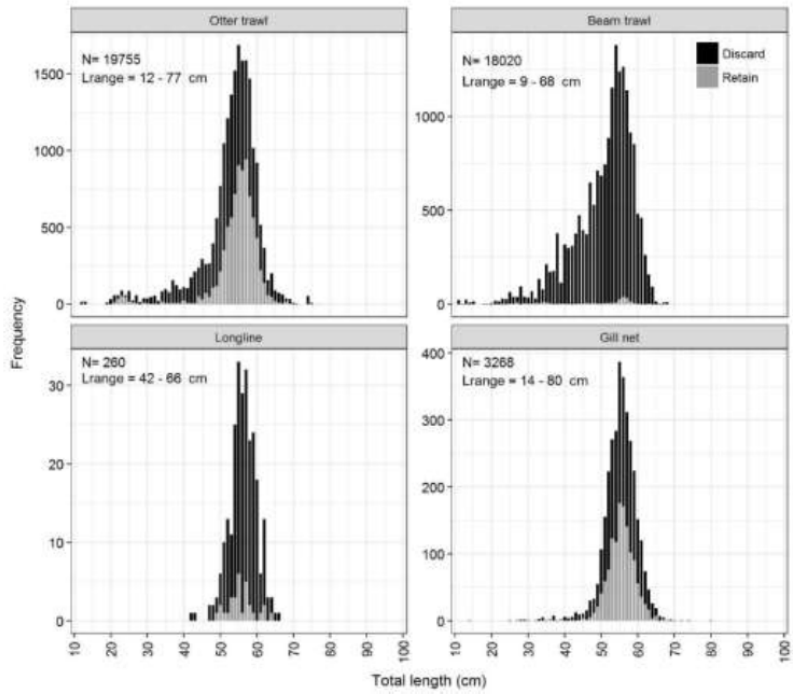

Figure 5.11: Length-based discard-retention pattern of lesser-spotted dogfish *S. canicula* in the North Sea ecoregion (Subarea 4 and Division 7.d) in otter trawl, beam trawl, longline and gillnet as recorded during the UK (English) observer programme (2002–2016).

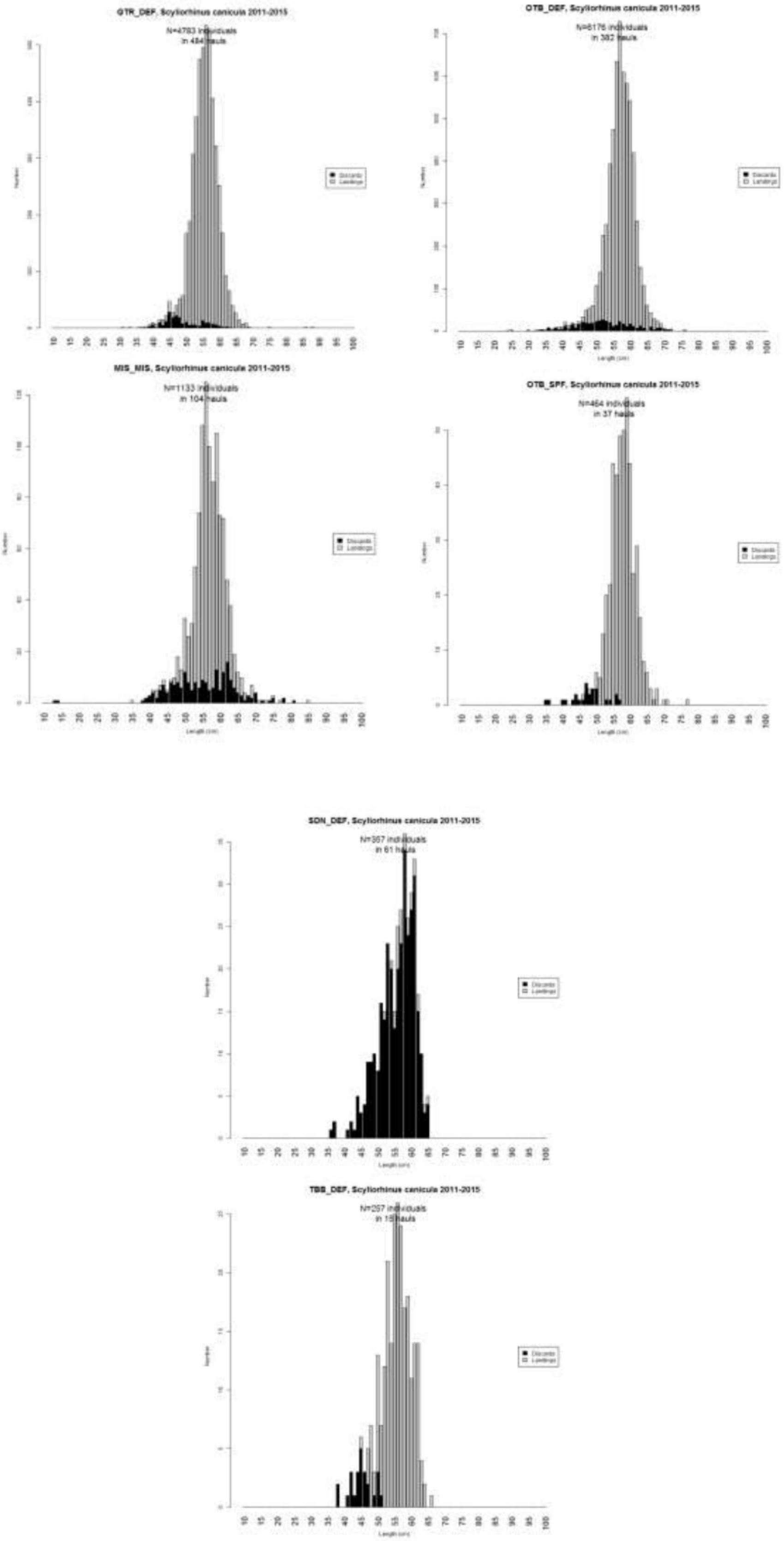

Figure 5.12: Length-based discard-retention pattern of lesser-spotted dogfish, *S. canicula* by métier, (Subareas 3, 4 and Division 7.d), as recorded during the French observer programme (data combined for the years 2011–2016).

ICES 27 Subareas 6, and divisions 7.a–c, 7.e–k
Data: National observer programmes in UK (England), Ireland and France (figures 5.13–5.15)
Full results in: WKSHARK3 report (ToR a), 2017

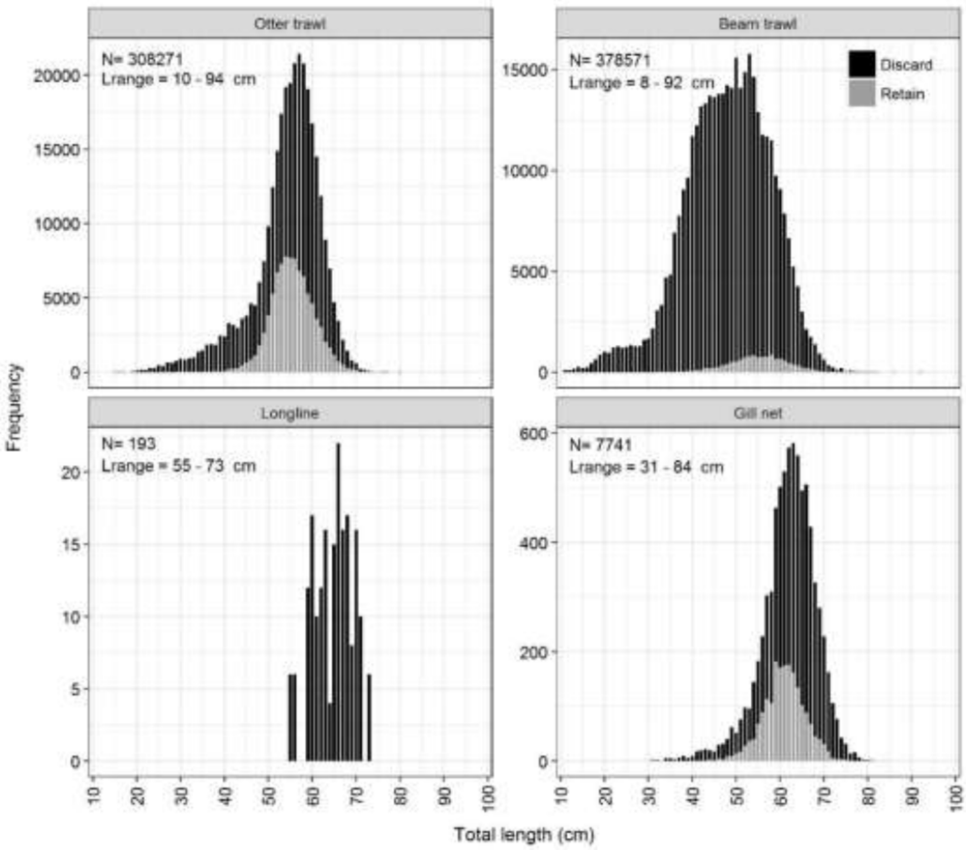

Figure 5.13: Length-based discard-retention pattern of lesser-spotted dogfish *S. canicula* in the Celtic Seas ecoregion (Subarea 6 and divisions 7.a–c and 7.e–k) in otter trawl, beam trawl, longline and gillnet as recorded during the UK (English) observer programme (2002–2016).

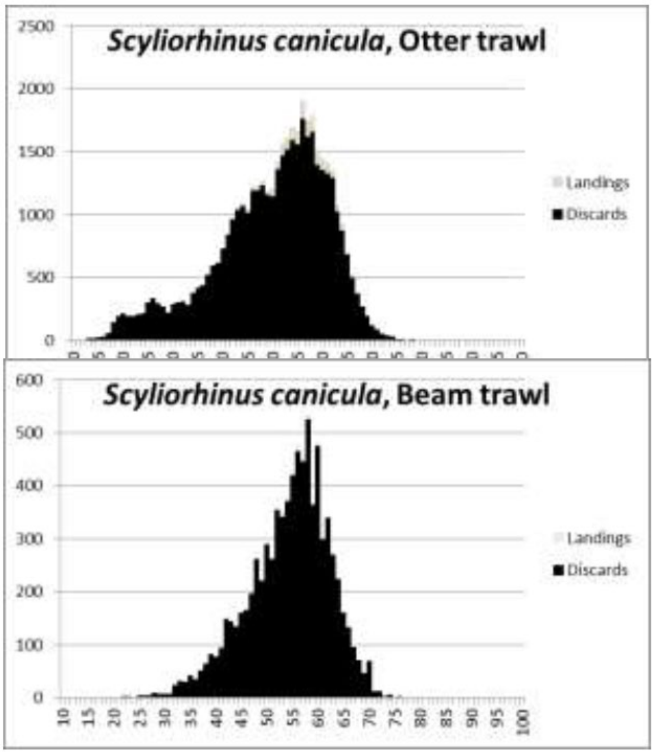

Figure 5.14: *S. canicula*. Discard/landings records from Irish observers.

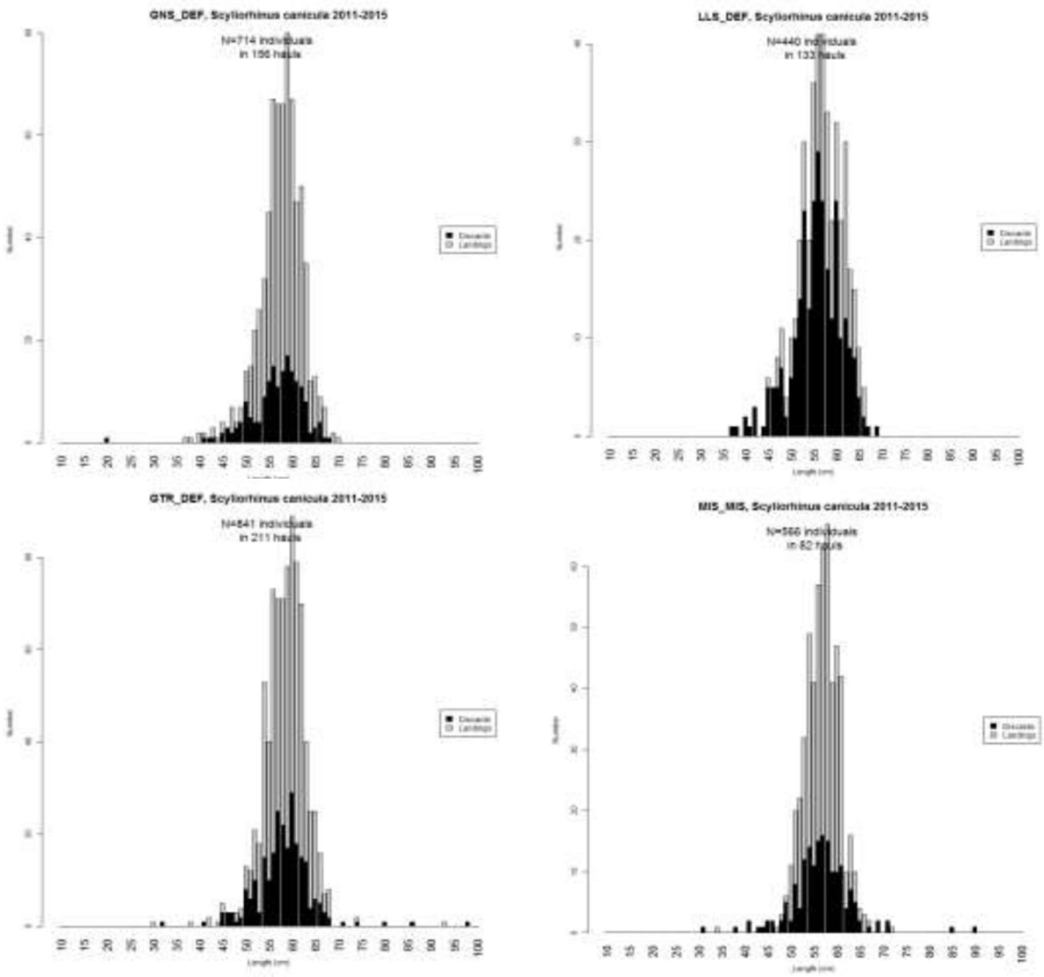

Figure 5.15: Length-based discard-retention pattern of lesser-spotted dogfish, *S. canicula* by métier, (divisions 7.a–c, 7.e and 7.k), as recorded during the French observer programme (data combined for the years 2011–2016).

