







# Final Report: NEREIDA: RESEARCH IN SUPPORT OF THE REASSESSMENT OF NAFO BOTTOM FISHERIES IN 2022

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# 1- EXECUTIVE SUMMARY

The NEREIDA study was funded by the European Union through the NAFO Secretariat. The proposed activities under NEREIDA were specifically designed to address NAFO Commission requests and contribute directly to respond to them. Work on the project started several months late due to various administrative issues. These delays have had a significant impact on the development of the planned tasks and have posed a major challenge to the delivery of the work. Overcoming these obstacles has required considerable effort and adaptation from the team while striving to achieve the goals despite the initial setbacks.

This study was divided into three main tasks to be accomplished.

The aim of the **Task 1**: "Analysis of the methodology to study the bottom-fishing footprint in the NAFO Regulatory Area (NRA): Quality of NAFO VMS and logbook data", was to better understand the extent of fishing activities within NAFO Regulatory Area (NRA) by characterising the distribution and intensity of fishing effort from 2016 to 2022. The analysis was based on three data sources: Vessel Monitoring System (VMS), logbook information and data from the IEO Scientific Observer Programme. Quality control was applied to both VMS and logbook information data to curate the database information. An open source R quality control procedure was developed to make such data more reliable for characterising bottom fishing effort in the NRA. Furthermore, an improvement of the "coupling of VMS and logbook data" methodology was carried out, as previous research had identified several problems in some steps of the original methodology. This improvement also implied a refinement of the demersal fishing footprint. Finally, annual cumulative fishing effort maps, together with annual fishery specific effort maps, were produced from 2016 to 2022 using the new improved "coupling of VMS and logbook data" methodology together with the "simple speed" filter methodology. The maps produced contribute to a better knowledge of the spatial and temporal distribution of fishing effort in the NRA. In addition, an overlay analysis was carried out to estimate the area of the VME polygons of the seven VME taxa defined by NAFO that were overlapped by the cumulative fishing footprint and by the different fishery-specific footprints.

Both **Tasks 2** and **3** were performed in order to give response to the NAFO Commission's request to continue monitoring and providing updates resulting from relevant research related to the potential impact of activities other than fishing (e.g. COM Request #9¹), as there were strong arguments that justified the need to conduct new studies to better understand the non-fishing activities occurring in the NAFO context.

**Task 2** "Activities other than fishing in the NAFO Regulatory Area (Divs. 3LMNO): Seabed litter" was focused on providing updates about spatial distribution of seabed litter in the NRA (Divs. 3LMNO). A comprehensive review, update and standardization of the list of seabed litter categories and codes was performed, with particular attention to the existing data recorded in the NRA, to obtain a standardized master file. A cross-check of the groundfish survey data collection form with the database and with photographic

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<sup>&</sup>lt;sup>1</sup> **COM Request #9** (2024): "The Commission requests the SC to monitor and provide regular updates on relevant research related to the potential impacts of activities other than fishing in the Convention Area, subject to the capacity of the Scientific Council" (NAFO, 2024).

records was carried out to ensure that the seabed litter did not contain errors and that all photographed items matched the records in the database, respectively. The analysis conducted provided updated information about seabed litter composition, abundance, densities and spatial distribution in the areas where EU groundfish surveys operate. Additionally, outcomes from this research will help in further analysis that is in progress to: (i) identify the main sources of seabed litter, (ii) elucidate the potential drivers on seabed litter distribution, (iii) improve the current seabed protocol, and (iv) provide recommendations and good practices. An update of this study is expected to be presented during next WGESA meeting, scheduled for November 2024.

Work on **Task 3** "Activities other than fishing in the NAFO Regulatory Area (Divs. 3LMNO): Offshore oil and gas" was focused on gathering the updated information about spatial distribution of existing and planned activities of the offshore oil and gas activities in the NRA (Divs. 3LMNO), including an extensive literature review of the current knowledge on its potential impacts on the marine ecosystem, and the potential conflicts of such activities with other marine users. Based on the latest information available the main natural and socioeconomic ecosystem components were identified and mapped. Spatial overlap among users (user-user) and between users and the ecosystem (userenvironment) were identified, including overlapping trends for the period 2018-2024. This exercise was primarily focused on offshore oil and gas activities, deep-sea fisheries and Vulnerable Marine Ecosystems (VMEs). The main gaps and needs in research and the priority challenges regarding scientific monitoring and mitigation of potential impacts of other activities than fishing taking place in the NAFO Regulatory Area were also highlighted. In addition, the role of area-based management tools (i.e., NAFO closure No. 10) was emphasized, as well as the implications of multisectoral areas for the process of identifying, assessing and reporting other effective area-based conservation measures (OECMs).

