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Analysis of the NAFO VMS and logbook data

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Abstract

The objective of the ecosystem approach is to protect the structures, processes and interactions of the ecosystem through a sustainable use of the natural resources. A key step when studying the environmental impact of the fishing activity is to assess the fishing footprint.

There are two methodologies to study the fishing effort and footprint in the NAFO Regulatory Area (NRA). The first one uses a simple speed filter to select the Vessel Monitoring System (VMS) pings most likely to be associated with fishing effort. The second one filters the VMS pings that correspond with the haul interval registered by the skipper in the logbook.

The purpose of this study is to analyse the quality and coverage of the VMS and logbook data used in these two methods. Data collected by the IEO Scientific Observer Program on board fishing vessels were also used to measure the coverage.

The results show that the current speed range (0.5-5 knots) used in the speed filter method may be adequate to study effort in trawl fisheries but is not representative for longline fisheries. It was also observed that both databases, VMS and logbook, contain errors and the effects of the misreporting are enhanced when both data sets are merged. Data from scientific observers allowed to measure these errors and, as a result, only around 60-70% of the total pings were taken into account with the merging approach.

Despite the merging approach is widely considered an improvement in relation to the former method (i.e. simple speed filter) and a powerful tool for describing the spatial distribution of fishing activity, this improvement relies on the coverage and quality of the available information.

The quality of information, both in the VMS system and in the logbooks, should be of concern to NAFO. The improvement of the quality of these data is crucial for better studying the effort distribution and the tasks related to this effort (SAI, fisheries footprint, fishing overlap with VME, assessments, etc).

Keywords: Vessel Monitoring System (VMS), logbook, NAFO, fishing effort.

Introduction

The objective of the ecosystem approach is to protect the structures, processes and interactions of the ecosystem through a sustainable use of the natural resources. To regulate the fishing activity in an ecosystem approach framework requires assessing the environmental impact of this activity.

A key step when a study about the environmental impact of the fishing activity is conducted is to assess the fishing footprint (NAFO, 2009). With the development of new technologies, it is possible to determine the vessel tracks by using the Vessel Monitoring System (VMS). The VMS uses the Global Positioning System (GPS) to display the accurate geographic position of the vessel. The satellite monitoring device transmits the information (geographic position, speed, course, etc.) from the vessel(s) to the Fisheries Monitoring Centres (FMCs), the land-based national centres to which registered fishing vessels connect via satellites. Vessels data are transmitted and received at time intervals. The information sent in each time interval is known as ping. The information received by the FMCs is then forwarded to NAFO's Headquarters in the cases where the vessels are working in the NAFO Regulatory Area (NRA).

Applying a speed filter is a very common method for extracting VMS pings associated with fishing activities (Thompson and Campanis, 2007; WGDE, 2008; Campanis *et al.*, 2008, Campbell and Federizon, 2013). This method consists in filtering VMS points by using a simple speed filter directly related to fishing speeds. Thus, only the VMS records most likely to be associated with fishing effort are assigned as fishing activities. But this procedure presents challenges in terms of threshold speeds across entire fleets/gears, so there will inevitably be some points that are misclassified at a rate that is difficult to quantify (NAFO, 2017).

Use of the haul-by-haul data compiled in the logbooks permits VMS pings to be assigned as "fishing" or "non-fishing" based on whether they fall within fishing time intervals reported in the haul-by-haul data, instead of assigning them by the vessel's speed. That is, start and end of fishing timestamps from the logbooks are used to extract relevant VMS pings, which are then mapped in space to represent fishing effort. Because these VMS pings are directly within the reported fishing times interval, they are considered to be associated with fishing activity. Logbook data and VMS are complementary, and the coupling of both datasets has already proven powerful for better describing the spatial distribution of fishing activity with a higher precision than each one separately (NAFO, 2018; NAFO, 2019).

This approach to track and trace the fishing effort by merging VMS and logbook data, that is widely considered an improvement of the former method (i.e. the simple speed filter), was first presented and used in 2017 in the NAFO framework to create fishery-specific effort maps and conduct an overlay analysis of Vulnerable Marine Ecosystems (VME) and fishing footprint (NAFO, 2017).

In 2019, the NAFO SC Working Group on Ecosystem Science and Assessment (WG-ESA) developed the guidelines to create standard VMS data products to study the effort based on the available data (VMS and logbooks) (NAFO, 2019).

The main objective of this study is to analyse the quality and coverage of the available VMS and logbook data used in these two methods. Data collected by the IEO Scientific Observer Program on board of trawl fishing vessels were used for the analysis, considering that the information collected by the scientific observers is assumed to be equal to the real effort exerted by the fleet.

