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Analysis of 3M cod catch in all the fisheries across the Flemish Cap

by

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Abstract

Analyses of the haul by haul data from 2016 to 2020, as well as samples from observers on board, from the directed and no-directed fishery catching 3M cod, were conducted in order to consider whether measures, such as depth restrictions, spatial and mesh changes, could reduce the catch of juvenile and immature cod across all fisheries in 3M. The recent bycatch of 3M cod in other fisheries is considered low when compared to the directed cod fishery. Therefore, at this time, the implementation of measures to avoid juvenile cod bycatch would be premature, given that the burden of implementing and enforcing these measures on multiple fisheries may outweigh its potential benefits. With respect to the directed 3M cod fishery, and considering that new measures have been just implemented, it is prudent to analyze the effectiveness of these measures to protect juveniles before considering which additional and/or different technical measures may be required to further reduce juvenile cod catches, if needed.

Introduction

In 2020 the Commission adopted technical measures, in force since January 2021 (NAFO CEM 2021), to try to protect the productivity of Division 3M cod stock. These measures included the closure of the directed fishery of the 3M cod during the first quarter, as well as the mandatory use of sorting grids in this fishery.

That year, the Commission requested the Scientific Council to consider whether other measures, such as depth restrictions, spatial and mesh changes, could reduce the catch of juvenile and immature cod across all fisheries in 3M.

The aim of this analysis is to try to find any pattern in the directed and non-directed fisheries of this stock that could reduce the catch of juvenile and immature cod. Nevertheless, it is important to point out that, as a result of the measures implemented this year, a change in the selectivity is expected and, in consequence, the results from the analysis of the directed fishery of 3M cod could be not representative of the current situation. It is necessary to analyze in the years to come the effect of the measures adopted in 2020 to protect juveniles (i.e. sorting grids).



Material and Methods

Data from the haul by haul database provided by the NAFO Secretariat have been used to study the catch and bycatch of the 3M cod. As the haul by haul database is only fully available since 2016, data from 2016 to 2020 was used. It is considered that a haul is targeting a particular species when this species represents the highest percentage, in weight, in the total catch of the haul. The other species that appear in the total catch composition of the haul are considered bycatch of the directed fishery.

The length distribution was analyzed, both in the directed and non-directed fisheries. Some analyses with the total fishery samples, including data from the directed fishery and from other fisheries catching cod as bycatch, were performed too. Samples collected by the Scientific Observers Program on board fishing vessels were used. For the analysis of the length distribution of Division 3M cod directed fishery, samples from the trawler fishery from EU-Portugal, EU-Spain, EU-Estonia and Norway and from the longliner fishery from Faroes and Norway were used for years 2016-2020. For the analysis of the length distributions of 3M cod in the non-directed fishery, length samples from the 3M redfish fisheries, since the other fisheries have a negligible catch of 3M cod (see results section), from EU-Portugal, EU-Spain and EU-Estonia for years 2016-2020 were used.

Table 1 shows, among other things, the availability of samples from each country by year.

The raw samples were used in the analyses, without making any type of weighting. But as it can be seen in Table 1, the proportion of catches is more or less proportional to the availability of samples, so the differences between using raw samples or length distribution of the total catches may be negligible.

The percentage of individuals below the Minimum Landing Size (MLS) and the length at first maturity were also used to perform the analysis. The MLS for 3M cod is 41 cm to the fork (NAFO CEM, 2021), that corresponds to 42 cm to the total length (González-Costas *et al.*, 2018). The length at first maturity (L_{50}) used in this document was taken as the mean of the 2016-2019 length at first maturity, corresponding to 54 cm (Garrido *et al.*, 2020).

Length samples with positions were also used to create some maps of percentage of individuals below the MLS and percentage of individuals below the L_{50} by haul to identify areas or depths where the juveniles and immatures represent a significant part of the catch. These data are available for almost all the trawler fishery samples and for some Norwegian longline samples.

Results

Bycatch analysis

According to the 2016-2020 data from the haul by haul database, the bulk of the catches of this stock are from the 3M cod directed fishery, with bycatch of cod in other fisheries representing less than 5% of the total catches (Table 2). The cod bycatch from 2016 to 2020 is between 1.9% (in 2017) and 4.9% (in 2020), with an average value for the whole period of 3.3%. Most of the cod bycatch is attributable to the 3M redfish fishery, since it represents between 88.7% (in 2020) and 98.6% (in 2019) of total cod bycatch for the same period. Thus, the study of the bycatch in this document is focused in the 3M redfish fishery.

According to the CESAG reports of the period 2016-2020, between 70%-80% of the 3M redfish fishery is carried out by EU-Spain and EU-Portugal, increasing to 90-95% when considering EU-Estonia. In that period, cod was taken in a total of 3,467 hauls during redfish directed operations. A total of 86 cod length samples in the redfish Div. 3M fishery taken by observers on board from EU-Spain, EU-Portugal and EU-Estonia are available for the period 2016-2020. Despite the low number of bycatch size samples, these samples have been analyzed to get an idea of their spatial and temporal length composition.

Figure 1 represents all the hauls in which 3M cod was taken, identifying those coming from directed fishery and the bycatch. Most of the bycatch is taken in the season and area where the 3M redfish fishery is carried out, in the first and third quarters and at intermediate depths.

Figure 2 shows the hauls not directed to cod in which length samples of 3M cod were taken. It is remarkable that there are no samples of cod in the fourth quarter, and only one in the second quarter, therefore, the analysis will be carried out per semester, with most of the information corresponding to the first and third quarters.

Figure 3 represents an histogram of the length in the samples of hauls not directed to cod, all together. It is remarkable the presence of individuals with length below the MLS, although the majority of the individuals are between the MLS and the L_{50} . In the first semester, more individuals below the L_{50} and the MLS are taken than in the second semester.

Figure 4 contains the histogram of the haul percentage of immature individuals of the cod samples in the Div. 3M redfish fishery. There are some sampled hauls with a high percentage of immature cod, being even in some cases all the individuals. Based on the results of the histogram, the percentages have been grouped into three classes to show their spatial distribution in Figure 5. A first class containing the hauls with less than 10% of immature individuals in green, in black hauls with a percentage of immatures ranging from 10 to 30% and a last class in red with hauls in which the percentage of immature is above 30%. It can be seen that, especially in the first semester of the year, most of the hauls present a high percentage, above 30%, of individuals below L_{50} . Those hauls with a higher percentage of immature individuals are located mainly in the North-West of the Flemish Cap, while at the South-West the hauls have a lower percentage. In the second semester, most of the hauls have a percentage of less than 10% of immature, and most of them are taken closer to the center of the bank.