A summary of each of the tasks presented in this report was presented to the Scientific Council at its meeting in June 2024 (see Annexes of each Task).

# 2- INTRODUCTION

Undertaken activities within this study were designed to address several NAFO Commission Requests (namely, re-assessment of NAFO bottom fisheries, continue to monitor and provide updates resulting from relevant research related to the potential impact of activities other than fishing) and therefore contributing directly to respond to them. These activities are important to:

- (i) have a better understanding on the extent of fishing activities within NRA, together with a characterization of distribution of fishing effort, to better understand if and how is changing over the years;
- (ii) assess the overlap of NAFO fisheries with VME to evaluate fishery specific impacts in addition to the cumulative impacts for NRA fisheries;
- (iii) monitor the spatial and temporal distribution of seabed litter, contributing to improved knowledge of their characteristics, and
- (iv) update of available information on spatial distribution of existing and planned activities other than fishing in NRA, particularly oil and gas.

This action supports NAFO (Northwest Atlantic Fisheries Organization) in relation to the protection of Vulnerable Marine Ecosystems (VMEs). Results obtained might have a direct influence on the management measures adopted in NAFO to protect VMEs in accordance with published NAFO Conservation and Enforcement Measures (CEM).

# Tasks performed

The project was structured into 3 Tasks:

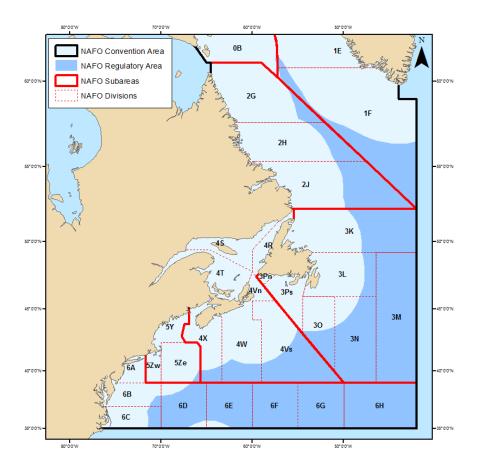
- <u>Task 1:</u> Analysis of the methodology to study the bottom-fishing footprint in the NAFO Regulatory Area (NRA): Quality of NAFO VMS and logbook data
- <u>Task 2:</u> Activities other than fishing in the NAFO Regulatory Area (Divs. 3LMNO): Monitoring the spatial and temporal distribution of seabed litter, contributing to improved knowledge of their characteristics
- <u>Task 3:</u> Activities other than fishing in the NAFO Regulatory Area (Divs. 3LMNO), with focus on offshore oil and gas: Spatial distribution and literature review of its potential impacts, its interactions with deep-sea fisheries and criteria/methodologies for studying them

# Objective and structure of the Final Report

The aim of this final report is to provide an update on the progress made to date, with the main results and outcomes achieved, and to specify the work under the specific tasks that were developed. The text for each task is structured into the following sections: Introduction; Objective; Material and methods, Sub-tasks; References and Annexes.

# 3- STUDY AREA

The project was conducted in the NW Atlantic Ocean within the Northwest Atlantic Fisheries Organization (NAFO) Regulatory Area (NRA) (Map 1). The study area is located in international waters of the Northwest Atlantic Ocean, to the east of the Canadian coastline, in a depth range of about 45-1,500 m. This area corresponds to a part of the Grand Banks of Newfoundland and its slopes, the top and the slopes of the Flemish Cap, and the deep waters of the Flemish Pass. It covers the major international bottom fishing grounds (e.g., Greenland halibut, redfish, cod and skates) within the NRA (NAFO Divisions 3LMNO), as well as important areas for other human activities (e.g., offshore oil and gas). In addition, the study area hosts cold-water corals, sea pen fields and sponge grounds and, moreover, the fishing closures implemented by NAFO to protect VMEs. The NRA is located in the high seas (water column), and partly lies above the seabed within the extended continental shelf of the coastal state (Canada). This implies a complex situation derived from the intersection of the jurisdictional regimes affecting the water column beyond 200 miles (NAFO competence) and the extended continental shelf (coastal state competence).



Map 1. NAFO Regulatory Area. Source: www.nafo.int

# 4- TASKS ADDRESSED

An introduction, objective, materials and methods, along with a description of each subtask and the main outcomes obtained, are provided below for each of the three tasks.