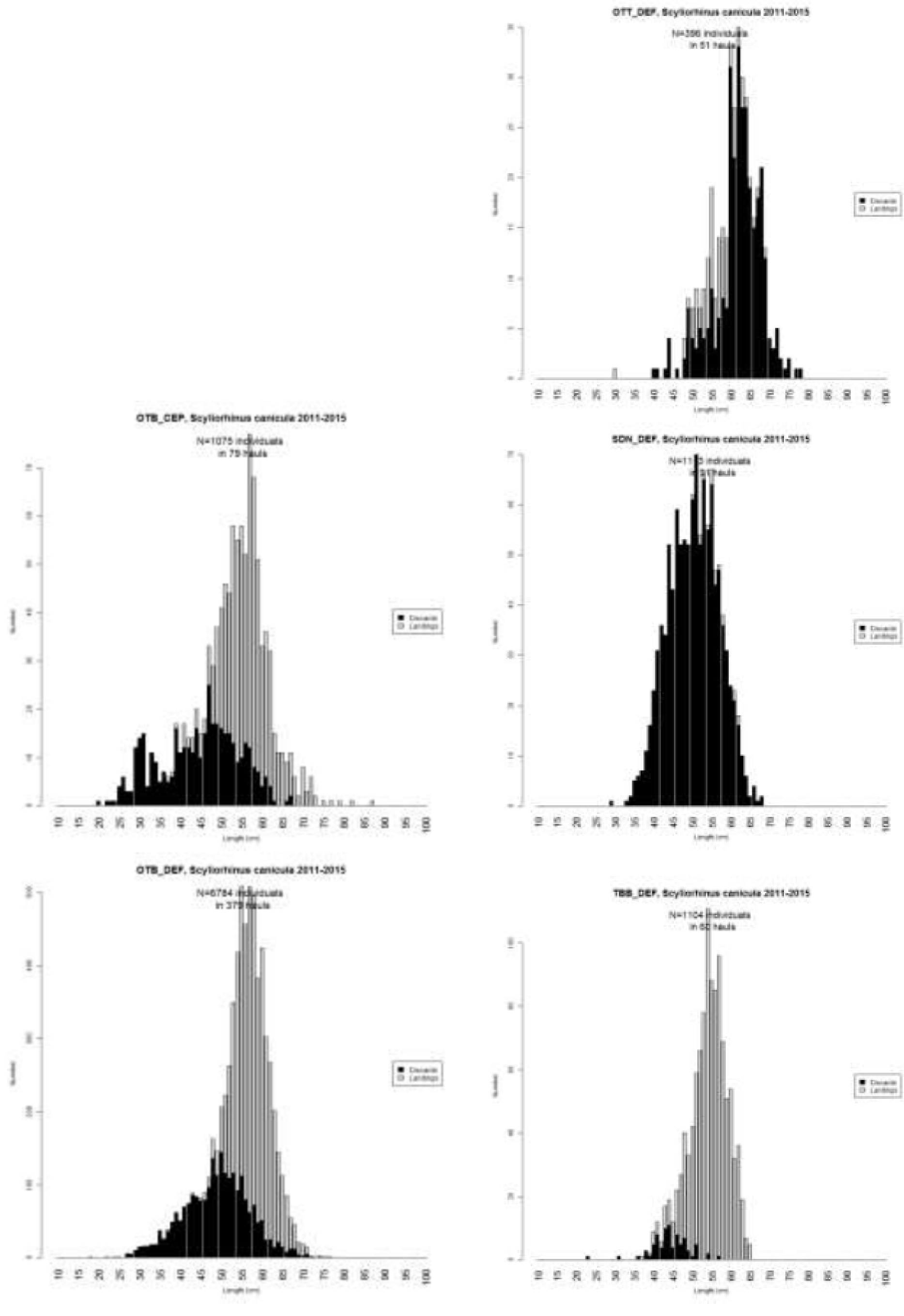

Figure 5.15 (cont'): Length-based discard-retention pattern of lesser-spotted dogfish, *S. canicula* by métier, (divisions 7.a–c, 7.e and 7.k), as recorded during the French observer programme (data combined for the years 2011–2016).

ICES 27 Divisions 8.a.b.d
Data: National observer programmes in France and Spain (Basque Country) (figures 15.16–5.17)
Full results in: WKSHARK3 report (ToR a), 2017

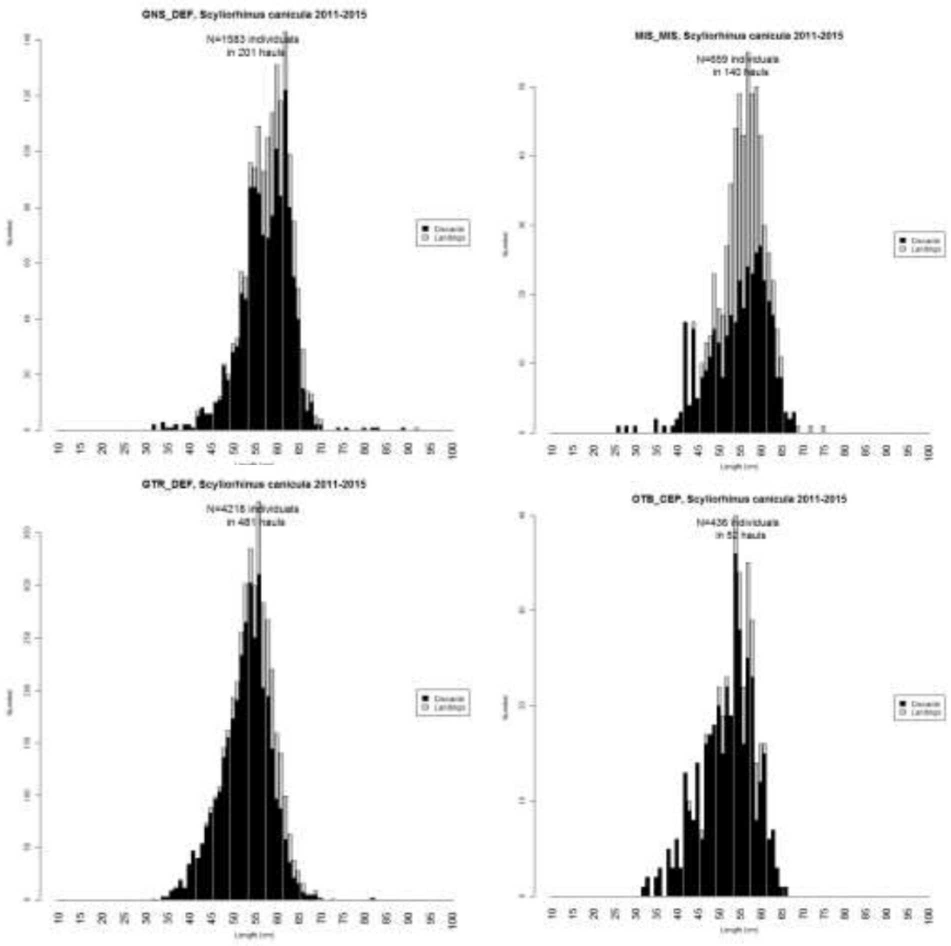

Figure 5.16: Length-based discard-retention pattern of lesser-spotted dogfish, *S. canicula* by métier, (divisions 8.a.b.c.), as recorded during the French observer programme (data combined for the years 2011–2016).

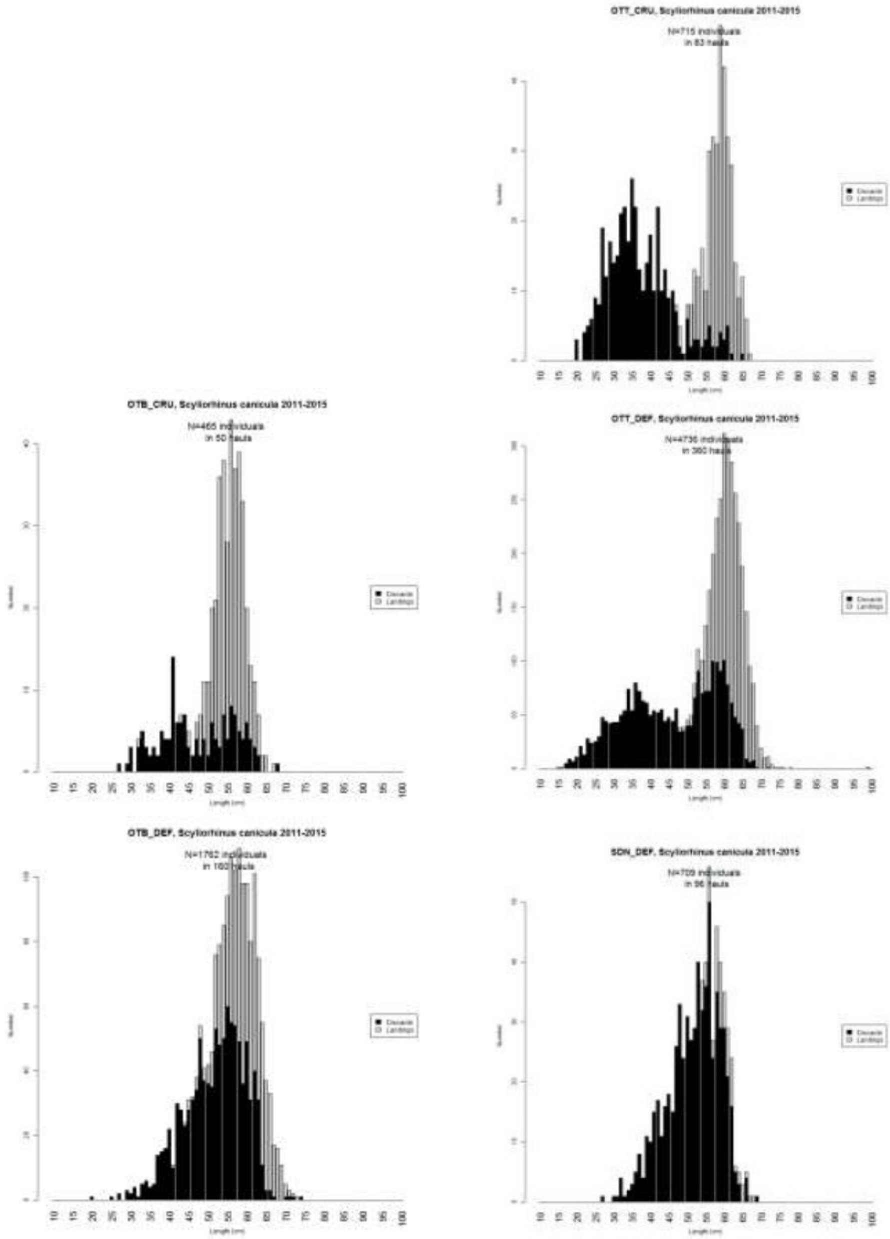

Figure 5.16 (cont'): Length-based discard-retention pattern of lesser-spotted dogfish, *S. canicula* by métier, (divisions 8.a.b.c.), as recorded during the French observer programme (data combined for the years 2011–2016).

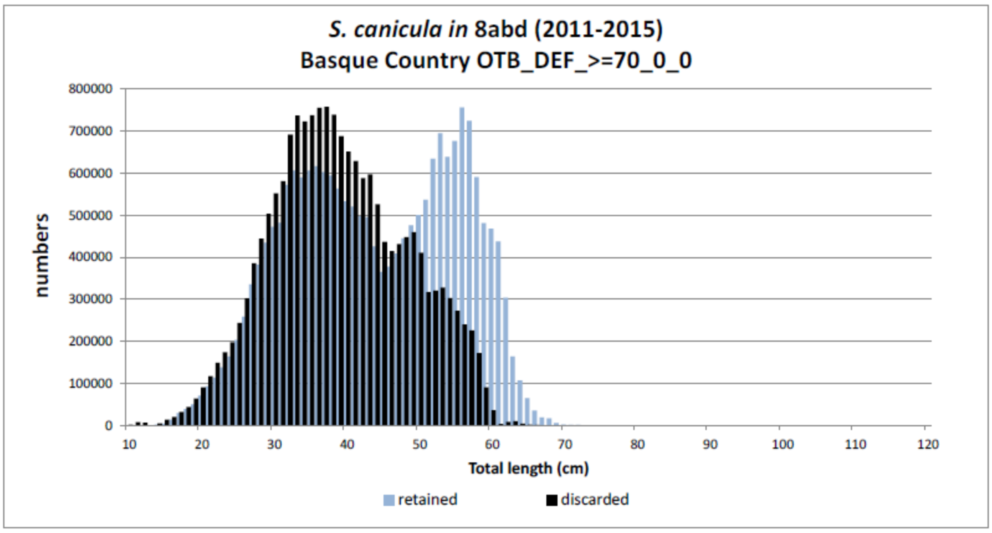

Figure 5.17: Length frequency distribution of lesser-spotted dogfish, *S. canicula,* discarded and retained fractions sampled onboard Basque Country's OTB (divisions 8.abd) in the period 2011–2015. Numbers raised to the total trips.