Figure 6 presents a histogram of the cod bycatch samples of the 3M redfish fishery with the percentage of cod individuals taken below the MLS. Most of the hauls have no individuals below the MLS. Based on the results of the histogram, the percentages have been grouped into three classes to show their spatial distribution in Figure 7. A first class containing the hauls with less than 10% of individuals below the MLS in green, in black hauls with a percentage of small individuals ranging from 10 to 20 % and a last class in red with hauls in which the percentage of individuals below the MLS is above 20%. Only a few hauls have a percentage of more than 20% of the individuals below MLS, two in the first semester and three in the second one. In the second semester is when a lower percentage is present.

Total and directed catch analysis

Two different gears are currently used in the directed fishery of Division 3M cod, trawl and longline. According to the CESAG reports, most of the catch comes from trawlers (Table 3). Longliners are used by Faroes (exclusively since 2017) and Norway every two years (even years).

In many years, trawl and longline catches length distributions for the total fishery (directed and bycatch) are available for several countries, used for getting the total length distribution of the total catch of 3M cod. Table 4 shows for the period 2016-2020 the total number and percentage of the individuals of the total catch Division 3M cod length distributions.

In the trawler (total) fishery, the percentage of individuals below the MLS is very high in 2016, around the 28%, raising up to 65.6% in the case of the individuals below L_{50} . So, most of a quarter of the individuals caught in 2016 by the trawler fishery were below MLS, and almost three quarters were below L_{50} . After 2016, the percentage decreased steeply, being less than 5% of the individuals below the MLS and than 33% of the individuals below the L_{50} . In the case of the longliner (total) fishery, always less than the 3% of the percentage are below MLS and less than the 14% below L_{50} .

In order to see the spatial distribution of the lengths in the directed fishery of 3M cod (in this case, without bycatch), some samples georeferenced are available from EU-Portugal, EU-Spain, EU-Estonia and Norway for trawlers and from Norway for longliners (Table 1). In Figure 8, the position of the trawl and longline hauls of the directed fishery of 3M cod from 2016 to 2020 by semester can be observed, as well as the position of the hauls with length samples of this stock that are georeferenced. The fishery is distributed across the year, but the position of the hauls is different between semesters. For the trawler fishery, in the first semester, they are mostly in the South-West of the bank and in the second are mostly in the North-Center. The effort in the second

semester is much less than in the first. In the case of the longliner fishery, more effort can be seen in the South in the first semester and in the East in the second semester.

Figure 9 represents an histogram of the length in samples of hauls directed (without bycatch) to cod (geo and non-georeferenced), by gear and semester. Whereas in the redfish fishery the majority of the sampled lengths are between the MLS and the L_{50} , in the directed fishery most of the sampled lengths are above L_{50} . It is remarkable the presence of some individuals with lengths below the MLS, both for trawlers and longliners. Here it must be taken into account that the amount of individuals are quite different between the redfish and the cod fishery, as the number of samples and so the number of sampled individuals are very different, being much higher in the case of the directed fishery. The same difference between the trawlers and the longliners, as more individuals are available from the trawler fishery (Table 1).

Figure 10 contains the histogram of the percentage of immature individuals by haul and by gear for the directed fishery (without bycatch) for the samples with and without position information. In general, both for trawlers and longliners, most of the hauls have a percentage of immature individuals by haul between 0 and 10%, although there are a number of sets in the trawler fishery where the percentage is above 50%, reaching the 100% of the individuals in some cases. This is not the case in the longliner fishery, where only a couple of sets present a percentage of immature individuals above 40%, and the rest of the sets the percentage does not reach 30%. This information is represented in a map in Figure 11 for the georeferenced hauls. Based on the results of the histogram, the percentages have been grouped into three classes to show their spatial distribution in Figure 11. A first class containing the hauls with less than 10% of immature individuals in green, in black hauls with a percentage of immatures ranging from 10 to 30% and a last class in red with hauls in which the percentage of immature is above 30%. The sets with a high percentage of individuals below the L_{50} in trawlers are present in both semesters of the year, although the number of those hauls is slightly bigger in the first semester. In the case of the the longliner fishery, none of the georeferenced hauls presents more than 10% of immature individuals.

Figure 12 presents a histogram with the percentage of cod individuals taken below the MLS by haul in the directed (without bycatch) 3M cod fishery. Most of the hauls have zero individuals below the MLS. In general, both for trawlers and longliners, most of the hauls have a percentage of individuals below the MLS by haul between 0 and 10%, although there are a number of sets in the trawler fishery where the percentage is above 50%, reaching the 100% of the individuals in some cases. It is not the case in the longliner fishery, where only a couple of sets present a percentage above 20%, and the rest of the sets the percentage does not reach 15%. Figure 13 shows the spatial distribution of that percentage in the georeferenced hauls. Based on the results of the histogram, the percentages have been grouped into three classes to show their spatial distribution in Figure 13. A first class containing the hauls with less than 10% of individuals below the MLS in green, in black hauls with a percentage of small individuals ranging from 10 to 20 % and a last class in red with hauls in which the percentage of individuals below the MLS is above 20%. The sets with a high percentage of individuals below MLS in trawlers are present in both semesters of the year, although the number of those hauls is slightly bigger in the first semester. In the case of the longliner fishery, none of the georeferenced hauls presents more than 10% of individuals the MLS.

Comparison between the directed and the bycatch samples

Figure 14 shows the cumulative frequency of the lengths of 3M cod in the sampled hauls, for the directed and the bycatch fishery, by semester. It can be observed that in the first semester, the proportion of individuals between 35 and 85 cm is always higher in the bycatch fishery than in the directed fishery. The bycatch fishery catches rarely individuals of more than 85 cm, being the 50% of the individuals of less than 47 cm. In the directed fishery, the 50% of the individuals are bigger than 64 cm, far from the L_{50} , and the individuals of more than 115 cm are quite rare. In the second semester the picture is different. The length distribution between directed and bycatch fisheries are quite similar, especially until 55 cm, with less proportion of individuals of less than that length. The 50% of the lengths is quite similar, 65 cm in the bycatch and 62 in the directed fishery. As in the first semester, the directed fishery catches rarely individuals bigger than 85 cm, whereas the bycatch fishery catches individuals of no more than 105 cm.

From this Figure, it is clear that in general, in proportion, the bycatch fishery catches individuals smaller than the directed fishery, although, as it was seen above, the number of individuals that the bycatch fishery catches is much smaller than the ones by the directed fishery so it is not probable that the bycatch fishery could produce a remarkable damage to the stock.