TASK 1. Analysis of the methodology to study the bottom-fishing footprint in the NAFO Regulatory Area (NRA): Quality of NAFO VMS and logbook data

# **INTRODUCTION**

The ecosystem approach aims to protect ecosystem structures, processes and interactions through the sustainable use of natural resources. The regulation of fishing activities requires an assessment of their environmental impact, with a key step being the definition and precise delineation of the fishing footprint. In 2020, an analysis of Vessel Monitoring System (VMS) and logbook data was carried out to assess the quality of the data used to delineate the bottom fishing footprint in the NAFO Regulatory Area (NRA). This analysis was updated in 2023 and the results are presented in this analysis, which was carried out under the NEREIDA project and supported by the European Union through the NAFO Secretariat. This work aims to respond to specific requests from the NAFO Commission and is crucial for the upcoming reassessment of NAFO demersal fisheries in 2026, focusing on the distribution of fishing effort and its overlap with Vulnerable Marine Ecosystems (VMEs).

Applying a speed filter is a very common method for identifying VMS pings associated with fishing activity (Thompson and Campanis, 2007; Campanis *et al.*, 2008; WGDEC, 2008; Campbell and Federizon, 2013). This approach involves filtering VMS pings through a simple speed filter directly related to fishing speed. Thus, only those VMS records with a high probability of being associated with fishing effort are classified as fishing activity. However, there are challenges with this method in terms of threshold speeds across entire fleets/gears, leading to misclassification of some pings at a rate that is difficult to quantify accurately (NAFO, 2017). The use of haul-by-haul data from logbooks allows VMS pings to be categorised as "fishing" or "non-fishing" based on whether they fall within the haul-by-haul on the basis of whether they fall within the fishing time intervals reported in the haul-by-haul data, instead of according to the speed of the vessel. This means that the 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 and to delineate the fishing footprint.

As these VMS pings fall directly within the reported fishing time interval, they are considered to be associated with fishing activity. Logbook data and VMS are complementary, and merging the two data sets has already been shown to describe the spatial distribution of fishing activity with greater accuracy and precision than when each dataset was assessed independently (NAFO, 2018a; NAFO, 2019).

The main objective of this study was to analyse the quality and coverage of available VMS and logbook data used in these two methods (speed-filtered & logbook-filtered). Comparisons were made with data collected by the IEO Scientific Observer Programme on board bottom trawl vessels, as the information collected by these was considered to

be representative of the real effort exerted by the Spanish fleet. Resulting cumulative fishing effort and fisheries-specific effort maps and their overlapping with VME analysis are shown in the sub-task 1.4 section.

# **OBJECTIVE OF TASK 1**

The main objective of this task is to better understand the extent of fishing activities within NAFO Regulatory Area (NRA) through a characterization of distribution and intensity of fishing effort from 2016 to 2022. Analysis have been conducted based on three data sources: Vessel Monitoring System (VMS), logbook information and IEO Scientific Observer Program data. A summary of this information was presented to the NAFO Scientific Council during the June 2024 meeting (NAFO, 2024a).

### **MATERIAL AND METHODS**

This comprehensive analysis was carried out utilizing data from Vessel Monitoring System (VMS), logbook records and IEO Scientific Observer Program, covering the period from 2016 to 2022:

# Vessel Monitoring System (VMS)

The NAFO 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 ping rate which has improved 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 logbook data.

VMS data used in this study (period from 2016 to 2022) were supplied by the NAFO Secretariat, who is responsible for collecting and maintaining these data from fishing vessels operating in the NRA. In addition, to being an integral part of the NAFO's Monitoring, Control and Surveillance (MCS) scheme, the VMS data are also used in various scientific applications by NAFO (e.g. for the assessment of Significant Adverse Impacts (SAIs) on VMEs and in some fish stock assessments).

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, 2024b).

# 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, 2024b).

The current logbook data format (NAFO, 2024b) was implemented by NAFO in 2016, and was an improvement over 2015, when the haul data records included only 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 the NAFO Secretariat.

# **IEO Scientific Observer Program**

The Instituto Español de Oceanografía (IEO, CSIC) employs scientific observers who are onboard during fishing operations conducted by the Spanish commercial fleet within the NRA. Around 30 % of the annually effort deployed by the Spanish fleet is sampled by the IEO Scientific Observer Program. The collection of these data falls under the responsibility of IEO, under the European Union Fisheries Data Collection Framework. 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.

It is important to note that the Spanish fleet is made up exclusively of bottom trawlers, so the conclusions drawn at any point from the information obtained by the IEO observers may only be extended to the bottom trawling fleet. It is also important to highlight that due to administrative issues, the information recorded by Spanish scientific observers in the year 2020 was not considered in this analysis.

The data used for the analysis presented in this task correspond to the period from 2016 to 2022. This time interval aligns with the availability of the current format of the haulby-haul catch data, ensuring the inclusion of the latest and most relevant information in the analysis.