ICES 27 Division 9.a

Data: National data from Portugal (Figure 5.18)

Full results in: WKSHARK3 report (ToR a), 2017

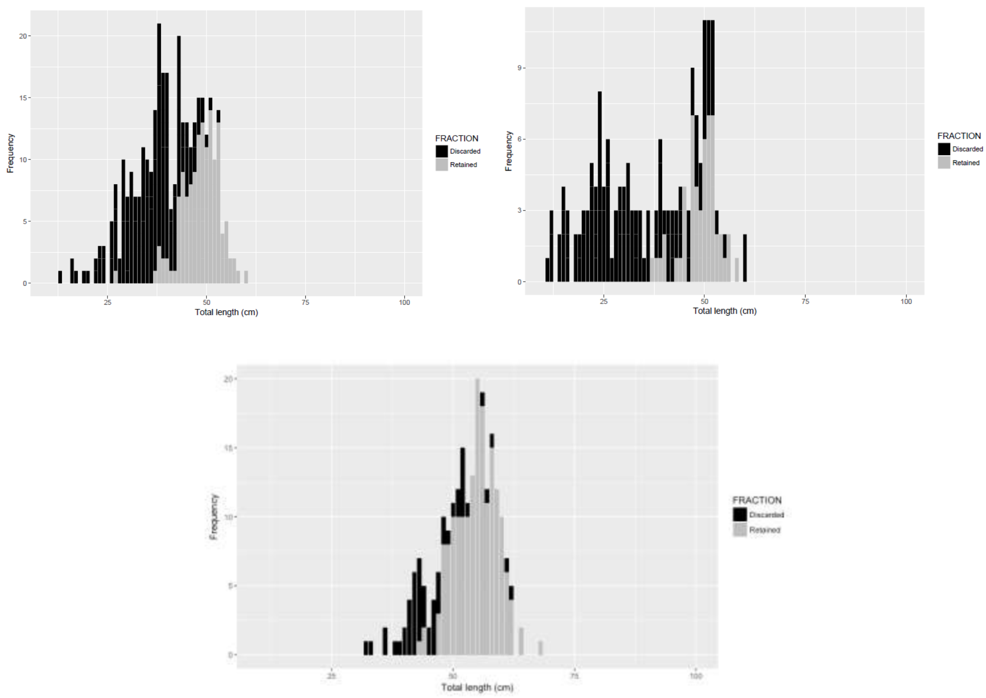

Figure 5.18: Length frequency distribution of lesser-spotted dogfish, *S. canicula,* discarded and retained fractions sampled onboard Portuguese vessels (Division 9.a) for 2011–2014, using: top left: otter bottom trawl for demersal fish (n = 348), top right: otter bottom trawl for *Nephrops* (n = 182), and bottom: set nets (n = 227). Data not raised to the total landings.

Smooth-hounds *Trikidae*

ICES 27 Subarea 4
Data: Dutch self-sampling programme (2011–2016)
Full results in: WKSHARK4 report (ToR a), 2018)
Result summary:
When comparing the length frequency distributions between the gear groups, beam-trawls appeared to have a larger spectrum of length classes in their discards. There was no clear difference between the gear groups.

A.2.2 Skates and rays

Thornback ray *Raja clavata*

ICES 27 Subarea 4
Data: Dutch market and discard self-sampling programme ((2011) 2014–2017)
Full results in: WKSHARK4 report (ToR a), 2018; new plots here.
Result summary: When comparing the length frequency distributions between the gear groups, beam-trawls appeared to have a larger spectrum of length classes in their discards: the size range in beam-trawls and seines were 13–81 cm and 22–57 cm, respectively (see Figure 3.6 in WKSHARK4 report). In the beam-trawl fishery, it looks like most individuals smaller than 60 cm get discarded, whereby larger individuals get landed.

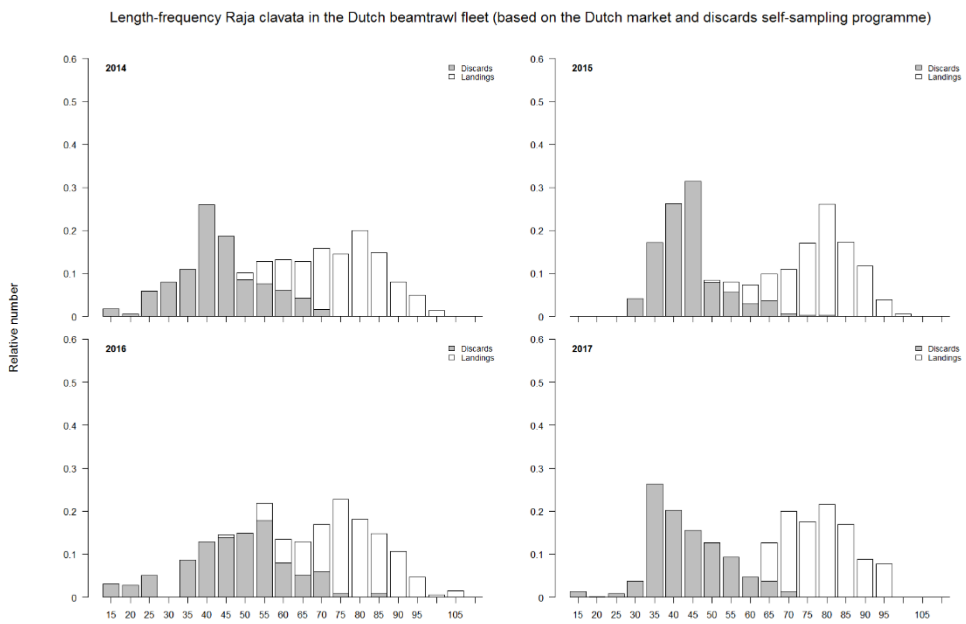

Figure 5.19: Length distribution of *R. clavata* caught and discarded in 27.4, expressed in relative numbers (thousands) per year as a function of year for 2014–2017. Data are based on the Dutch market and discards self-sampling programme.

ICES 27 Divisions 4.b, 4.c and 7.d – combined data

Data: National data for UK (England), France, the Netherlands and Spain (Basque Country) (figures 5.20–5.24).

Full results in: WKSHARK3 report (ToR a), 2017

Result summary:

All gears show similar patterns of retention and discarding, with the exception of longlines. These are much more selective for larger fish, and so there are few small fish discarded. French data were available for most common métiers from 2011–2015. Otter-beam trawl_DEF (Figure 5.21) show discarding across size ranges and a general increase in the proportion of discards of smaller fish since 2011, with a particularly noticeable increase in 2015 compared to previous years. Further data are required to determine whether the 2015 figures are part of an increasing trend, or a particularly large year-effect.

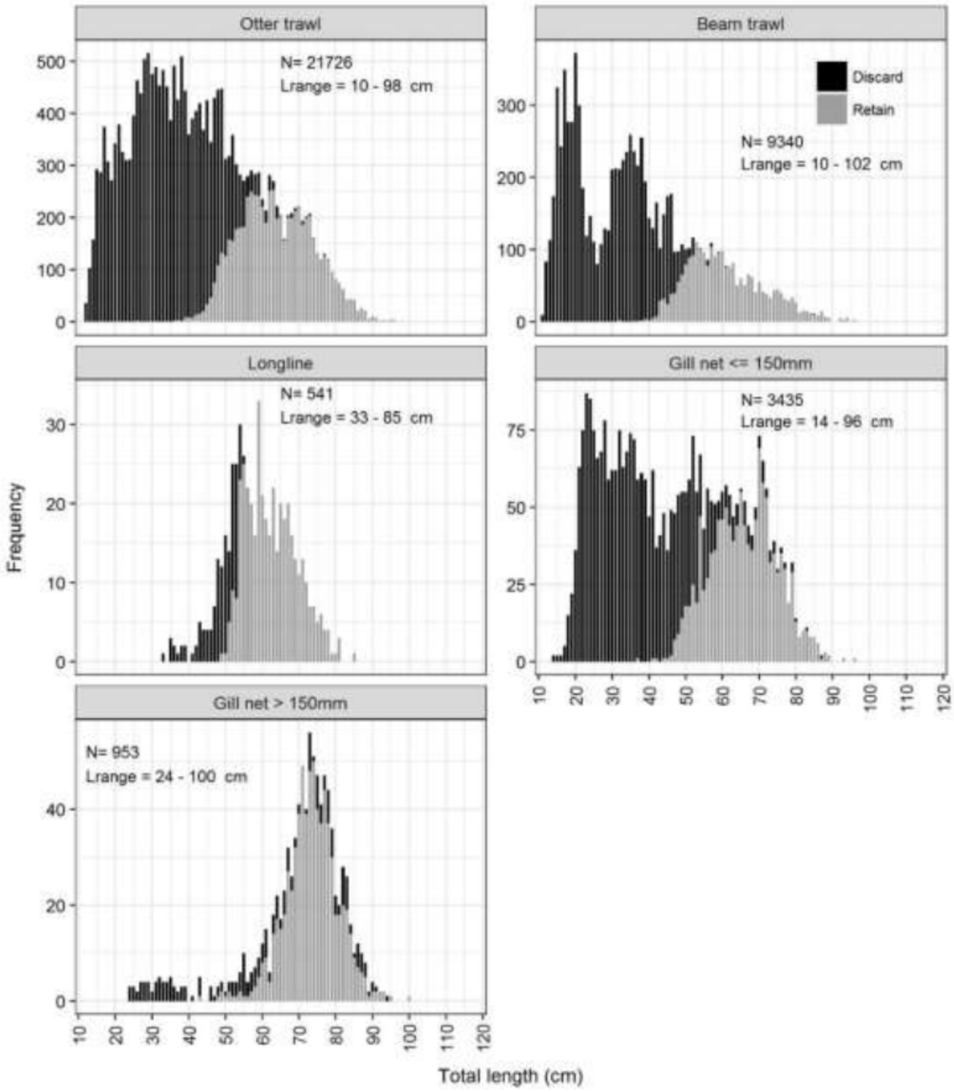

Figure 5.20: Length-based discard-retention pattern of thornback ray *R. clavata* (ICES divisions 4.b.c and 7.d) for otter trawl, beam trawl, longline, gill net (≤150 mm mesh size) and gillnet (>150 mesh size) as recorded during the UK (English) observer programme (2002–2016).

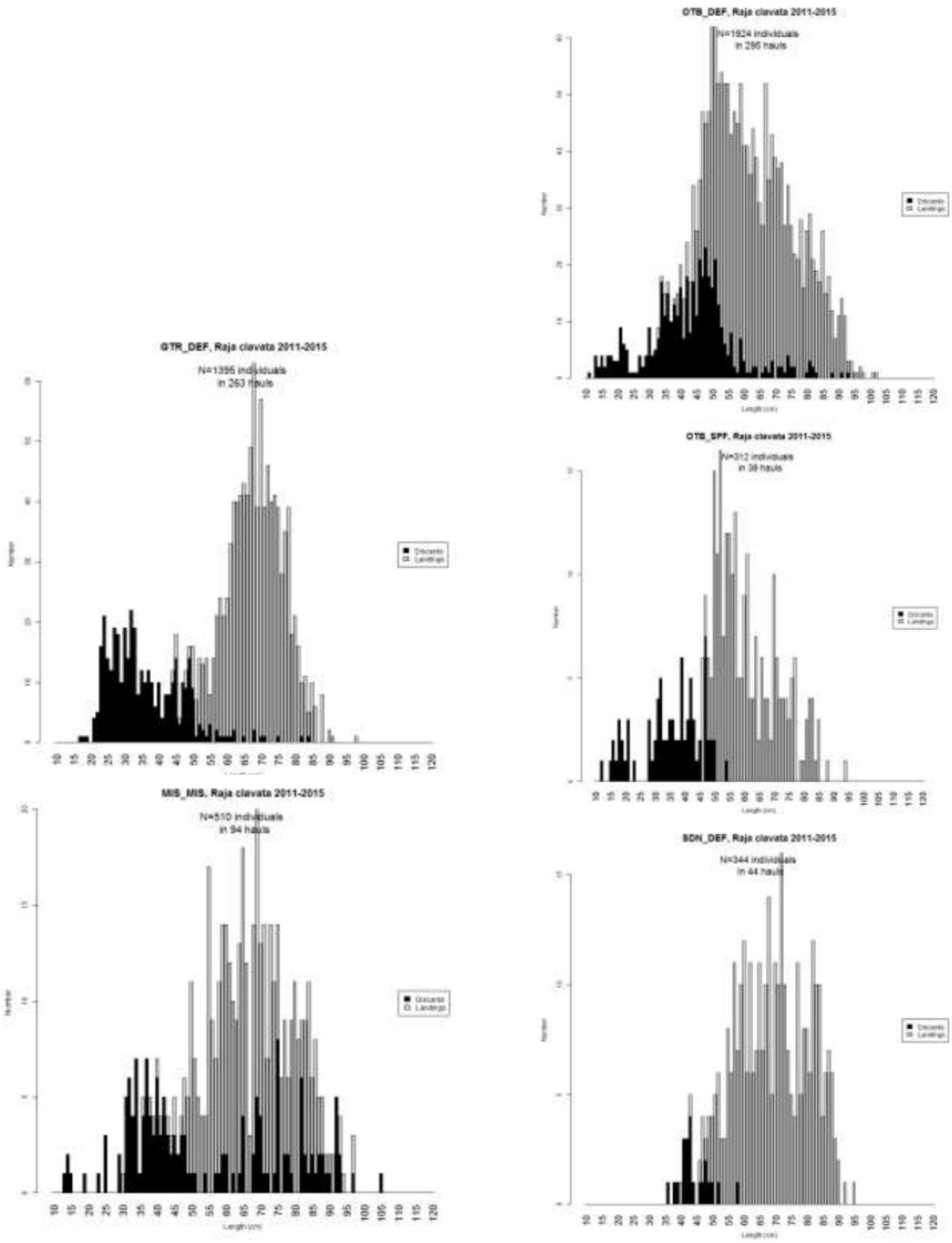

Figure 5.21: Length-based discard-retention pattern of thornback ray, *R. clavata* by métier, ICES divisions 4.b.c and 7.d, as recorded during the French observer programme (data combined for the years 2011–2016).