Conclusions

In conclusion, the recent bycatch of 3M cod in other fisheries is considered low (both in weight and in number of individuals) when compared to the directed cod fishery. Consequently, the level of bycatch of 3M cod observed in 2016-2020 is not likely to have had a significant impact on the trajectory of the stock during this period. A large proportion of the cod caught, both as bycatch and in the directed fishery, were above the MLS, with most of them being mature. Therefore, at this time, the implementation of measures to avoid juvenile cod bycatch would be premature, given that the burden of implementing and enforcing these measures on multiple fisheries may outweigh its potential benefits.

With respect to the directed 3M cod fishery, and considering that new measures have been just implemented, it is prudent to analyze the effectiveness of these measures to protect juveniles (i.e. sorting grids) before considering which additional and/or different technical measures may be required to further reduce juvenile cod catches, if needed. Pointed out that, in recent years, the number of individuals below the L_{50} in the directed fishery of cod is low, being very low for individuals below the MLS. But how these numbers can affect the trajectory of the stock is unknown.

Acknowledges

Thanks to the members of the subgroup for answering the Request 15 for their valuable comments to our analyses: Carmen Fernández, Carsten Hvingel, Kalvi Hubel, Lisa Ready, Luis Ridao and Mariano Koen-Alonso.

Thanks to the scientists that provided the length samples data: Kjell Nedreaas (for Norwegian samples), Kalvi Hubel (for EU-Estonian samples) and Luis Ridao (for Faroeses samples).

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- Gonzalez-Costas, F., D. Gonzalez-Troncoso, A. Ávila de Melo and R. Alpoim, 2018. 3M cod assessment input data. SCR Doc. 18-001. Serial No. N6778.
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Table 1. Availability of no-georeferenced and georeferenced samples from each country by year (2016-2020) for the total fishery of 3M cod (directed + bycatch).

| FlagState | With Positions | | | | | | | |
|-----------|-------------------|-----------|------------------|--------------------|-------------|-----------|------------------|--------------------|
| | Directed catch | | | | By_catch | | | |
| | Samples (n) | Indiv (n) | Total Catch (kg) | Sampled Catch (kg) | Samples (n) | Indiv (n) | Total Catch (kg) | Sampled Catch (kg) |
| Estonia | 124 | 4980 | 669552 | 320993 | 40 | 852 | 233746 | 121437 |
| Faroese | - | - | - | - | - | - | - | - |
| Norway | 56 | 2176 | 691938 | 10000 | - | - | - | - |
| Portugal | 318 | 32094 | 2683981 | 59494 | 46 | 3601 | 45819 | 5193 |
| Spain | 84 | 8963 | 679749 | 21230 | 22 | 1003 | 12375 | 3735 |
| FlagState | Without positions | | | | | | | |
| | Directed catch | | | | By_catch | | | |
| | Samples (n) | Indiv (n) | Total Catch (kg) | Sampled Catch (kg) | Samples (n) | Indiv (n) | Total Catch (kg) | Sampled Catch (kg) |
| Estonia | - | - | - | - | - | - | - | - |
| Faroese | 179 | 17916 | 3440078 | 84468 | - | - | - | - |
| Norway | 20 | 607 | 393521 | 2143 | - | - | - | - |
| Portugal | - | - | - | - | - | - | - | - |
| Spain | - | - | - | - | - | - | - | - |

Table 2. 3M cod catch in tons by year (2016-2020), in the directed fishery, as a bycatch and total catches. Final column is the percentage of the 3M redfish fishery cod bycatch with respect to the total cod bycatch.

| Year | 3M cod catch (tons) | | | % cod bycatch | Bycatch of 3M cod by fishery | | | | | | | RED (%) |
|------|---------------------|---------|---------|---------------|------------------------------|---------|---------|---------|---------|---------|---------|---------|
| | Directed | bycatch | Total | | CAB (t) | GHL (t) | HAD (t) | HAL (t) | RED (t) | REG (t) | WIT (t) | |
| 2016 | 10980.5 | 341.0 | 11321.5 | 3.0 | 0.0 | 0.0 | 12.3 | 0.4 | 302.5 | 0.0 | 6.2 | 94.5 |
| 2017 | 9775.1 | 192.8 | 9967.9 | 1.9 | 0.0 | 0.0 | 0.0 | 0.4 | 187.6 | 0.0 | 4.8 | 97.3 |
| 2018 | 10213.3 | 494.4 | 10707.6 | 4.6 | 1.9 | 0.0 | 0.0 | 0.0 | 484.0 | 0.0 | 8.5 | 97.9 |
| 2019 | 18723.1 | 379.7 | 19102.9 | 2.0 | 0.0 | 2.3 | 0.0 | 0.6 | 374.2 | 1.8 | 0.8 | 98.6 |
| 2020 | 6931.9 | 360.9 | 7292.8 | 4.9 | 0.0 | 4.9 | 0.0 | 0.0 | 320.1 | 0.0 | 35.9 | 88.7 |
| Mean | 11324.8 | 353.8 | 11678.5 | 3.3 | 0.4 | 1.4 | 2.5 | 0.3 | 333.7 | 0.4 | 11.2 | 95.4 |

Table 3. 3M cod total catch (in tons) by year (2016-2020) and gear from the CESAG catches.

| Year | Catch OTB (Tn) | Catch LL | Total | %OTB |
|-------|----------------|----------|-------|------|
| 2016 | 10208 | 3814 | 14023 | 73 |
| 2017 | 10762 | 3166 | 13928 | 77 |
| 2018 | 4210 | 3166 | 6447 | 65 |
| 2019 | 12968 | 4552 | 17520 | 74 |
| 2020 | 5416 | 3042 | 8458 | 64 |
| Total | 43565 | 17740 | 60376 | 72 |

Table 4. 3M cod total number of individuals (thousands) and percentage by year (2016-2020) taken in the commercial total fishery (directed + bycatch) by gear (BT=Trawl, LL=Longline).

| | 2020 | | | 2019 | | | 2018 | | | 2017 | | | 2016 | | |
|--------------|-------|-------|-------|-------|-------|-------|-------|------|-------|-------|------|-------|-------|------|-------|
| TOTAL NUMBER | BT | LL | TOTAL | BT | LL | TOTAL | BT | LL | TOTAL | BT | LL | TOTAL | BT | LL | TOTAL |
| < 42 cm | 61 | 23 | 84 | 174 | 23 | 197 | 113 | 32 | 144 | 207 | 1 | 208 | 1526 | 0 | 1526 |
| < 54 cm | 543 | 94 | 637 | 2056 | 144 | 2200 | 637 | 104 | 741 | 960 | 31 | 991 | 3562 | 70 | 3632 |
| TOTAL | 2234 | 827 | 3061 | 6421 | 1089 | 7509 | 3169 | 1104 | 4273 | 4569 | 638 | 5207 | 5428 | 856 | 6284 |
| Percentage | | | | | | | | | | | | | | | |
| < 42 cm | 2.74 | 2.78 | 2.75 | 2.71 | 2.08 | 2.62 | 3.56 | 2.86 | 3.38 | 4.54 | 0.10 | 4.00 | 28.11 | 0.02 | 24.29 |
| < 54 cm | 24.33 | 11.32 | 20.81 | 32.02 | 13.24 | 29.30 | 20.08 | 9.43 | 17.33 | 21.01 | 4.85 | 19.03 | 65.62 | 8.16 | 57.79 |