Material

Vessel Monitoring System (VMS)

The NAFO *Vessel Monitoring System (VMS)* is a satellite-based monitoring system that provides data on the location, heading and speed of fishing vessels. All vessels operating in the NRA have been required to submit VMS data since the early 2000s, with a minimum polling rate which has decreased from once every six hours in 2004 to hourly since 2011. The transmission of such data provides high resolution positions recorded at higher frequencies when compared to the reporting logbook data.

VMS data used in this work were supplied by NAFO Secretariat, who has the responsibility for collecting and maintaining these data from fishing vessels operating in the NRA. In addition to be an integral part of NAFO´s Monitoring, Control and Surveillance (MCS) scheme, the VMS data are also used for scientific purposes, e.g. for the assessment of Significant Adverse Impacts (SAIs) on Vulnerable Marine Ecosystems (VMEs) and in some fish stock assessments (NAFO WEB page).

VMS data include the following information: NAFO Vessel Identification; Flag State; Radio (vessel call sign); UTC date and time of the vessel position; vessel position by latitude and longitude; speed and heading (NAFO, 2020).

Haul-by-haul (logbook data)

Haul-by-haul catch data are logbook data collected during fishing vessel activities. They provide details for each haul on catch and discards by species, type of gear used, timestamps and geographic coordinates for gear deployment and retrieval and geographic position collected during fishing vessel activities. The provision of these data is a responsibility of the skipper of each vessel (NAFO, 2020).

The current logbook data format (NAFO, 2020) was implemented in NAFO in 2016, and was an improvement over 2015, when the data were recorded by haul only for the top three species caught by weight and did not include fishing timestamps. Haul-by-haul logbook data used in this study were also supplied by NAFO Secretariat.

IEO Scientific Observer Program

IEO Scientific Observer Program data are collected during fishing activities of the Spanish commercial trawl fleet operating in the NRA by the IEO scientific observers onboard. As in the haul-by-haul logbook data, full information of the gear deployment and retrieval is recorded (i.e. timestamps, geographic coordinates and depth), as well as the catch and discard weight by species. IEO is responsible for their collection under the European Union Fisheries Data Collection Framework.

The data used for carrying out the analysis presented in this document correspond to the period from 2016 to 2019, for which the current haul-by-haul catch data are available.

Methodology

The analysis of the data has been completely developed in open-source statistical computing environment R (R Core Team, 2019). To conduct this analysis, a script previously developed by Corina Favaro (Fisheries and Oceans Canada, DFO) was used. This script was originally developed to merge VMS and logbook data, used later in the overlay analysis of VME and fishing footprint under the NAFO NEREIDA project (NEREIDA, 2020). An error in the original script was amended and some minor changes were made in order to treat the data by haul, instead of handling them by spatial grid as it was in the NEREIDA analyses (NEREIDA, 2020).

Differences with the original script

In the original script, the common fields between both data sets (i.e. VMS and logbook) were NAFO Vessel ID and Date. In a detailed analysis of the performance of the merging, it was observed that only pings which coincided with the haul start day were selected as “fishing” pings. This implies that in the hauls that started one day and finished the following day, which are not unusual in the bottom trawl fisheries in the NRA, pings from the second day of the haul were discarded and assigned as “non-fishing” when they were actually “fishing” pings, underestimating the effort. Some changes were introduced in the original script to solve this problem.

In the original analysis (NAFO, 2017), to create the fishery-specific effort maps, the effort deployed by the fishing fleets was calculated by 0.05 x 0.05 degrees’ grid, while in the present analysis of the performance of the VMS and logbook data merging the effort was calculated by haul. This implies a difference in the effort data processing when estimating the forward difference in time between VMS pings. To estimate the effort by grid, when the interval between two consecutive VMS pings was greater than two hours (when one or more intermediate pings were missing), the procedure was to assign two hours in order to avoid inflating effort within a particular cell. This two hours value was settled taking into account the size of the cells and the average trawl speed (3-5 knots). On the other hand, when estimating the effort by haul, the observed time interval between two consecutive pings was calculated as the real time difference between those two consecutive pings.

General analysis of VMS and logbook databases errors

In many instances, both sources of data (i.e. VMS and logbook) contain erroneous entries, namely: points with incomplete timestamps; wrong vessel positions; duplicated records; headings outside compass range, etc. After a deep review of the databases, these data were removed or flagged.

Once data cleaning was performed, the VMS and haul-by-haul datasets are ready for “Data Matching” using the vessel identification and the date as common fields between both data sets. This step is particularly important as all subsequent analyses depend on the success of the linking. The resulting joint database only contains the pings (VMS data) of each vessel and haul that coincide with the hours the vessel was working (logbook data), discarding all the pings where the vessels were not fishing.