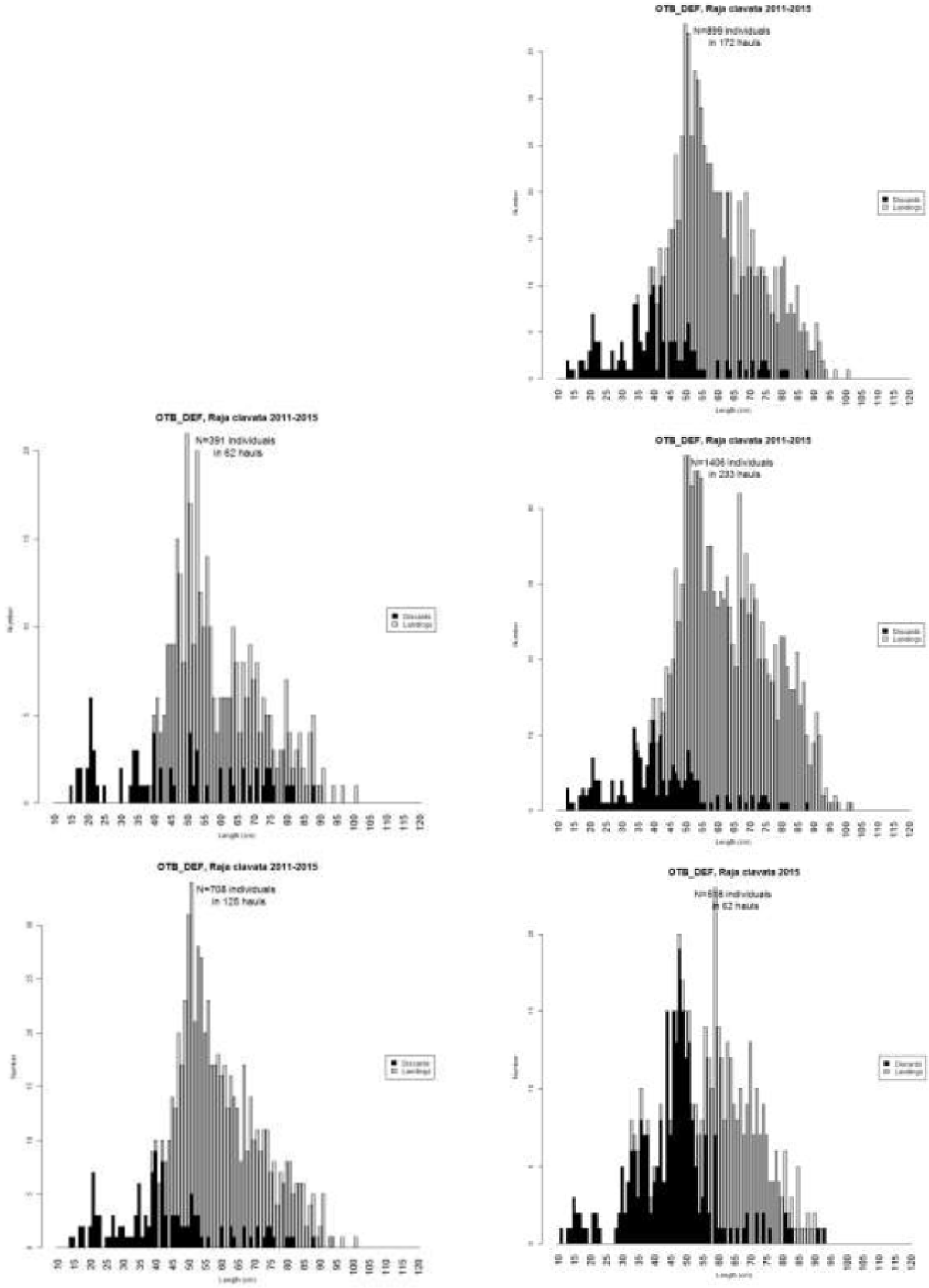

Figure 5.22: France OTB-DEF discards and retentions of *R. clavata*, 2011–2015.

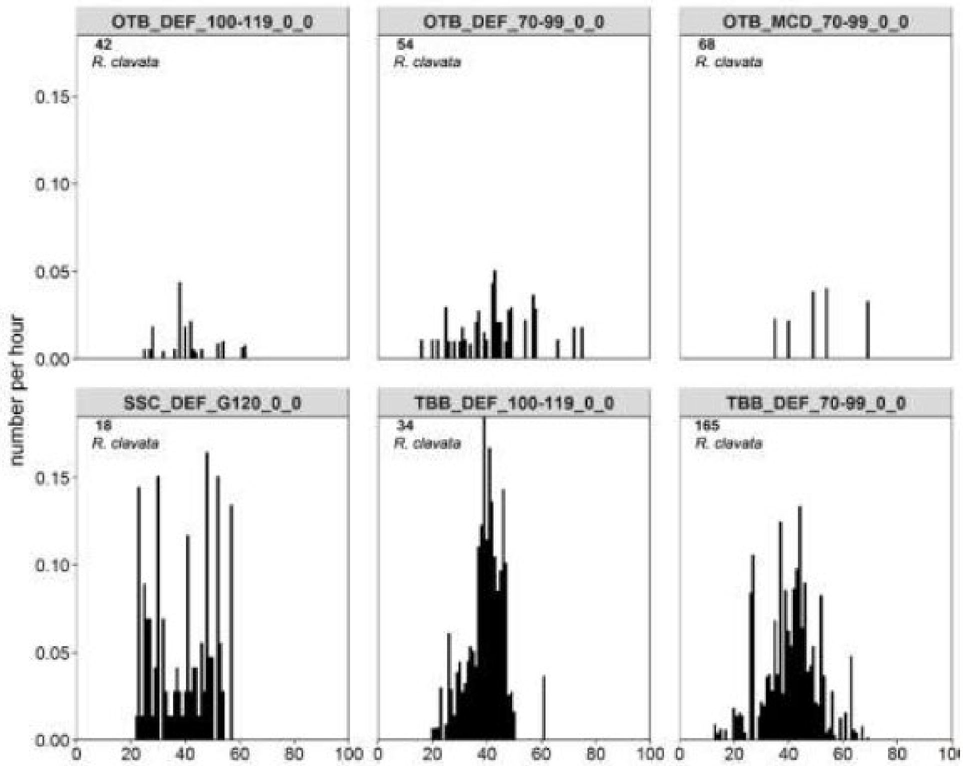

Figure 5.23: Panels show the discards per centimetre classes for *R. clavata*. Data are based on self-sampling of the Dutch fishing fleet in divisions 4.c and 4.b. The numbers in the left corner of each panel represent the number of trips sampled in that métier. Metiers for which less than 15 trips were sampled were excluded from the analysis.

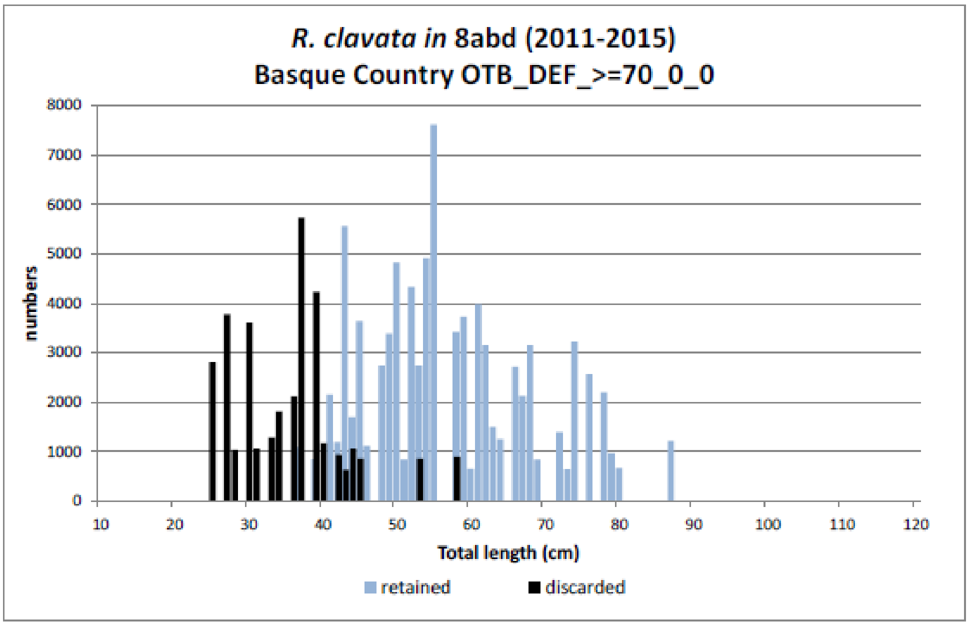

Figure 5.24: Length frequency distribution of thornback ray *R. clavata* discarded and retained fractions sampled onboard Basque Country's OTB (divisions 8.abd) in the period 2011–2015. Numbers raised to the total trips.

ICES 27 Subarea 8

Data: French onboard observer programme (2010–2017).

Full results in: WKSHARK4 report (ToR a), 2018

Result summary: Generally, it looks like larger individuals are landed rather than discarded for all gear types except for gillnets (GNS), for which *R. clavata* seem to be discarded or landed irrespective of its size. (NOTE: fishing operations for GNS mainly came from two vessels and so may not necessarily be representative of practices of the whole fleet.)

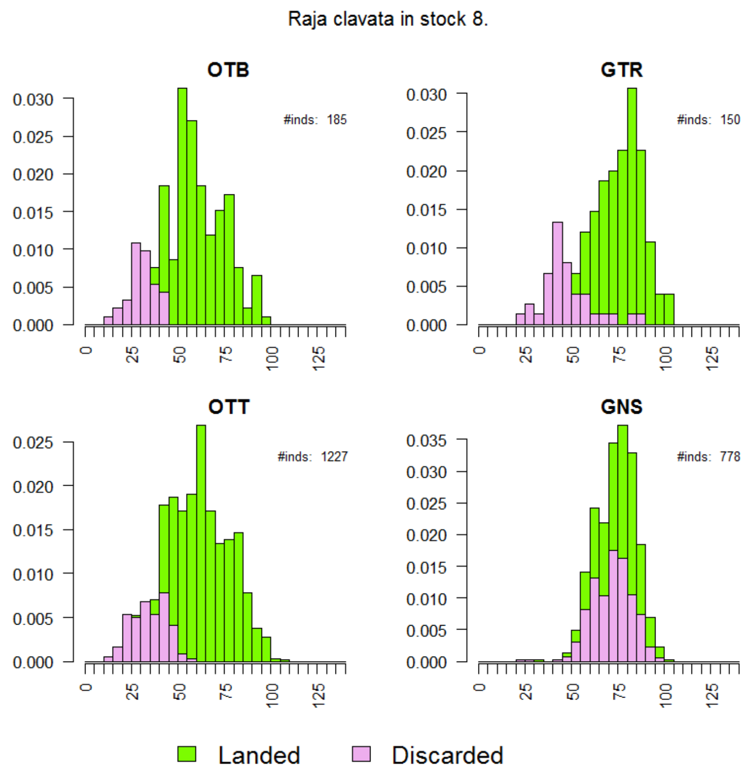

Figure 5.25: Length distribution of *R. clavata* catches (rjc.27.8) expressed in frequencies as a function of gear, distinguishing landed and discarded components, based on French onboard observer data 2010–2017. OTB = Bottom otter trawl, OTT = Otter twin trawl, GTR = Trammel nets, GNS = Set gillnets (anchored).