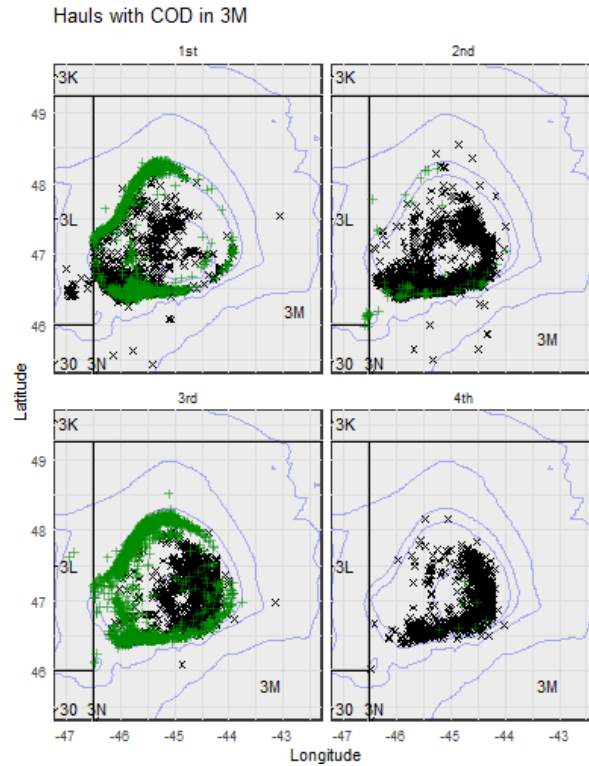


Figure 1. Position of hauls with cod by quarter (2016-2020). In black, hauls directed to cod. In green, hauls with bycatch of cod, most of which are directed to redfish.

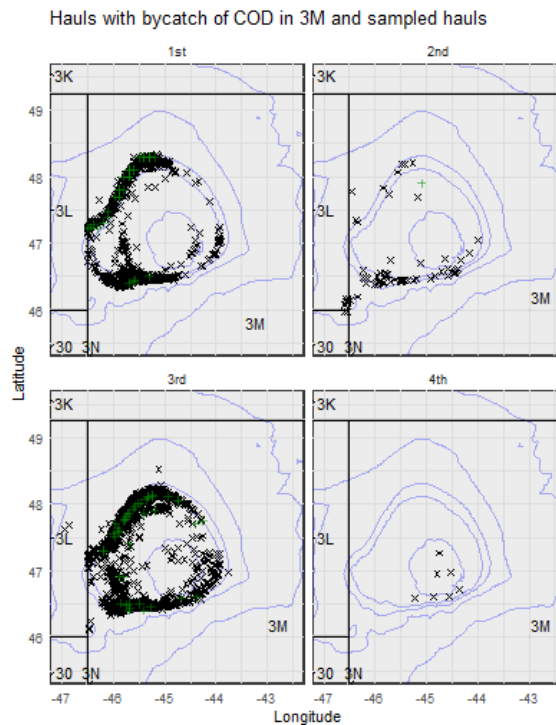


Figure 2. In black, hauls with bycatch of cod in 3M by quarter in the redfish fishery. In green, hauls not directed to cod in which there is length sampling of cod. Data for 2016-2020.

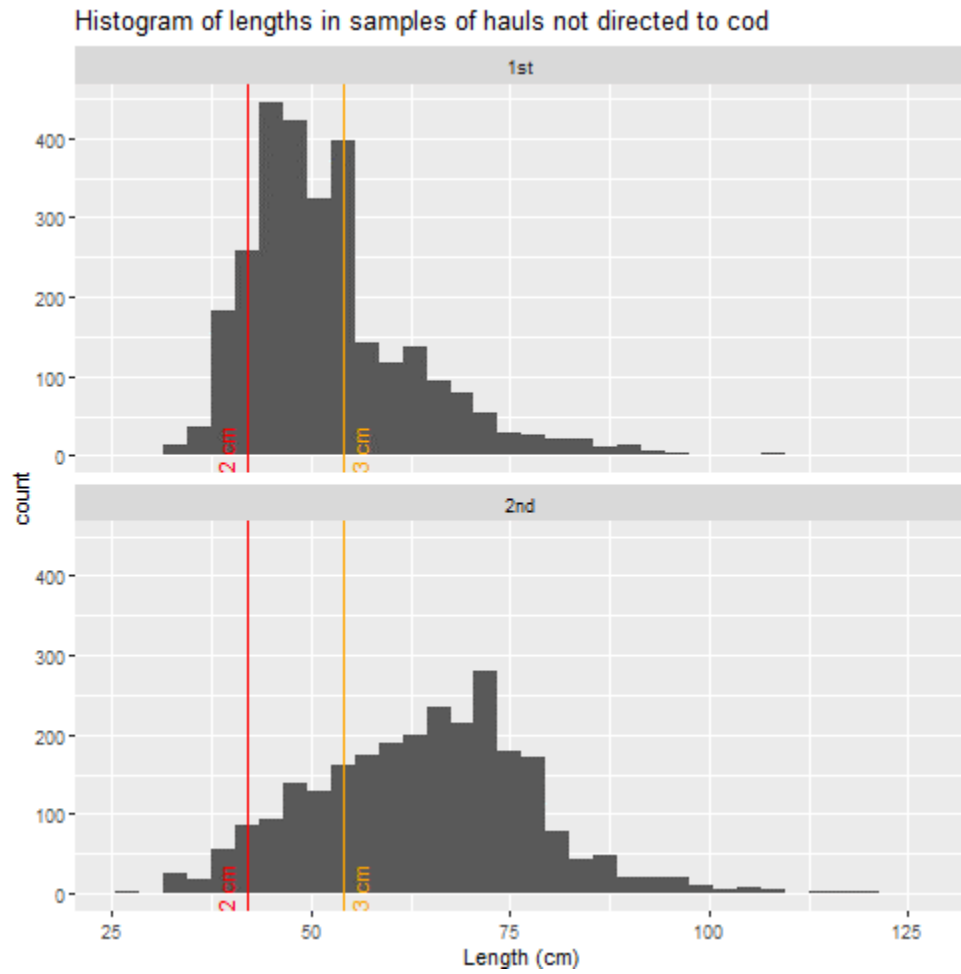


Figure 3. Histogram of length in samples not directed to cod by semester. Data for 2016-2020.