Filtered VMS pings from each haul were assigned a “ping-time” interval, calculated as the forward difference in time between successive VMS pings.

The first analysis with the merged data base consisted in identifying possible errors in the resulting data. These errors may be due to problems with the data in the logbooks or due to problems in the VMS data. It can be reasonably assumed that errors will be more frequent in the logbooks than in the VMS since they depend to a greater extent on the human factor. The speed associated to "fishing" pings by gear was also characterised.

Analysis of the coverage based on the Spanish Observers trawl hauls

Since the errors can be present in both data sources, the following step was to select in the joint database (VMS and logbooks) the hauls where a Spanish scientific observer was on board a trawl vessel to try to measure the representativeness of the errors in each source, assuming that the real effort exerted in these selected hauls is exactly the one collected by the scientific observers. This selection was also based on the vessel ID and the date as common fields in both databases. To measure the coverage of the VMS and logbook data, an "ideal world" of all scientific observed hauls was recreated. Comparing the results obtained in the "ideal world" with the results from the available data allows estimating the coverage of the VMS, logbook and the merged VMS and logbook data information.

<u>Ideal world</u>

A VMS ping database was artificially generated. This database, called Hourly Ping Data (HPD), was created generating a ping for every hour of the analysed period (1 Jan 2016 - 31 Dec 2019). The HPD database only contains information of date and time. Thus, when it was merged with the observers' records or with logbooks, the same ping was assigned to every vessel conducting fishing activities at the same time in the NRA. This allowed simplifying the ping register for all the analysed vessels.

The "ideal world" was created by merging the HPD with the Spanish scientific observers' data. As a result, the number of fishing trips and hauls, the duration of each haul (in hours) and the number of VMS fishing pings that should be registered, if the coverage of VMS and logbook was complete for the scientific observers' hauls, was obtained.

<u>Coverage of logbook</u>

To analyse the haul coverage of the logbooks, the HPD dataset was filtered by the logbook and then the hauls where a scientific observer was present were selected.

The results were compared to the "ideal world", where HPD dataset was directly merged with the observers' records. The existing differences in the results are only going to be due to differences in the records of the scientific observers and the skippers, showing the number of hauls and fishing trips that are not recorded in the logbook.

<u>Coverage of VMS</u>

To estimate the number of missing VMS pings, the HPD and the VMS datasets were directly filtered by the scientific observers' records of start and end of each haul, avoiding the differences between observers and logbook's records described above.

This approach allows evaluating the coverage of the VMS system. Since the "ideal world" dataset contains all the VMS pings that should be sent in those hauls, it can be compared with the number of pings actually sent. All the missing pings obtained with this approach are due to a real misrecording in the VMS system, and not to possible missing hauls in the logbooks.

Analysis of the performance of merging VMS and logbook datasets

Identified the missing hauls/trips, the performance of merging VMS and logbook was analysed. To accomplish this analysis, the results from "ideal world" (where the HPD was merged directly with the observers' records) were compared to the results from the "real world" (where the real VMS data were merged with the logbook and filtered after by observers' records).

As a result, it is possible to determine the combined effect that a simultaneous lack of information in both data sets may have on the estimates of the effort deployed.

Results

General analysis of VMS and logbook databases errors

Errors in the logbook data

Table 1 presents the duration of each haul recorded in the logbook by range of hours, in number and percentage, for the period 2016-2019, and Figure 1 the histogram of those data. It is remarkable the existence of sets with negative values in both the trawl and the longline gears, around 3% of the total hauls in the analysed period. Most of the sets of the longline gear have a fishing time of less than 30 hours (90%), although there are sets with more than 40 hours (3.5%). In the case of the trawl gear, most of the hauls have a fishing time of less than 10 hours (90%), with a minor part of the sets with more than 20 hours (2%).

Errors in the VMS and logbook merged dataset

Table 2 shows the number of pings per year that are obtained in the merged VMS and logbook database with the original and new scripts as well as the percentage of pings that were lost with the original script. Results show that in the analyses carried out in previous years with the merged VMS and logbook data, around 14% of the fishing pings were erroneously discarded.

Table 3 presents the number of hauls with errors in the frequency of the pings reported by flag state for the period 2016-2019. The results show that, although the percentage of sets with problems by country varies between 1% and 10%, most countries have around 3% of hauls with under- or over-reporting errors. It can also be observed that although the total sets with over or under-reporting are similar, their distribution by countries is quite different. While in some countries the most frequent error is the under-reporting, in others it is the over-reporting.