Blonde ray *Raja brachyura*

ICES 27 Divisions 4.c and 7.d
Data: National data for UK (England), and France (figures 5.26–5.27).
Full results in: WKSHARK3 report (ToR a), 2017
Result summary:
Gill-nets show small numbers of discarded *Raja brachyura* within all countries' data. Both UK and French data show high proportions of discarded small fish from otter trawls.

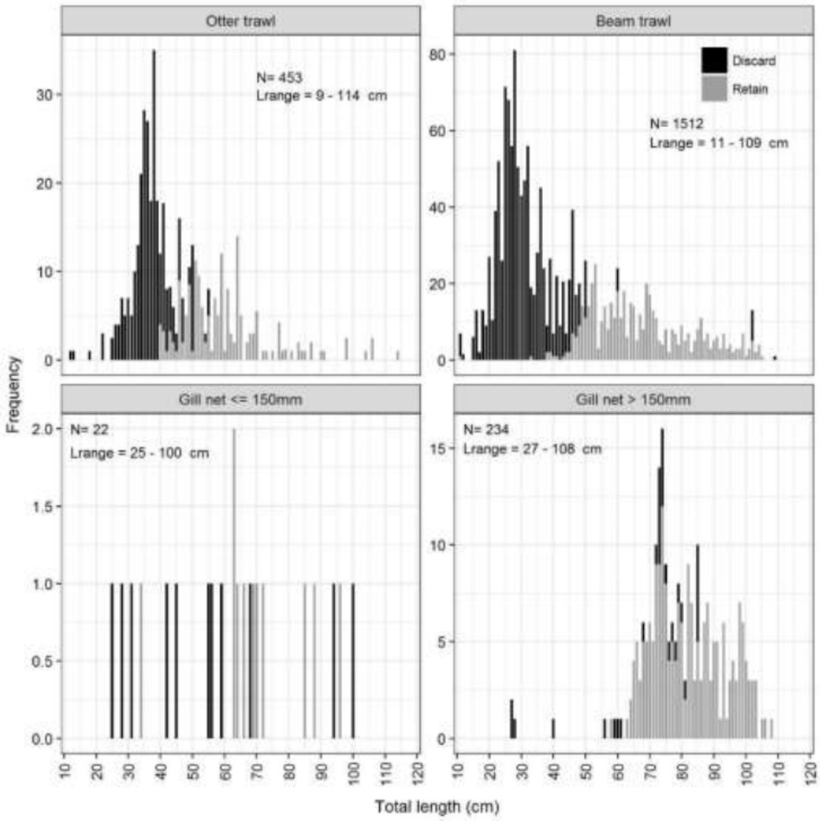

Figure 5.26: Length-based discard-retention pattern of blonde ray *R. brachyura* (ICES divisions 4.c and 7.d) for otter trawl, beam trawl, gill net (≤150 mm mesh size) and gillnet (>150 mesh size) as recorded during the UK (English) observer programme (2002–2016).

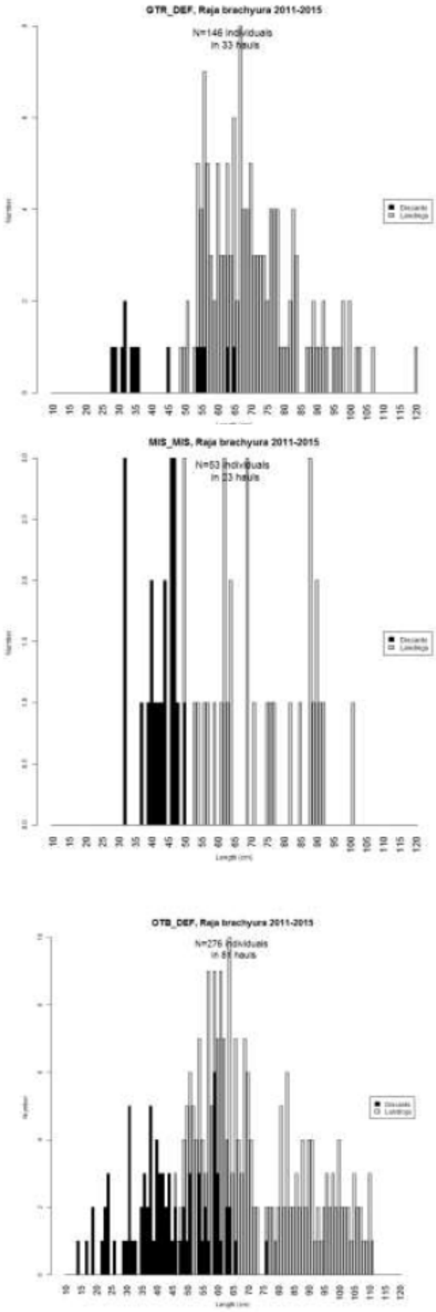

Figure 5.27: Length-based discard-retention pattern of blonde ray, *R. brachyura* by métier, ICES divisions 4.c and 7.d, as recorded during the French observer programme (data combined for the years 2011–2016).

ICES 27 Subarea 4
Data: Dutch self-sampling programme ((2011) 2014–2017)
Full results in: WKSHARK4 report (ToR a), 2018; new plots here
Result summary: When comparing the length frequency distributions between the gear groups, beam-trawls appeared to have a larger spectrum of length classes in their discards (see Figure 3.6 in WKSHARK4 report). In the beam-trawl fishery, it looks like most individuals smaller than 60 cm get discarded (with some exceptions), whereby larger individuals get landed.

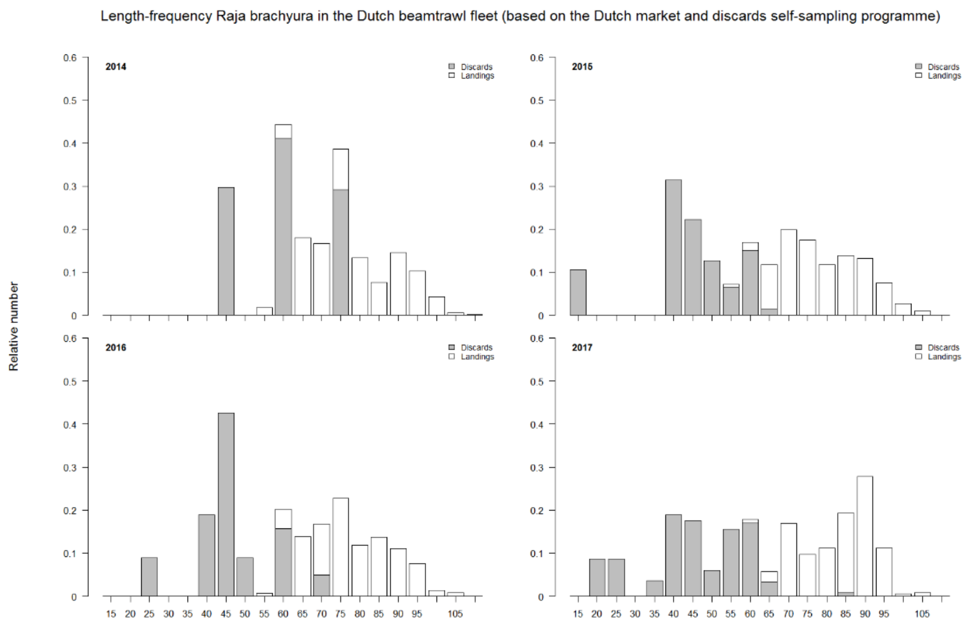

Figure 5.28: Length distribution of *R. brachyura* caught and discarded in 27.4, expressed in relative numbers (thousands) per year as a function of year for 2014–2017. Data are based on the Dutch market and discards self-sampling programme.

Cuckoo ray *Leucoraja naevus*

ICES 27 Subareas 3 and 4
Data: French observer programme (2011–2016)
Full results in: WKSHARK3 report (ToR a), 2017)
Result summary: The numbers of fish sampled by the French fleet in the North Sea are too small to determine trends.

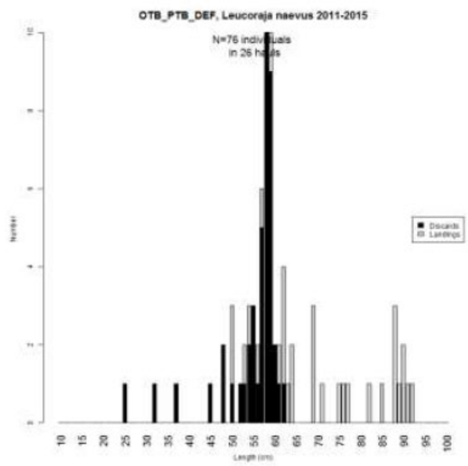

Figure 5.29: Length-based discard-retention pattern of cuckoo ray, *L. naevus* by métier, ICES subareas 3 and 4, as recorded during the French observer programme (data combined for the years 2011–2016).

ICES 27 Subarea 4
Data: Dutch self-sampling programme (2011–2016)
Full results in: WKSHARK4 report (ToR a), 2018)
Result summary: When comparing the length frequency distributions between the gear groups, beam-trawls appeared to have a larger spectrum of length classes in their discards. For Dutch data see Figure 3.6 in WKSHARK4 report.

ICES 27 Subareas 3, 4, 6 and 7

Data: National data for UK (England), France, Ireland, and Spain (Basque country) (figures 5.30-5.32).

Full results in: WKSHARK3 report (ToR a), 2017

Result summary:

Fishers in the Celtic Sea and Irish Sea report differing discard rates between Irish and French vessels. This is based on differing market requirements. This is corroborated by the figures below (figures 5.30 and 5.32). Irish otter trawls operating in 7.a.e-k discard most of their catches of *L. naevus,* whereas they are retained by French vessels operating in the same area. UK vessels operating in the same area show a discard pattern midway between these two extremes, with some discarded and some retained. In the UK trawl fisheries individuals smaller than 50 cm seem to be discarded whereby in gillnets, individuals of equal sizes are landed and discarded, albeit from a narrower size spectrum (30–79 cm, as compared to 10–96 cm in trawl fishery). Irish otter trawl sampling in ICES Subarea 6 shows two distinct cohorts in the data that are not visible in other gears or from data for other countries.

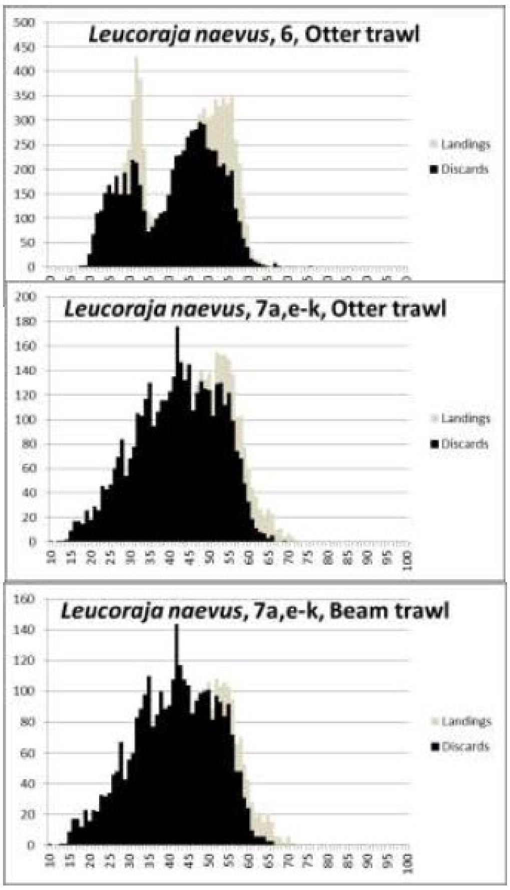

Figure 5.30: *L. naevus*. Discard/landing records from Irish observers (ICES Subarea 7).

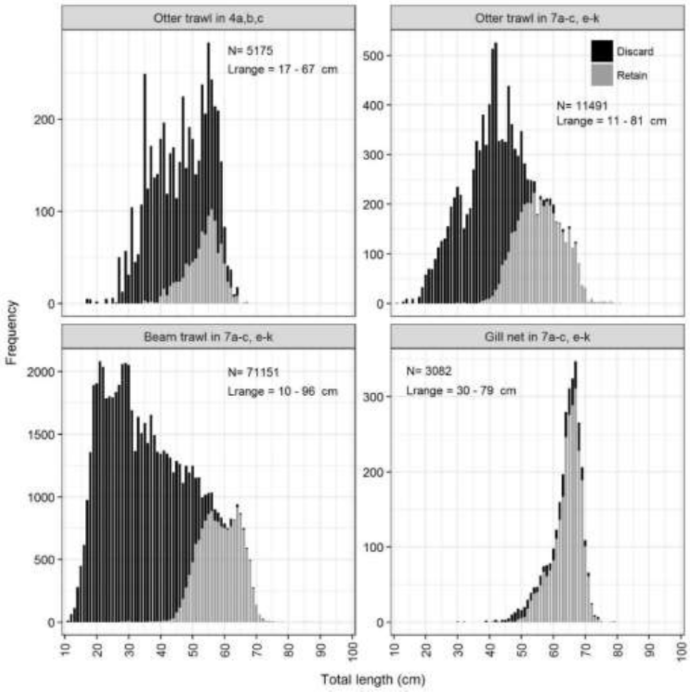

Figure 5.31: Length-based discard-retention pattern of cuckoo ray *L. naevus* in ICES Subarea 4 (otter trawl only) and divisions 7.a-c and e-k (otter trawl, beam trawl and gillnet) as recorded during the UK (English) observer programme (2002–2016).