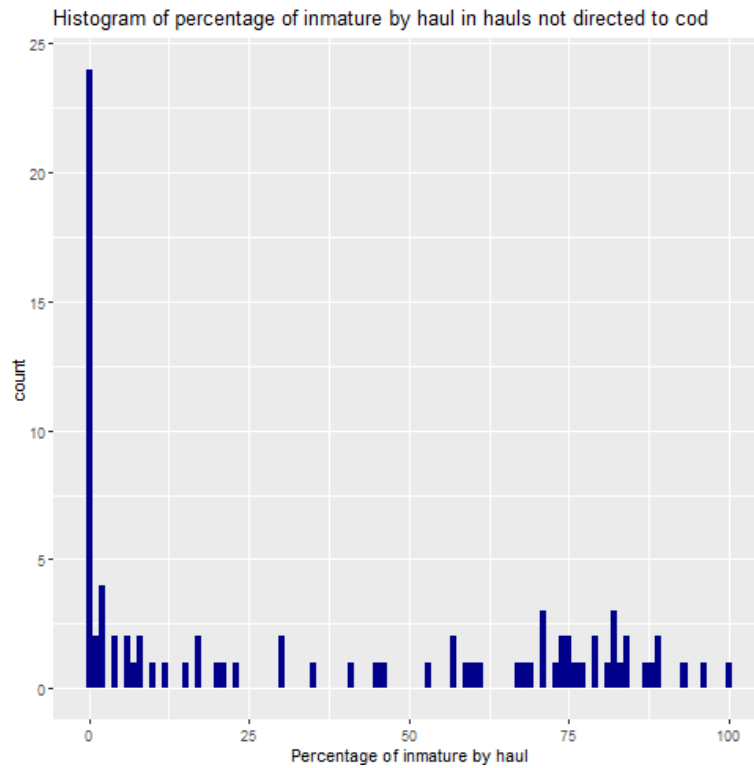


Figure 4. Histogram of percentage of immature cod (individuals of less than the $L_{50} = 54$ cm) by haul with samples of cod in the redfish fishery. Data for 2016-2020.

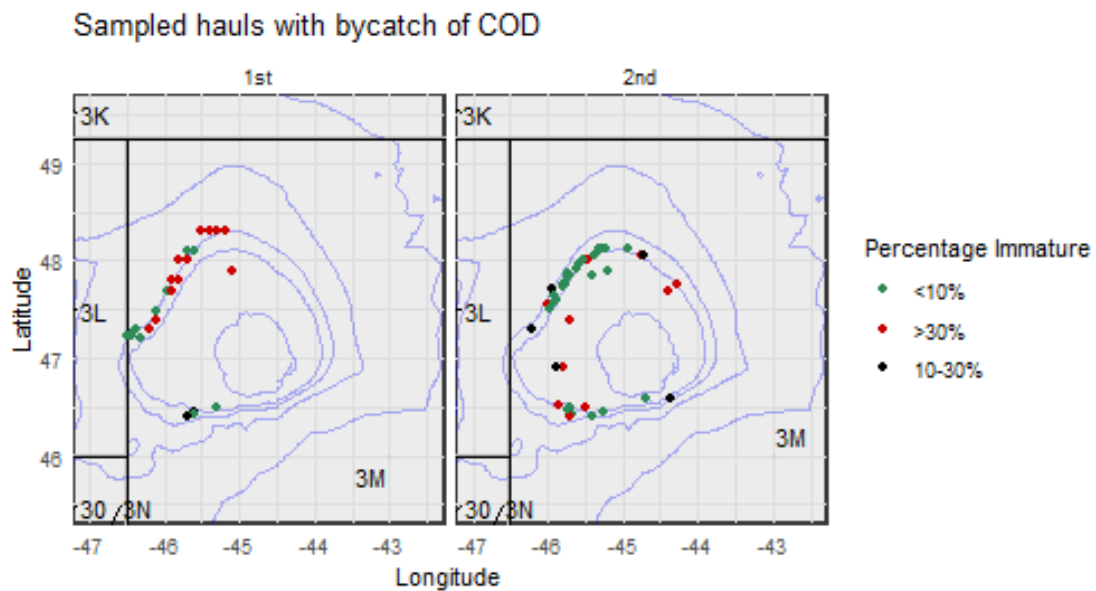


Figure 5. By semester, percentage of immature cod (individuals of less than the $L_{50} = 54$ cm) by haul for hauls with samples of cod in the redfish fishery. Data for 2016-2020.

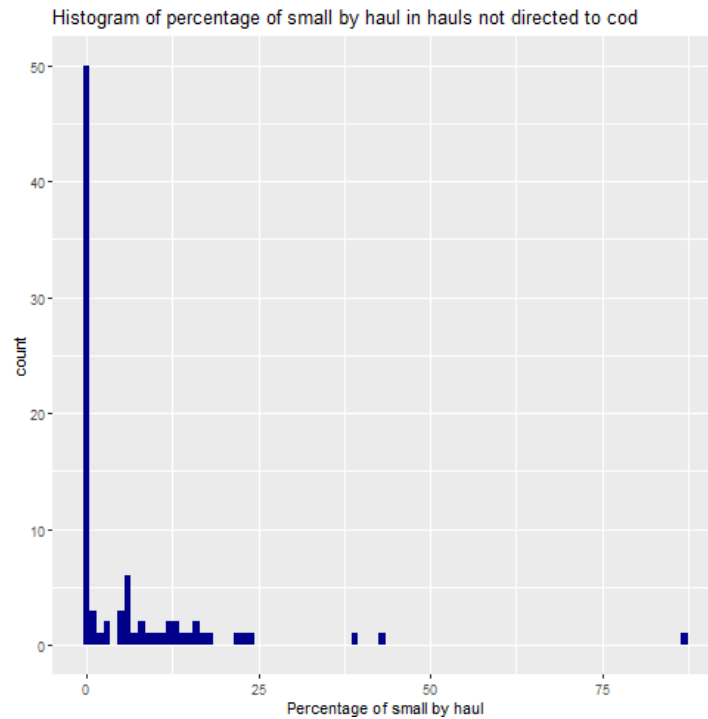


Figure 6. Histogram of percentage of small individuals (individuals of less than the MLS = 42 cm) by haul with samples of cod in the redfish fishery. Data for 2016-2020.