Figure 2 shows the histogram of time between consecutive pings for each haul. Most pings have an interval of 1 hour, but there is a 25% of pings for which the interval is different. As commented above, the number of sets with under- and over-reporting is similar, but when counting the number of pings involved, it translates in a larger number of pings with low frequencies. A case of under-reporting would be a haul of 5 hours that involves only 2 pings instead of 5 (for example, when the interval between two consecutive pings is of 3 hours). A case of over-reporting could be a haul of 5 hours for which the frequency of polling is one ping per minute, which would translate in 300 pings for that haul.

Trawl and longline speed

Figure 3 shows the histogram of the speed distribution of pings by fishing gear of the merged VMS and logbook datasets with the new script. In this figure it can be seen that the distribution of speeds of the pings that correspond to the hauls in the logbooks are quite different for the trawlers and the longliners. The longliners have a much wider distribution of speeds, between 0-10 knots, than trawlers, where most of the pings are between 0 and 5 knots.

Analysis of the coverage based on the Spanish Observers trawl hauls

The information collected by the Spanish scientific observers on board trawl vessels was used to measure the coverage of both logbook and VMS and the effects of the lack of information over the merged database.

With regard to the logbook coverage, not being 100% supposes that not all fishing trips and hauls recorded by the scientific observers are recorded by the skippers in the logbook. Table 4 summarises the number of trips and hauls that are missing each year. In 2016 and 2019 all the fishing trips where a scientific observer was onboard were recorded in the logbook, while in 2017 and 2018 two complete fishing trips are missing each year. Regarding the total number of hauls, in 2016 and 2019 the number of missing hauls was around 100, raising up to 200-250 in 2017 and 2018, which translates in a minimum percentage of missing hauls of 12.5% on 2016 and a maximum of 39.3% in 2018.

The number of hauls where no pings were received (Table 5), and consequently totally disappeared from the analysis, was around 10 hauls from 2016 to 2018, representing 2.3% of the total number of hauls analysed in 2017 and less than 1% in 2016 and 2018. In 2019, this percentage raised up to the 6.1% with 42 missing hauls. The number of total missing pings is around 500 - 1 100 every year, which represents a percentage of between 10 - 30% depending on the year. Considering that the average duration of a single haul in the trawl fishery is around 5 hours, it means that there are many more hauls with some missing pings than hauls where all the pings are missing.

Finally, Table 6 represents the combined effect of a simultaneous lack of information in both datasets (VMS and logbook). The number of hauls that completely disappear after the merging slightly increases compared with the missing hauls in Table 4, by the effect of adding those hauls where no pings were received to those hauls that were not recorded in the logbook. However, the effect on the number of missing pings suffers a remarkable increment. When the effects of the hauls not recorded in the logbook are overlapped to the missing pings in Table 5, the percentage of missing pings increases up to 30-40%.

Discussion

There are two methodologies to track and trace the fishing effort deployed by the fishing fleet in the NRA. The first one uses a simple speed filter (0.5-5 knots) to select the VMS pings most likely to be associated with fishing effort that are then assigned as fishing activities. The second one filters the VMS pings that correspond with the haul interval registered by the skipper in the logbook and then are assigned as fishing activities (NAFO, 2017).

General analysis of VMS and logbook databases errors

Various problems have been found with data from logbook and from VMS. These errors may have an impact on the subsequent analyses that are carried out with the VMS, the logbooks or the merged VMS logbooks data.

One of the problems that have been detected in the information of the logbooks is that there are sets where the haul interval is negative, around the 3% of the total hauls in the period 2016-2019 (Table 1). This may be usually due to typing errors in the start and/or end of the hauls. This type of failure implies that the information of the available pings (VMS data) of these erroneously typed hauls (logbook data) is lost when conducting the merging of both databases.

Another problem regarding the information of the logbooks is that there are sets where the haul time is very long (Table 1). As in the previous case, this is also due to typing errors when entering data in the logbooks. These failures imply that the selected pings of these hauls in the merging (VMS and logbook) database are incorrectly selected, including pings that correspond to time where the vessels are not fishing. The number of pings assigned erroneously will depend on the error in the duration of the haul typed in the logbook. These errors are easier to detect in the trawlers than in the longliners since the trawl fishing times are much more concentrated and shorter than those of the longliners. Most of the trawl tows are less than 10 hours and tows greater than 15/20 hours could be considered as possible errors, representing around 5% of the total trawl sets. In the longliners case, if hauls greater than 40 hours are considered as errors, this would mean around 3.5% of the longliners hauls.

The problem in the data filter in the original script to obtain the merged VMS and logbook data was solved and communicated to those in charge of creating fishery-specific effort maps and conducting the overlay analysis of VME and fishing footprint in the NAFO WG-ESA to update the analysis. The number of pings that were erroneously discarded with the original script represents around 14% of the total pings obtained with the new script (Table 2).