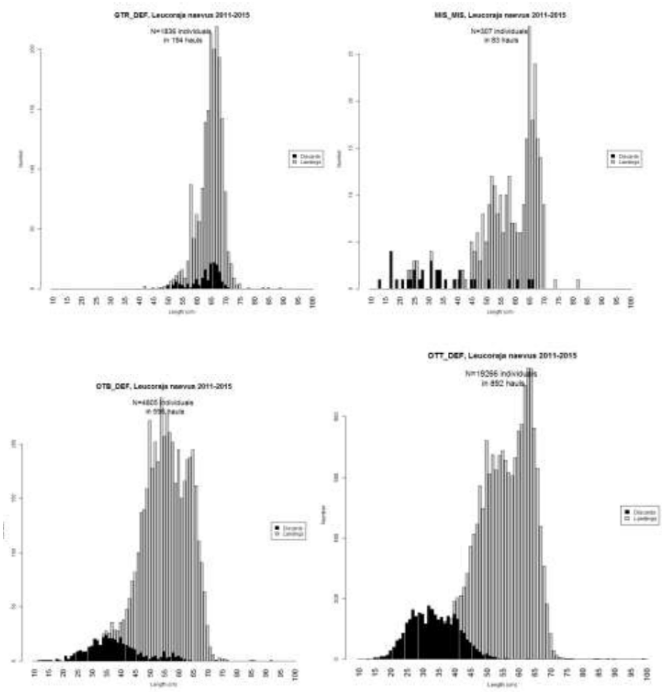

Figure 5.32: Length-based discard-retention pattern of cuckoo ray, *L. naevus* by métier, ICES subareas 6 and 7, as recorded during the French observer programme (data combined for the years 2011–2016).

ICES 27 Subarea 8
Data: National data for Spain (Basque country) (Figure 5.33).
Full results in: WKSHARK3 report (ToR a), 2017
Result summary:
Discards/retentions by the Basque Fleet in Subarea 8 show that most fish below a certain size are discarded, with larger specimens retained.

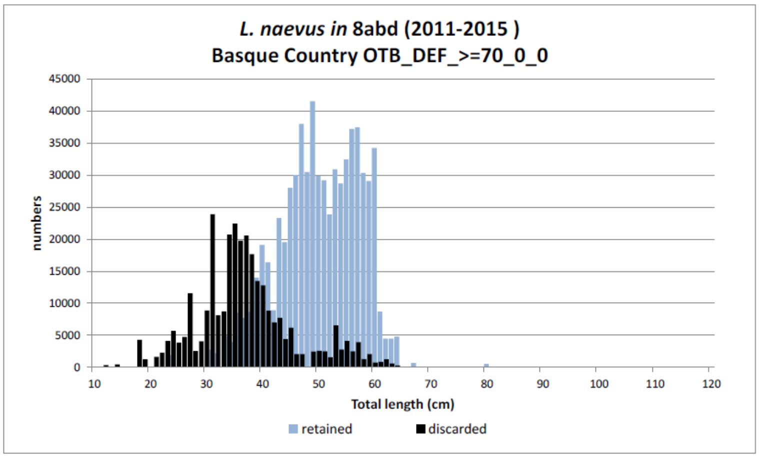

Figure 5.33: Length frequency distribution of cuckoo ray *L. naevus* discarded and retained fractions sampled onboard Basque Country's OTB (divisions 8.abd) in the period 2011–2015. Numbers raised to the total trips.

Thorny skate *Amblyraja radiata*

ICES 27 Subareas North Sea

Data: Dutch self-sampling programme (Figure 5.34)

Full results in: WKSHARK3 report (ToR a), 2017

Result summary: While observer data are available from all countries, not all métiers are sampled to a level that can allow patterns in discard/retention ratios to be observed. Similarly, few métiers have been intensively sampled enough to allow changes in pattern to be determined. Otter trawl-based métiers have the most number of samples for almost all examined species. These are most likely to be of use in stock assessments. Length-based indicators are probably only going to be useable for this gear-type for the majority of demersal elasmobranch stocks. Whilst some nations have large samples sizes for various gillnet métiers, the length-distributions are influenced greatly by mesh size, which would need to be considered in future evaluations of length-based indicators.

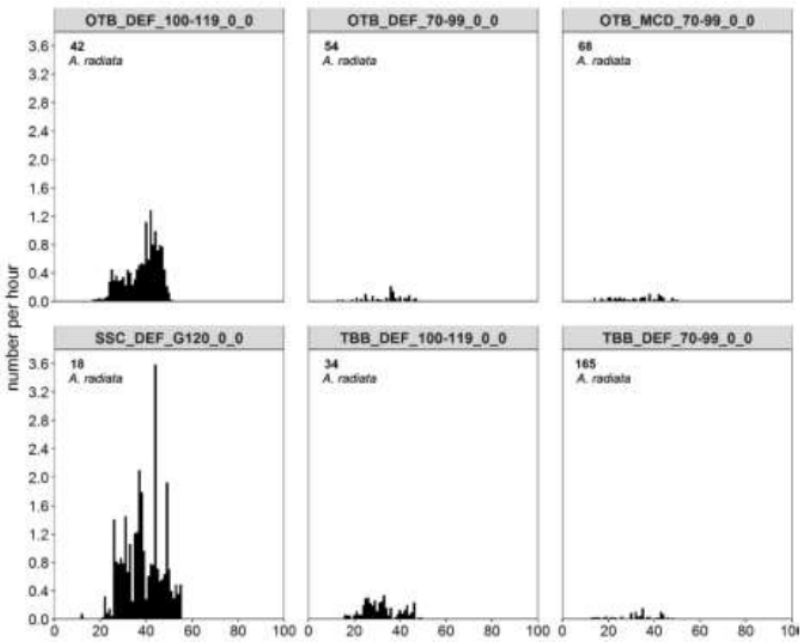

Figure 5.34: Panels show the discards per centimetre classes for *A. radiata*. Data are based on self-sampling of the Dutch fishing fleet in divisions 4.c and 4.b. The numbers in the left corner of each panel represent the number of trips sampled in that métier. Metiers for which less than 15 trips were sampled were excluded from the analysis.

Undulate ray *Raja undulata*

ICES 27 Divisions 7.d and 7.e

Data: French self-sampling data (2015), following protocol in Gadenne (2017) (Figure 5.35)

Full results in: WKSHARK4 report (ToR a), 2017

Result summary: Catches from gillnets (GNS), trammel nets (GTR), and the combination of the two (GTN) were characterized by the absence of the smaller individuals (*i.e.* <70 cm TL) and much lower catches in general, unlike bottom longlines (LLS) and bottom trawls (OTB). LLS and OTB seem to have similar selectivity for landing larger individuals. No differences between sexes were seen in the length distributions of the catch for any of the gears. (NOTE: Landing data were limited by a maximum (97 cm) and minimum (78 cm) landing size authorisation in 2015)

ICES 27 Divisions 8.a and 8.b

Data: French self-sampling data (2015), following protocol in Gadenne (2017) (Figure 5.36)

Full results in: WKSHARK4 report (ToR a), 2018

Result summary: For GNS (for which a substantial amount of fishing operations were sampled), individuals larger than 95 cm TL seem to be absent, as opposed to ICES divisions 7.d–e. Also, it seems that for GNS at least that larger individuals are both landed and discarded, whereas smaller individuals <76 cm seem to be all discarded. (NOTE: The paucity of data in ICES Subarea 8 which was included in the analysis renders the interpretation of the corresponding length distribution more difficult).

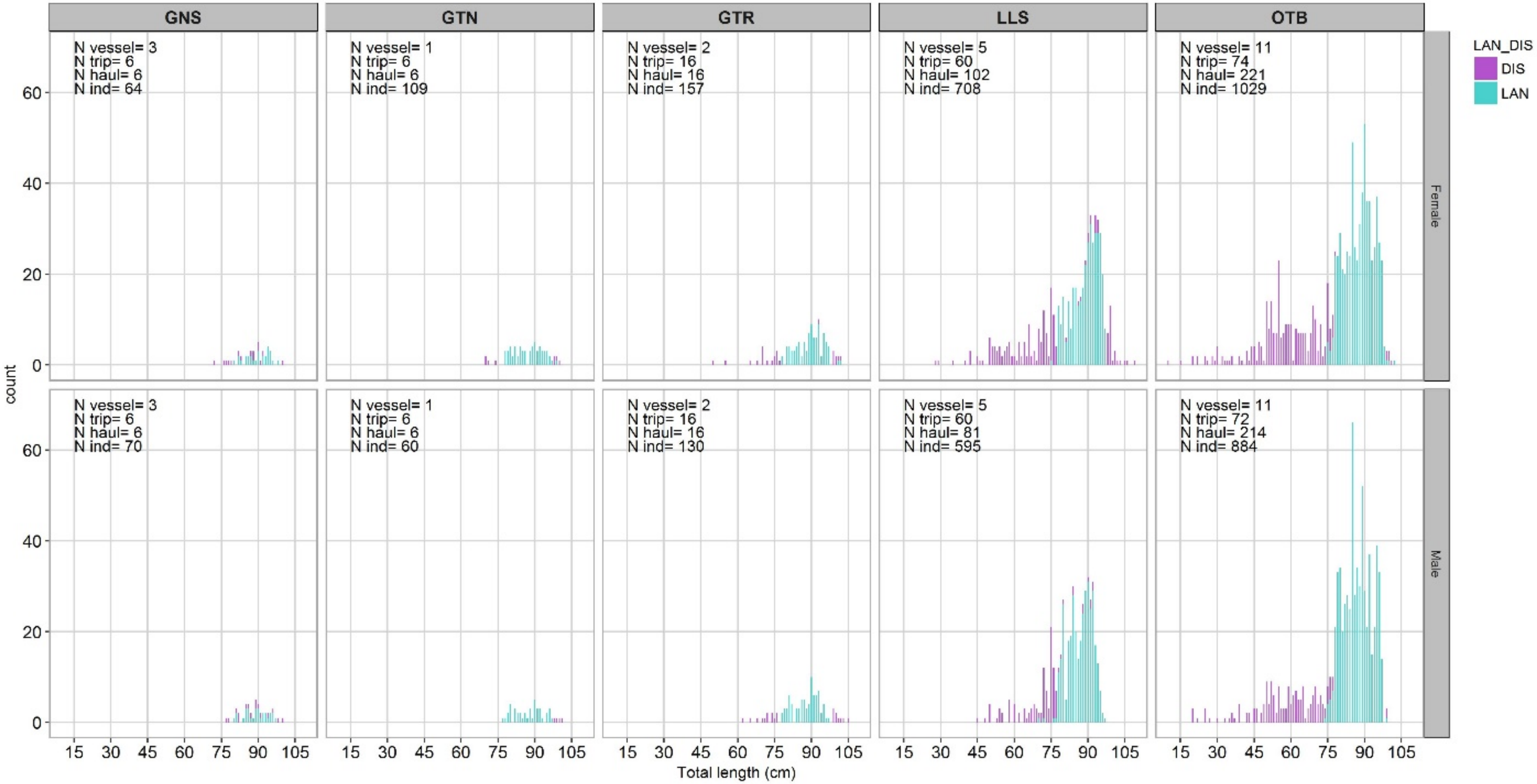

Figure 5.35: Length distribution of *R. undulata* catches in stock rju.27.7de by sex (females at the top, males at the bottom), expressed in numbers as a function of gear, distinguishing landed (LAN) and discarded (DIS) parts, based on the French self-sampling programme for *R. undulata* in 2015.