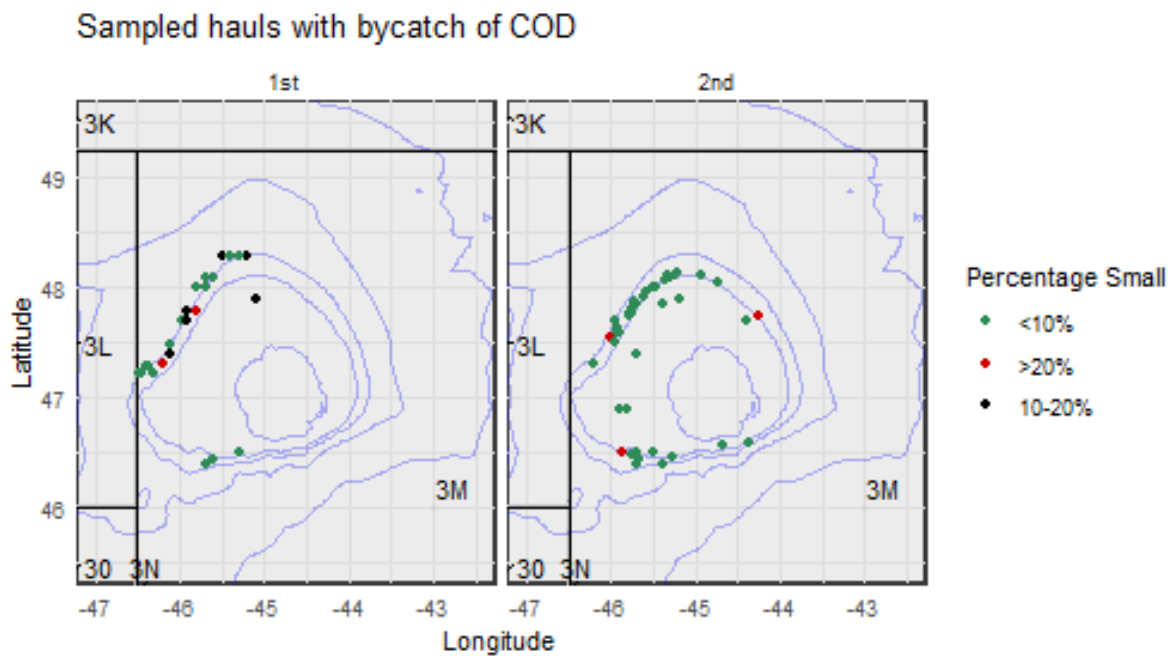


Figure 7. Percentage of small cod (individuals of less than the MLS = 42 cm) by haul for hauls with samples of cod in the redfish fishery. Data for 2016-2020.

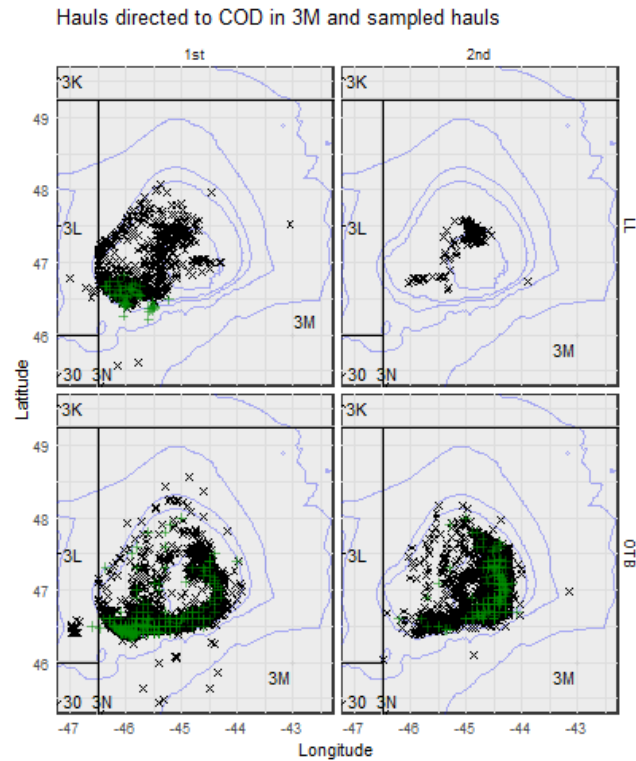


Figure 8. In black, hauls from the directed fishery of cod in 3M by semester and gear. In green, hauls in which there is length sampling of cod and they are georeferenced. Data for 2016-2020.

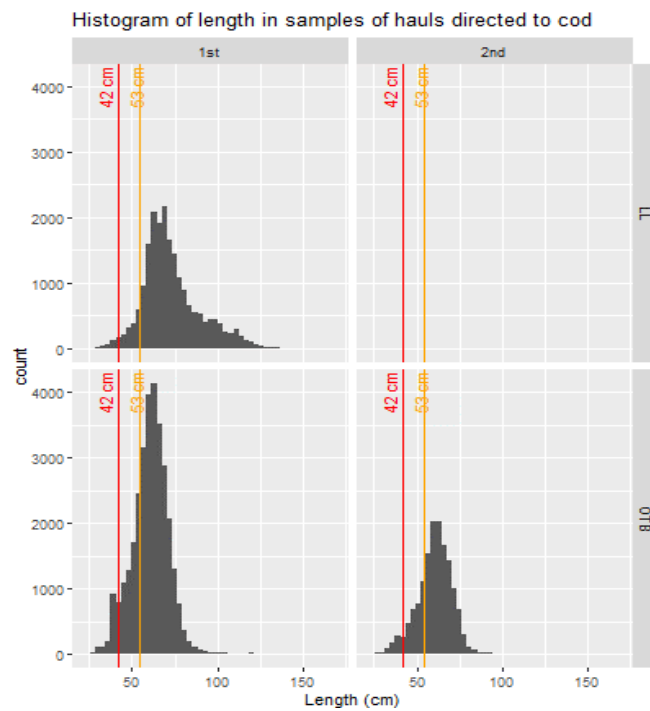


Figure 9. Histogram of length in samples from the directed fishery of 3M cod. Data for 2016-2020.