Although VMS pings are supposed to be sent automatically by the vessel at a frequency of around an hour, it is not always the case. This may be due to some technical error in the transmission systems. Thompson and Campanis (2007) remarked that such automatic transmission failures are uncommon in NAFO. This is contradictory with the results of this analysis. The results of Table 3 and Figure 2 show that around 3% of the sets have under- or over-reporting problems and that 25% of the received pings have different frequencies than one hour.

VMS data problems (over and under transmission) may have an effect in the VMS speed filter and in the merging (VMS and logbook) methods, as the missing pings are lost in both treatments. The speed filter method was used to study the Significant Adverse Impacts (SAI) of the bottom fishing activities in 2016 (NAFO, 2016). The problems with the logbook data affect the results of the merging method. This method was used to analyse the overlap of NAFO fisheries with VME. The impact that such problems may have on the estimation of the fishing effort were not an objective of this analysis, so further analyses should be conducted in order to determine them.

In Figure 3 it can be observed that the current speed filter (0.5-5 knots) used to select the fishing pings may be suitable for trawlers but it is not representative for longliners. Adding that the current information in the logbooks is not the most adequate to characterize the sets of the longliners, it could be concluded that the VMS data products agreed in the 2019 WG-ESA (NAFO, 2019) could be useful to study the trawl effort but not to study the longline effort.

Analysis of the coverage based on the Spanish Observers trawl hauls

It is difficult to measure the dimension that the errors described above in the VMS and logbooks data have since both databases have problems. To assess the possible scope of these errors, an analysis of the merging VMS and logbook datasets procedure was conducted based on recreating the "ideal world" using the Spanish scientific observers' trawl data. In this analysis it was assumed that the real effort exerted was exactly collected and computed by scientific observers.

Analysing the results it was possible to identify two major sources of missing data:

- Misreporting in the logbook. Not all the hauls and/or fishing trips are recorded in the logbook (Table 4). One reason for this, among others, is that not all the trips are available in the database due to submission problems or inadequate formats, as noted by the NAFO CESAG Working Group (NAFO, 2018b). This problem seems to have been improving since the implementation of the current logbook format in NAFO in 2016 and nowadays the submission rates of fishing trips information is near to 100%. On the other hand, the reasons for missing information within a recorded trip may be several. It has been observed that the last hauls of a fishing trip are missing. Some registers in the logbook that seems to be integrating several hauls have also been observed; in these cases, the catch information and the effort of the different hauls are grouped. Other problem detected was that some logbook registers with normal effort for a trawl haul seem to compile the catch information of different hauls.
- Misreporting in the VMS system. Around 10-30% of the annual pings that should be sent are missing in the hauls observed by the Spanish scientific observers (Table 5). These values of missing pings observed in the Spanish fleet could be lower in other trawl fleets, since the percentage of sets with missing pings seems to be higher in the Spanish fleet than in other fleets (Table 3). However, the percentage of sets with an overestimation of pings in the Spanish fleet is lower than that observed in other fleets. The reasons for these failures should be studied to try to avoid them and improve the quality of the VMS.

It was observed that after merging the two datasets, VMS and logbook data, the effects of the misreporting are enhanced when the coverage is not 100%. Missing hauls imply not to consider pings that have been sent, while missing pings may imply to discard hauls that actually were recorded in the logbook when there are no pings in those hauls. When both datasets were merged, only around 60-70% of the total pings were taken into account, because the information is missing (pings not sent) or discarded (hauls not recorded).

The conclusions drawn in this part would only be transferrable to the total NRA trawl data whether the sample used was representative of all trawl NAFO VMS and logbook data. This sample represents around 9% of the total NAFO trawl logbook data in the 2016-2019 period. Even if the Spanish fleet case was not transferable to all the trawl fleets operating in the NRA, the problem of the coverage of the VMS system is extensible to all the fleets based on the data sent by the NAFO Secretariat, in which it can be observed that hauls with pings problems are present in all the fleets, indicating that there is not 100% of coverage of the VMS system in the NRA (Table 3).

Conclusions

The current speed filter (0.5-5 knots) used to select the fishing pings may be suitable for trawlers but it is not representative for longliners to study the Significant Adverse Impacts (SAI).

VMS data problems (over- and under- transmission) may have an effect in the VMS speed filter and in the merging (VMS and logbook) methods, as the missing pings are lost in both treatments.

The logbook problems (missing trips and/or haul information) only affect the second method (merging VMS and logbook) used to analyse the overlap of NAFO Fisheries with VME.

It was also observed that after merging the two data sets, VMS and logbook data, the effects of the misreporting are enhanced when the coverage is not 100%. When both data sets were merged, only around 60-70% of the total pings were taken into account.