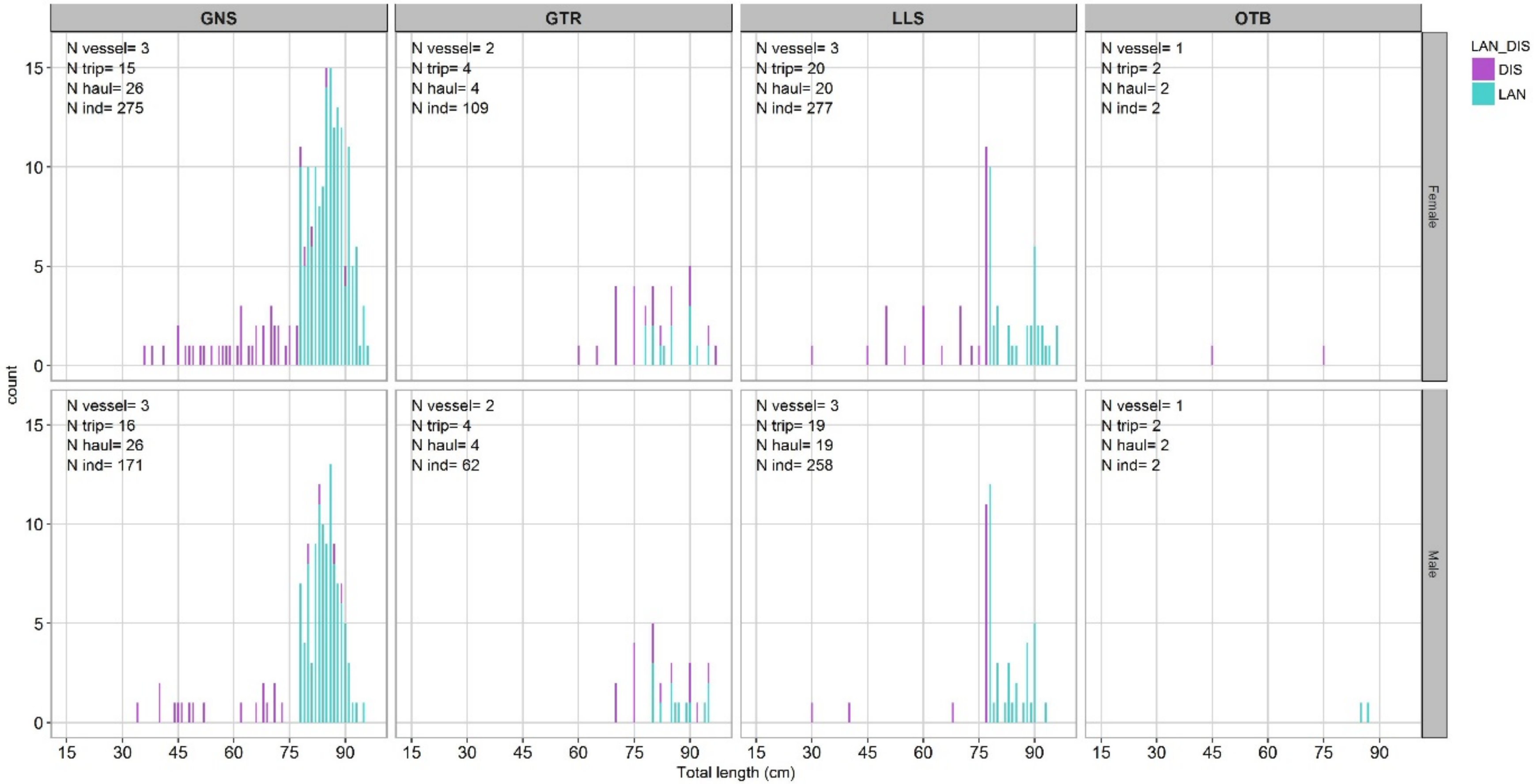

Figure 5.36: Length distribution of *R. undulata* catches in stock rju.27.8ab by sex (females at the top, males at the bottom), expressed in numbers as a function of gear, distinguishing landed (LAN) and discarded (DIS) parts, based on the French self-sampling programme for *R. undulata* in 2015.

Spotted ray *Raja montagui*

ICES 27 Subarea 4
Data: Dutch market and discards self-sampling programme ((2011) 2014–2017)
Full results in: WKSHARK4 report (ToR a), 2018; new plots here
Result summary: When comparing the length frequency distributions between the gear groups, beam-trawls appeared to have a larger spectrum of length classes in their discards (see Figure 3.6 in WKSHARK4 report). In the beam-trawl fishery, it looks like most individuals smaller than 55 cm get discarded, whereby larger individuals get landed.

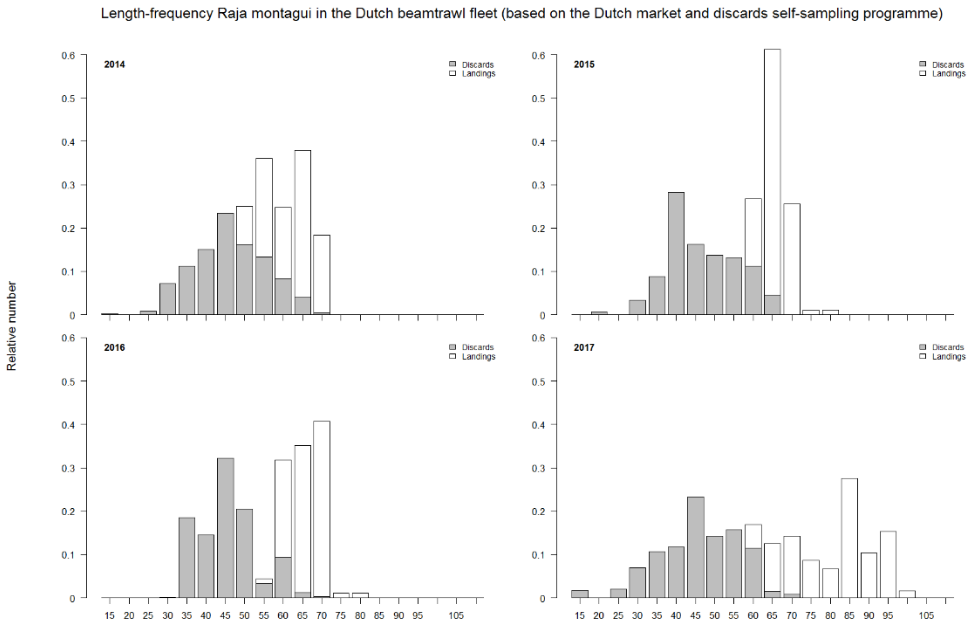

Figure 5.37: Length distribution of *R. montagui* caught and discarded in 27.4, expressed in relative numbers (thousands) per year as a function of year for 2014–2017. Data are based on the Dutch market and discards self-sampling programme.

Annex 3: *Raja undulata* – case-study

The coastal and discrete distribution of undulate ray together with its biological characteristics make this species quite vulnerable to fishing and easily targeted by fisheries. Those facts were considered for the inclusion of undulate ray stocks in 2010 in the EU list of prohibited species (Section 6 of CEC, 2010). In the 2015 EU Commission request on *Possible by-catch provisions for undulate ray in ICES areas VIIde, VIIIab and IX,* STECF noted that *lack of basic catch and effort data and the limited survey coverage remains a barrier to the development of an analytical assessment based on fishery dependent and independent data…* and … *that it is not in a position to determine whether such landings levels are in accordance with the provisions of the CFP (STECF-15-03).* STECF further advised that …*If managers decide upon a limited TAC … catches and effort be closely monitored and used as the basis of an adaptive management approach.*

Such rationale has implicitly the answering of the main questions:

i. What is the current stock status?
ii. What are the sustainable fishing levels for the stock?

Several assessment approaches have been proposed and the results obtained from the application of some of these approaches to *R. undulata* data are next presented:

No survey data but georeferenced catches derived from self-sampling programs

As a consequence of the coastal distribution of undulate ray in Division 9.a. (stock rju.27.9a) results that the species is infrequently caught by the surveys that take place in this Division. In fact, the species is absent in the Spanish IEO Q4-IBTS survey and is rarely caught in the Portuguese demersal survey (PtGFS-WIBTS-Q4). As a consequence, these surveys cannot be used to monitor the stock status.

In ICES Division 9.a, the rju.27.9a stock has been under moratorium between 2009 and 2015 (inclusive). After this moratorium, a small by-catch was allowed by the EU. To manage this small fishing opportunity, Portuguese authorities set a regulation where: i) only vessels holding a special fishing license are allowed to catch *R. undulata*; ii) the skippers of the licensed vessels authorize the onboard presence of IPMA scientific observers for data collection; iii) licensed vessels are obliged to collect and report information on catches of undulate ray by fishing haul; iv) only specimens over 780 mm and smaller than 970 mm in total length are allowed to be landed; v) daily landings are limited to no more than 30 kg live weight per fishing trip and; vi) landings are prohibited during May and June (Portaria no 96/2016, April 2016).

The Portuguese self-sampling programme had an experimental phase in 2016 as it was recognized that some time was needed to inform fishermen about the programme and to guarantee that they fully understand and comply with the programme requirements. Given this, only data collected during 2017 were considered for abundance/biomass and potential catch estimates.

For 2017 data, the potential abundance of *R. undulata* was estimated for different regions off the Portuguese continental waters (Figueiredo *et al*., 2015) and using depth and bottom sediment as predictor variables. Figure A2.1 presents the *R. undulata* abundance estimates for different regions of the Portuguese coast and Table A2.1 the biomass estimates (these were calculated by multiplying the abundance estimates by the mean individual weight).

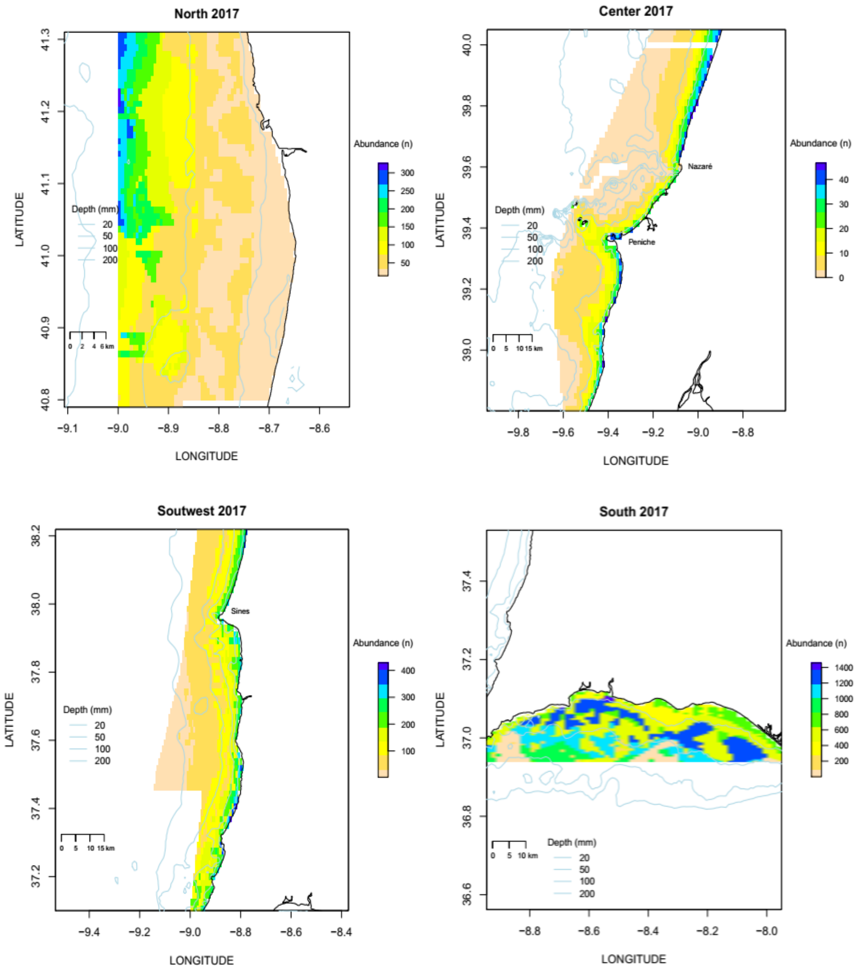

Figure A2.1: rju_pore stock. Abundance estimates by region of the Portuguese coast for 2017.

Table A2.1: rju_pore stock. Abundance, density and biomass estimates of *Raja undulata* by region of the Portuguese coast for 2017.

Region	Estimate of total abundance (numbers)	Area (km²)	Density estimate (number per km²)	Biomass estimate (tonnes)
North	236034	1525.3	155	1426
Centre	10773	3503.6	3	65
Southwest	201457	2132.9	94	1217
South	1641420	1330.4	1234	9919
Total	2089684	8492.3		12627

R. undulata length data collected in 2015 under the Portuguese DCF were used. A length-cohort analysis (LCA) with Rodney approach was adjusted (Jones, 1981). The estimated fishing mortality was 0.07. This value was considered consistent and reflecting the fact that the species has been under moratorium for several previous consecutive years.

Further, based on the available knowledge of *R. undulata* biology and dynamics, a Beverton-Holt yield per recruit (Y/R) model was adjusted. The fishing mortality for different potential spawning ratio were estimated Table A2.2.

Table A2.2. rju_pore stock. Yield per recruit (Y/R for different levels of fishing mortality (F), total mortality (Z), exploitation rate (E) and an age of first capture = 7 years (TC).

	F	Z	E	Y/R (t)
F20%BPR	0.28	0.50	0.57	0.17
F30%BPR	0.20	0.41	0.48	0.15
F35%BPR	0.17	0.38	0.44	0.14
F40%BPR	0.14	0.36	0.40	0.13

Annex 4: Undulate ray in the English Channel

1. Calculation of LAEM (landings advice at exit of moratorium) for undulate ray in 7.d based on FR-CGFS-Q4 biomass indices of undulate ray and thornback ray and IBTS-Q4 biomass index of thornback ray (reference stock).

Biomass indices from FR-CGFS-Q4 are available for thornback, blonde and undulate ray. Other ray species are caught in too small numbers in this survey to derive indices. An increasing trend has been observed for the three species since about 2010 (Figure A3.1). The estimated biomass of undulate ray and blonde ray are similar to a level of about 10% of the estimated biomass of thornback ray. Note that indices used here are swept area biomass indices and differ from indices in kg h^{-1} used for the advice on rjc.27.3a47d (Table A3.1).

To calculate the LAEM for undulate ray, which was under moratorium in 2009–2014 with a small TAC thereafter, thornback ray and blonde ray can be used as reference stocks. Thornback ray and blonde ray occurring in 7.d are ascribed to ICES stocks rjc.27.3a47d and rjh.27.4c7d, respectively. ICES provides landings advices for both. The stock area of undulate ray is the English Channel (rju.27.7de), so different from the two reference species.