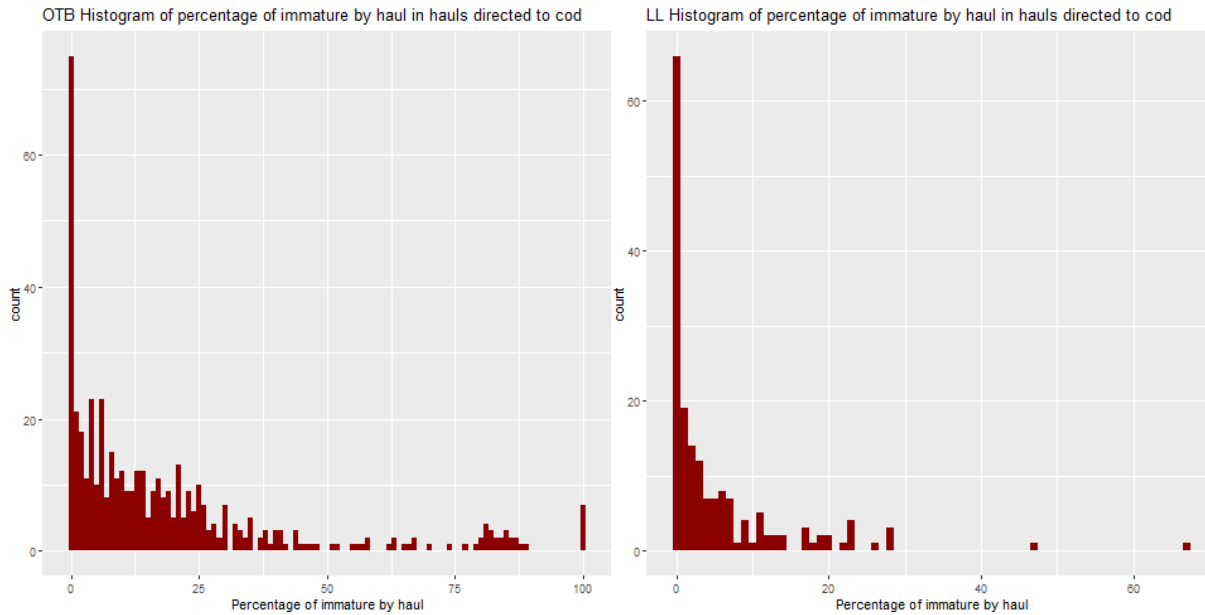


Figure 10. Histogram of percentage of immature cod (individuals of less than the $L_{50} = 54$ cm) by haul with samples of cod in the directed fishery for the trawler fishery (left) and the longliner fishery (right). Data for 2016-2020.

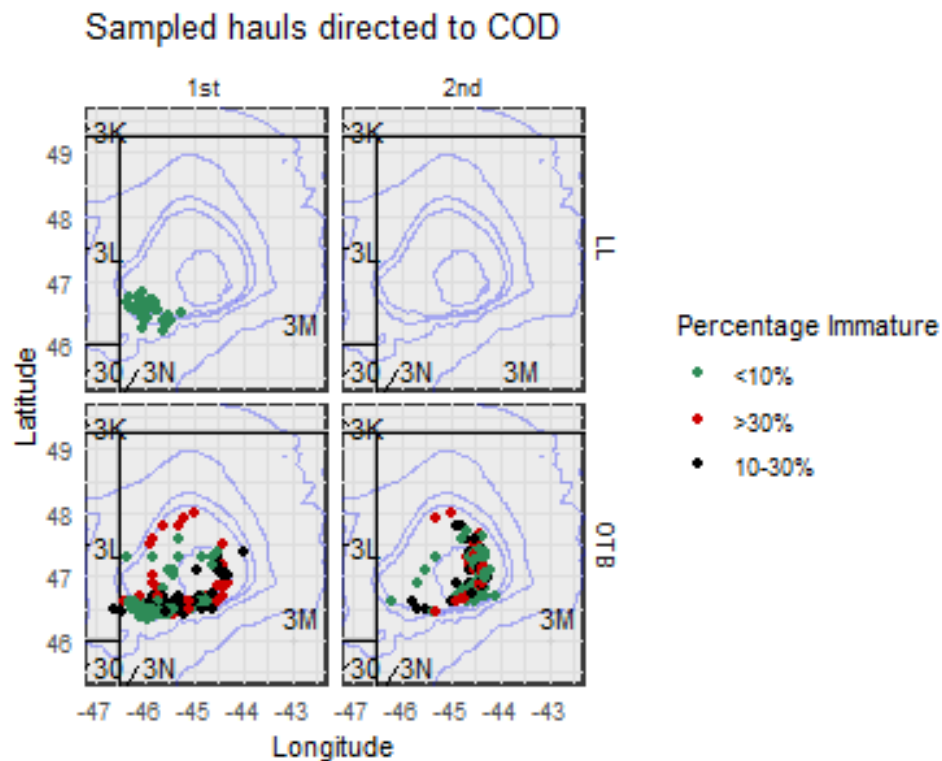


Figure 11. Percentage of immature cod (individuals of less than the $L_{50} = 54$ cm) by semester, gear and haul for hauls georeferenced and with samples of cod in the directed fishery. Data for 2016-2020.

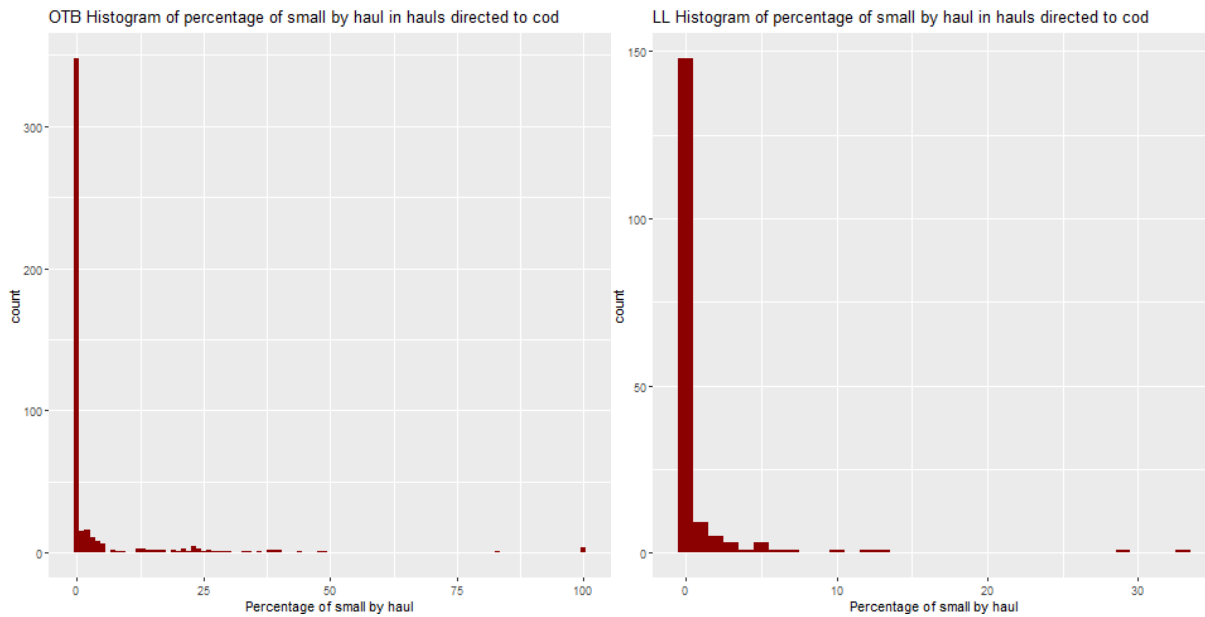


Figure 12. Percentage of small cod (individuals of less than the MLS = 42 cm) by haul for hauls with samples of cod in the directed fishery for the trawler fishery (left) and the longliner fishery (right). Data for 2016-2020.