Despite the methodology of the second approach is widely considered an improvement in relation to the former method and a powerful tool for describing the spatial distribution of fishing activity, this improvement relies on the coverage and quality of the available information. Once the data problem is solved, the method of merging the VMS and logbook data would be more accurate than the VMS speed filter to study the effort exerted.

The quality of the information, both in the VMS system and in the logbooks, should be of concern to NAFO. The improvement of the quality of these data is crucial for better studying the effort distribution and the tasks related to this effort (SAI, fisheries footprint, fishing overlap with VME, assessments, etc).

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Table 1. Logbook hauls fishing time by gear in number and percentage for the period 2016-2019.

Haul Time	LL Hauls		OTB Hauls		Total Hauls	
(Hours)	n	%	n	%	n	%
<0	34	3.5%	1082	3.2%	1116	3.2%
0-10	372	38.6%	30311	90.5%	30683	89.1%
10-20	149	15.5%	1540	4.6%	1689	4.9%
20-30	351	36.4%	440	1.3%	791	2.3%
30-40	24	2.5%	108	0.3%	132	0.4%
>=40	34	3.5%	9	0.0%	43	0.1%
Total	**964**	**2.8%**	**33490**	**97.2%**	**34454**	

Table 2. Number of pings per year and total for the period 2016-2019 that are obtained when merging VMS and logbook data with the original and new scripts, as well as the percentage of pings that were lost with the original script.

	Original	New	Perc. Diff
2016	33612	38520	12.7
2017	25111	29560	15.1
2018	43177	50857	15.1
2019	52994	61990	14.5
Total	**154894**	**180927**	**14.4**

Table 3. Number of total hauls and number and percentage of hauls with under- or over-reporting pings by flag state for the period 2016-2019.

	Total Hauls	Wrong Hauls		Under- reporting Hauls		Over-reporting Hauls	
Flag State	n	n	%	n	%	n	%
PRT	54355	726	1.34	332	0.61	394	0.72
CAN	4849	127	2.62	119	2.45	8	0.16
RUS	27242	1116	4.1	153	0.56	963	3.53
FRO	9416	313	3.32	144	1.53	169	1.79
ESP	45299	1535	3.39	1422	3.14	113	0.25
EST	17209	431	2.5	384	2.23	47	0.27
GBR	524	24	4.58	18	3.44	6	1.15
JPN	16578	1086	6.55	62	0.37	1024	6.18
USA	3159	318	10.07	12	0.38	306	9.69
NOR	2296	60	2.61	59	2.57	1	0.04
Total	**180927**	**5736**	**3.17**	**2705**	**1.50**	**3031**	**1.68**

Table 4. Number of fishing trips and number of hauls recorded by the Spanish scientific observers and by the skipper in the logbook, corresponding to the trawl fishing trips where an observer was present. The differences in number and percentage are also shown.

	Observers		Logbook		Difference (n)		Difference (%)	
	Trips (n)	Hauls (n)	Trips (n)	Hauls (n)	Trips	Hauls	Trips	Hauls
2016	7	927	7	811	0	116	0.0	12.5
2017	8	739	6	531	2	208	25.0	28.1
2018	7	684	5	415	2	269	28.6	39.3
2019	6	688	6	576	0	112	0.0	16.3

Table 5. Number of VMS pings that should be received (i.e. Ideal) and number of pings actually received (i.e. Real) when filtering VMS pings by the trawl observers' records. Also, the percentage of missing pings and the number and percentage of hauls where no ping was sent are shown.

	Ideal	**Real**	**Missing pings**		**Missing hauls**	
	Pings (n)		(n)	(%)	(n)	(%)
2016	5075	4217	858	16.91	6	0.65
2017	4548	3573	975	21.44	17	2.30
2018	4242	3786	456	10.75	6	0.88
2019	4026	2924	1102	27.37	42	6.10

Table 6. Number of fishing trips and hauls recorded by the Spanish scientific observers on board trawlers, and ideal pings associated ("Ideal world"). Also the number of fishing trips, hauls and pings obtained after merging logbook and VMS and selecting the hauls where a Spanish observer was aboard ("Real world"). The differences between them are presented in percentage.