Therefore, the advisable landings of undulate ray in 7.d can be calculated using Eq. 3

$$LAEM(mor, div) = \left[\frac{B\,(mor,div)}{B(ref,.)}\right] \times \frac{r(mor)}{r(ref)} \times Adv(ref) \qquad \text{(Eq. 3)}$$

Biological productivity was taken as the inverse of *Lmat*. *Lmat* values used are given in Table A3.2. For example, when using thornback ray as reference species, the productivity ratio is (1/83.8)/(1/73.7) = $\frac{r(mor)}{r(ref)}$ = 0.88. *Lmat* was chosen instead of *Lmax or L∞* because it is better estimated as it is less sensitive to outliers.

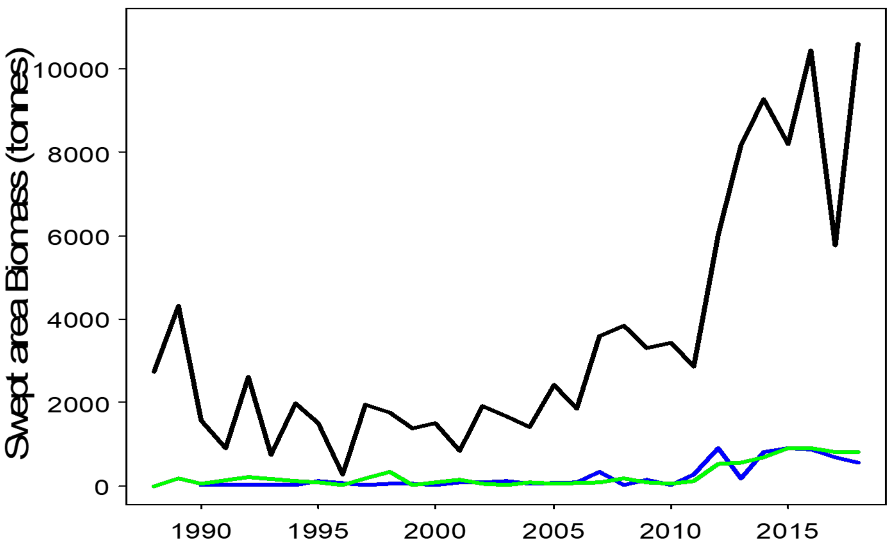

Figure A3.1: Swept area estimate of biomass of thornback ray (black), blonde ray (blue) and undulate ray (green).

Table A3.1: Swept area estimates of biomass of the main three ray species in the Eastern Channel.

Year	Thornback	Blonde	Undulate
1988	2731	0	4
1989	4323	0	187
1990	1568	7	67
1991	907	0	0
1992	2617	0	216
1993	748	0	0
1994	1976	23	106
1995	1500	123	99
1996	274	0	34
1997	1947	35	191
1998	1759	45	346
1999	1367	50	25
2000	1500	26	73
2001	836	95	136
2002	1927	68	64
2003	1652	125	24
2004	1417	37	80
2005	2427	0	65
2006	1859	70	0
2007	3585	328	73
2008	3841	15	168
2009	3309	150	71
2010	3434	30	50
2011	2847	262	114
2012	6018	919	513
2013	8170	180	544
2014	9283	817	688
2015	8211	892	893
2016	10428	871	894
2017	5773	670	800
2018	10585	550	805
Five last years average	8856	760	816

Table A3.2: Length at maturity of female blonde, thornback and undulate ray used as proxies of productivity (as 1/*Lmat*) of each species.

Species	Area	Used for	Female *Lmat* (cm)	Reference
Undulate ray	English Channel (Gulf Normand-Breton)	RJU in 7d and 7e	83.8	Stéphan *et al.*, 2014
Undulate ray	Bay of Biscay	RJU in 8ab	83.8	Stéphan *et al.*, 2014
Thornback ray	North Sea	RJC in 7d	73.7	McCully *et al.*, 2012
Thornback ray	Celtic Seas	RJC in 7e	78.2	McCully *et al.*, 2012
Blonde ray	Combined	RJH in 7d and 7e	83.4	McCully *et al.*, 2012

The application of the approach is shown in Table A3.3. It is applied to calculate the LAEM of undulate ray from 7.d for every year since 2016, the first year where a landings advice was published for thornback ray (stock rjc.27.3a47d). The line shaded in grey shows which advisable landings would had been calculated in 2015 for 2016 based on data from 2014. As landings advice have been published for four years, the calculation was done for each of these years. Depending of the year where the exit of the moratorium could have been decided, the LAEM of undulate ray from 7.d only in that year could have been 83–136 tonnes. A simulation of the calculation of the LAEM for undulate ray in 2020 using the average of biomass indices in the last five available years (2014–2018) assuming that the landings advice for rjc.27.3a47d for 2020 will be the same as in 2018 and 2019 resulted in 120 tonnes (Table A3.4). The DLS category 3 rule may result in landings advice for rjc.27.3a47d in 2020 to be in the range of 64% (decrease by the uncertainty cap of 20% and application of the precautionary buffer) to 120% (increase by the uncertainty cap of 20%) of the previous advice. The calculation of the LEAM in 2019 for 2020 in 7.d would be expected to be in the range of 77–144 tonnes.

Table A3.3: Time series of swept area biomass indices (tonnes) of undulate ray (rju) and thornback ray (rjc) in Division 7.d based on FR-CGFS-Q4 and thornback ray in Subarea 4 and Division 3.a based on IBTS-Q1, landings advice for the stock rjc.27.3a47d since 2016 and LAEM of undulate ray in Division 7.d which would have been derived by applying the approach in years where the ICES advice on rjc.27.3a47d included a landings level. The grey shaded line represents indices in 2014 available in 2015 (assessment year) for advising in 2016.

Year	Biomass indices (tonnes)			Advices (tonnes)	
	rju 7.d	rjc 7.d	Rjc 3.a and 4	rjc.27.3a47d	LAEM rju 7d
2006	0	1859	4760		
2007	73	3585	858		
2008	168	3841	8251		
2009	71	3309	4569		
2010	50	3434	1473		
2011	114	2847	294		
2012	513	6018	13633		
2013	544	8170	3324		
2014	688	9283	6015		
2015	893	8211	5637		
2016	894	10428	4467	2110	83
2017	800	5773	13724	2110	120
2018	805	10585	4918	2574	136
2019				2574	93

Table A3.4: Simulation of LAEM of undulate ray in 7.d in 2020 calculated in 2109 (assessment year) based upon five years (2014–2018) average of swept area biomass indices (tonnes) of undulate ray (rju) and thornback ray (rjc) in Division 7.d and thornback ray in Subarea 4 and Division 3.a. Landings advice for rjc.27.3a47d in 2020 assumed equal to previous years.

Year	Biomass indices (tonnes)			Advice (tonnes)	
	rju 7.d	rjc 7.d	Rjc 3.a and 4	rjc.27.3a47d	LAEM rju 7d
2014	688	9283	6015		
2015	893	8211	5637		
2016	894	10428	4467		
2017	800	5773	13724		
2018	805	10585	4918		
	Five years average			2020 advice	
	816	8856	6952	2574	120

2. Calculation of LAEM for undulate ray in 7.d based on FR-CGFS-Q4 biomass indices of undulate ray and blonde ray and IBTS-Q4 biomass index of blonde ray (reference stock).

The calculation is carried as in the previous section. The reference stock is rjh.4c7d. The whole indices time series of blonde ray in the Eastern Channel is presented in Table A3.1, the ratio of *Lmat* is (1/83.8)/(1/83.4) = 0.99 (Table A3.2). LAEM of 46–155 tonnes would have been derived from the approach applied in 2015 to 2018 (Tables A3.5). The overall level of the LAEM is similar to that obtained by using rjc.27.3a47d as the reference stock, with larger year-to-year variations resulting from larger variations in the IBTS index of rjh. The simulation of the calculation of LAEM for 2019 based on the last five years average of indices and the assumption of the same recommended landings as for 2018 resulted in 85 tonnes, lower than using rjc.27.3a47d as the reference stock (Table A3.6).

Table A3.5: Time series of swept area biomass indices (tonnes) of undulate ray (rju) and blonde ray (rjc) in Division 7.d based on FR-CGFS-Q4 and blonde ray in Division 4.c based on IBTS-Q1, landings advice for the stock rjh.27.4c7d since 2016 and LAEM of undulate ray in Division 7.d which would have been derived by applying the approach in years where the ICES advice on rjh.27.4c7d included a landings level. The grey shaded line represents indices in 2014 available in 2015 (assessment year) for advising in 2016.

Year	Biomass indices (tonnes)			Advices (tonnes)	
	rju 7.d	rjh 7.d	rjh 4c	rjh.27.4c.7d	LAEM rju 7d
2006	0	70	34		
2007	73	328	185		
2008	168	15	535		
2009	71	150	48		
2010	50	30	15		
2011	114	262	14		
2012	513	919	1355		
2013	544	180	276		
2014	688	817	1573		
2015	893	892	658		
2016	894	871	242	162	46
2017	800	670	1137	162	92
2018	805	550	1872	195	155
2019				195	85

Table A3.6: Simulation of LAEM of undulate ray in 7.d in 2020 calculated in 2109 (assessment year) based upon five years (2014–2018) average of swept area biomass indices (tonnes) of undulate ray (rju) and thornback ray (rjc) in Division 7.d and thornback ray in Subarea 4 and Division 3.a. Landings advice for rjc.27.3a47d in 2020 assumed equal to previous years.

Year	Biomass indices (tonnes)			Advice (tonnes)	
	rju 7.d	rjc 7.d	Rjh 4.c	rjc.27.3a47d	LAEM rju 7d
2014	688	817	1573		
2015	893	892	658		
2016	894	871	242		
2017	800	670	1137		
2018	805	550	1872		
	Five years average			2020 advice	
	816	760	1097	195	85

3. Calculation of LAEM for undulate ray in 7.e based on the new FR-CGFS-Q4 survey in the western Channel biomass indices of undulate ray and blonde ray and IBTS-Q4 biomass index of blonde ray (reference stock).

Description of the survey

A new survey series has been initiated by France in the Western Channel. The survey is carried out with the R/V Thalassa. It is similar to CGFS in the eastern Channel and EVHOE, although with a trawl equipped with a slightly different ground gear because of harder seafloor found in the western Channel. The survey has been carried out three times in 2014, as a first trial and in 2017 and 2018 as the beginning of the time series.

Calculation of LAEM with thornback ray and blonde ray as reference species

As this survey does not yet make a time series, data for the three years combined were used by WKSHARK5. For thornback ray, Eq. 1 with the ratio of productivities of 0.88 (see above) and returned an LAEM for undulate ray in Division 7.e of 275 tonnes (Table A3.7).

$$LAEM(mor) = \left[\frac{B\ (mor)}{B\ (ref)}\right] \times \frac{r(mor)}{r(ref)} \times Adv(ref) \qquad \text{(Eq. 1)}$$

Table A3.7: Simulation of LAEM for undulate ray in 7.d in 2020 calculated in 2019 (assessment year) based upon swept area biomass indices (tonnes) from years 2014, 2017 and 2018 combined and advice for thornback in 7.e for 2019 and 2020.

Years	Biomass indices (tonnes)		Advice (tonnes)	
	rju.7.e	rjc.7.e	Advice rjc.27.7e	LAEM rju.7.e
2014, 2017, 2018	1688	1146	212	275

For blonde ray, the ratio is 0.99 and the calculation returned an LAEM for undulate ray in Division 7.e of 517 tonnes (Table A3.8).

Table A3.8: Simulation of LAEM for undulate ray in 7.d in 2020 calculated in 2019 (assessment year) based upon swept area biomass indices (tonnes) from years 2014, 2017 and 2018 combined and advice for thornback in 7.e for 2019 and 2020.

Years	Biomass indices (tonnes)		Advice (tonnes)	
	rju.7.e	rjh.7.e	Advice rjh.27.7e	LAEM rju.7.e
2014, 2017, 2018	1688	860	266	517

Combining at the stock level

In 7.d, several annual estimates were calculated to exemplify the combination of the two divisions. WKSHARK5 used only estimates based on several years combined. Estimates of LAEM were obtained based on indices for the five last years combined in Division 7.d (tables A3.4 and A3.6) and for the three last years in Division 7.e, (tables A3.7 and A3.8). In each Division, these two estimates were derived from using thornback ray and blonde ray as reference species. Several options are possible for selecting one estimate in one Division. Using the smaller one is more precautionary, the average may be more statistically sound, or using one species rather than the other could be considered based on additional knowledge on catchability to surveys or spatial distribution. The smaller LAEM are 85 tonnes in Division 7.d based on the estimate using blonde ray as reference (Table A3.6) and 275 tonnes in 7.e with thornback ray as reference (Table A3.7), resulting in a total of 360 tonnes for the whole stock rju.27.7de. Using thornback ray in both divisions, the LAEM would be 395 tonnes, and using blonde ray, the LAEM would be 602 tonnes.

Annex 5: Landing Obligation Exemption

Information on the Landing Obligation can be found on the website of the European Commission. Documents are available to download in 23 languages.

- https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32019R2238 (North Sea)
- https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32019R2239 (North-western Waters)
- https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32019R2237 (Southwestern Waters)