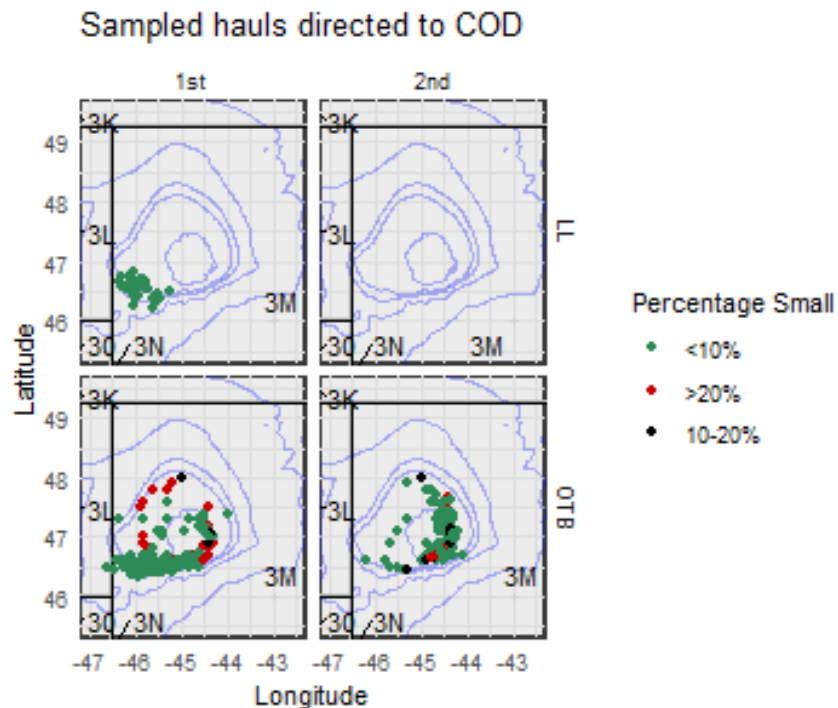


Figure 13. Percentage of small cod (individuals of less than the MLS = 42 cm) by semester, gear and haul for hauls georeferenced and with samples of cod in the directed fishery. Data for 2016-2020.

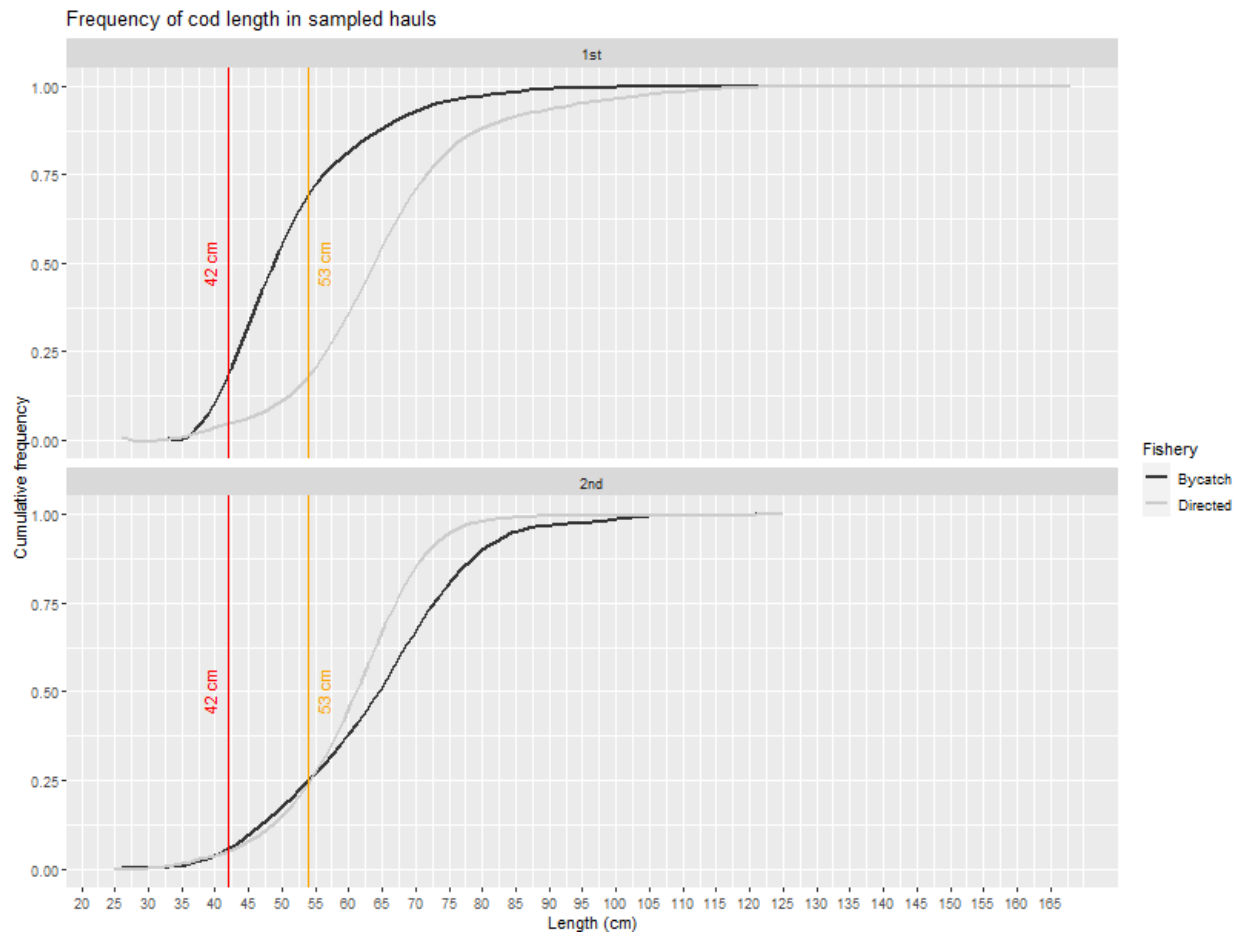


Figure 14. Cumulative frequency of the lengths of 3M cod in the sampled hauls, for the directed and the bycatch fishery, by semester. Data for 2016-2020.