	Ideal			**Real**			**Difference**		
	Trips (n)	Hauls (n)	Pings (n)	Trips (n)	Hauls (n)	Pings (n)	Trips (%)	Hauls (%)	Pings (%)
2016	7	927	5075	7	805	3699	0.0	13.2	27.1
2017	8	739	4548	6	524	2857	25.0	29.1	37.2
2018	7	684	4242	5	412	2637	28.6	39.8	37.8
2019	6	688	4026	5	536	2848	16.7	22.1	29.3

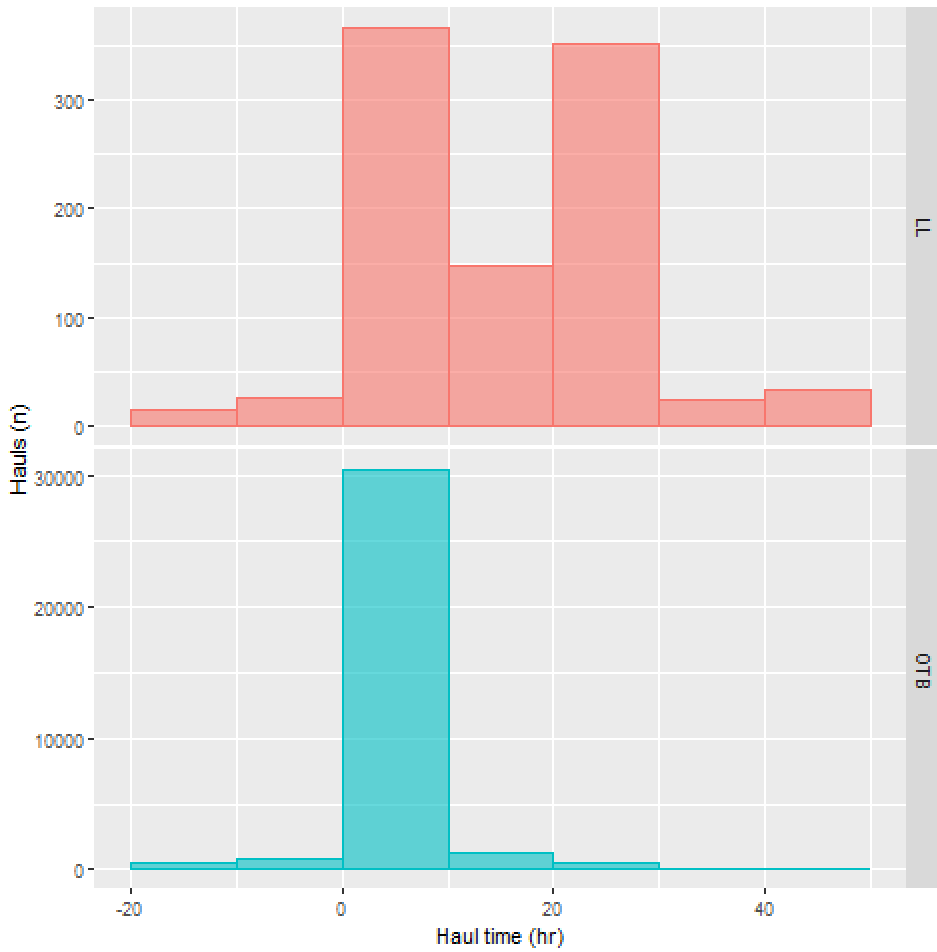

Figure 1. Histogram of the hauls fishing time of the logbook datasets for the studied period (2016-2019) by gear (LL=Longliners, OTB=Trawlers). Histogram class width = 10 hours. The first histogram class includes all the values below -10 hours and the last one all the values above 40 hours.

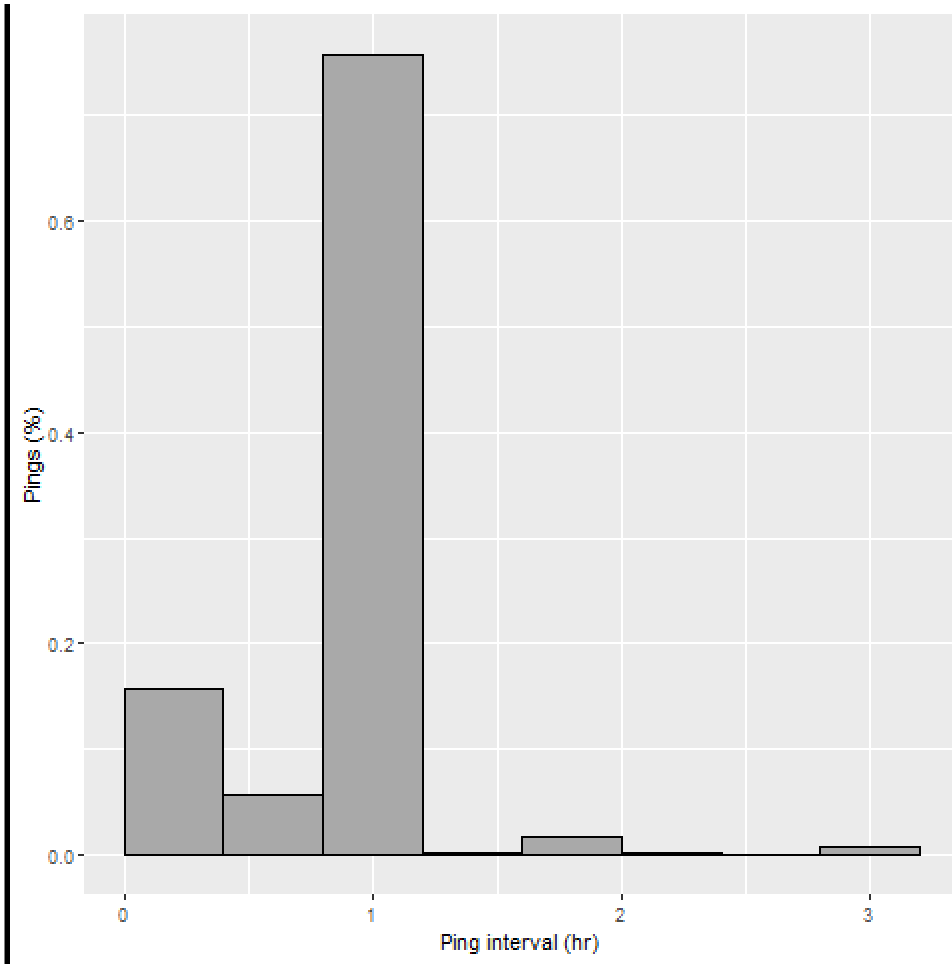

Figure 2. Histogram of time between consecutive pings for each haul. Histogram class width = 0.4 hours. Last histogram class includes all the values above 2.8 hours.

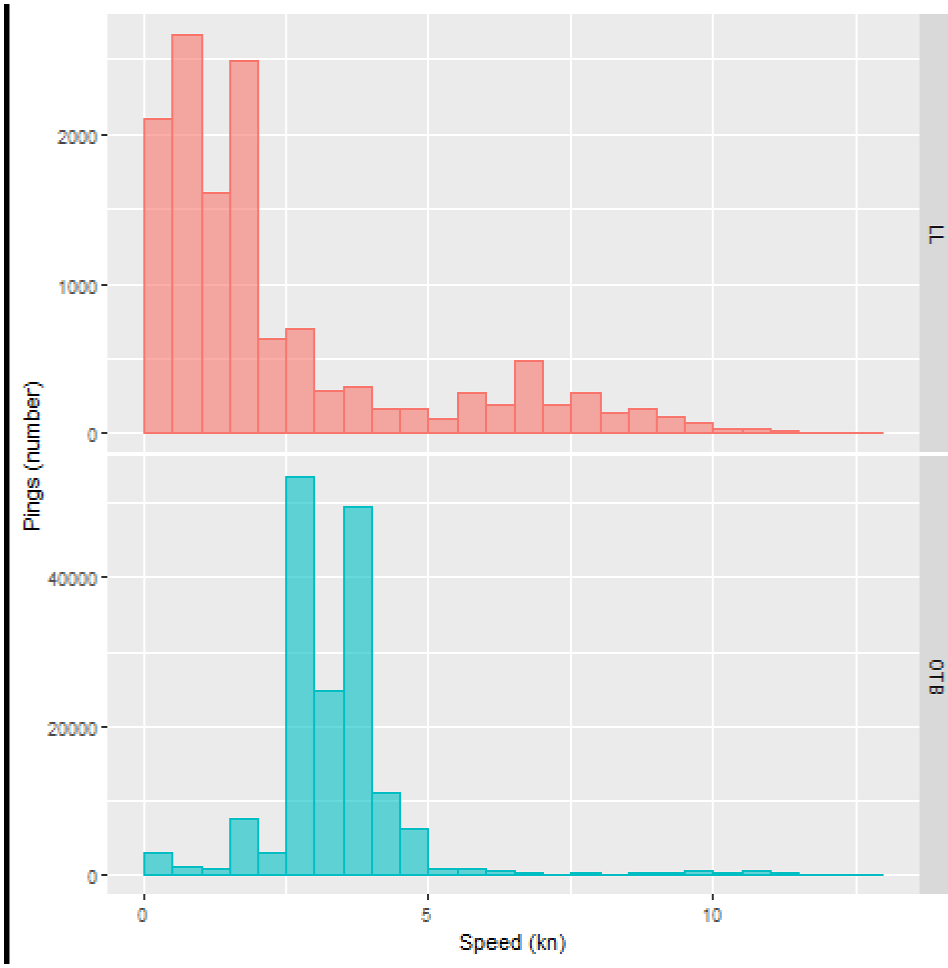

Figure 3. Histogram speed distribution of the pings of the merged VMS and logbook dataset for the studied period (2016-2019) by gear (LL=Longliners, OTB=Trawlers). Histogram class width = 0.5 knots. Last histogram class +12 knots.