The analysis of the data was completed using the open-source statistical computing environment R (R Core Team, 2023). The implementation of this analysis involved the use of a script developed by Fisheries and Oceans Canada (DFO). Originally developed for merging VMS and logbook data, the original script was improved and used in the overlay analysis of VME and fishing footprint.

To achieve the objective set in Task 1, sub-tasks described below were addressed:

# Sub-tasks 1.1 and 1.2: Quality control of VMS and logbook databases

In many instances, both data sources (i.e. VMS and logbook) contain erroneous entries, namely: points with incomplete timestamps; incorrect vessel positions; duplicated records; headings outside compass range, etc. Following a deep review of the databases, a process of removal or flagging of erroneous entries was undertaken. Upon completion of the data cleaning procedure, the VMS and haul-by-haul datasets are joined using

vessel identification and date as common fields between both datasets. This step holds particular significance, as the success of all subsequent analyses relies on accurately linking these datasets. The joined dataset only contains the pings (VMS data) of each vessel that coincide with the time reported as fishing in the logbook data, excluding pings from periods when vessels were not fishing.

Further analysis was conducted to identify potential errors in the merged dataset. These errors may be due to problems with the data in the logbooks or due to problems in the VMS data. Compared to the automated nature of VMS records, it is reasonable to assume that errors are more prevalent in the logbooks which rely on user input.

# ANALYSIS OF THE COVERAGE BASED ON THE SPANISH SCIENTIFIC OBSERVERS TRAWL HAULS

Given the potential presence of errors in both data sources, a subset of records in the merged database (VMS and logbooks) was selected for vessels with a Spanish scientific observer on board. The aim of this selection was to assess the representativeness of the errors in each data source, assuming that the actual effort exerted in these selected hauls was that reported by the scientific observers on board. Comparisons between datasets were made on the basis of common fields, in particular vessel identification and date.

In order to measure the coverage of VMS and logbook data, an "*ideal world*" scenario was recreated, representing all VMS pings in all hauls with the presence of a Spanish scientific observer. By comparing the results of this "ideal world" with the results of the available data, it was possible to estimate the coverage of VMS, logbook and combined VMS and logbook data.

# "Ideal world" scenario

In creating the "ideal world" scenario, an artificial database called Hourly Ping Data (HPD) was created. This database was created by generating a ping for each hour of the analysed period (1 January 2016 to 31 December 2022). The HPD database contains only date and time information. Thus, when merged with the observers' records or logbooks, the same ping was assigned to each vessel fishing in the NRA at the same time. This approach simplified the ping register for all vessels analysed.

The creation of the "ideal world" scenario involved merging the HPD with the dataset containing information from Spanish scientific observers. This integration allowed the derivation of the number of fishing trips, the number of hauls, the duration of each haul (measured in hours) and the expected number of VMS fishing pings. These were calculated on the assumption that the coverage of both VMS and logbook data was complete for these scientific observers' hauls.

# Coverage of VMS data

The coverage of the VMS system was assessed by filtering the VMS and HPD datasets directly through the Spanish scientific observer records, indicating the start and end of each haul. As the "ideal world" scenario includes all the VMS pings that should have

been sent in these hauls, it can be compared with the number of pings actually sent. Any erroneous pings identified in this way are then due to erroneous records in the VMS system.

# Coverage of Logbook data

In order to analyse the haul coverage of the logbooks, the HPD dataset was filtered based on the logbook entries, and then hauls with the presence of a Spanish scientific observer were isolated. The outcomes of this analysis were then compared with the "ideal world" scenario, where the HPD dataset was directly merged with these scientific observers records. The differences in the results can only be attributed to the differences in the records of the Spanish scientific observers and the skippers, highlighting, among other things, the number of hauls and fishing trips that are not recorded in the logbooks.

# ANALYSIS OF THE PERFORMANCE OF MERGING VMS AND LOGBOOK DATASETS

Once the missing hauls and trips had been identified, the performance of merging VMS and logbook data was analysed. This analysis involved comparing the results from the "ideal world" scenario, where the HPD was merged directly with the records from Spanish scientific observers, with the results of the "real world" scenario. In the "real world", the actual VMS data were merged with the logbook entries and then filtered based on records from scientific observers.

This made it possible to assess the combined effect that a simultaneous lack of information in both datasets can have on estimates of fishing effort.

# RESULTS FROM THE ANALYSIS OF VMS AND LOGBOOK DATABASES ERRORS

# VMS database

Table 1 presents the total number of pings and the number of erroneous entries in the VMS database by year. The identified errors include:

- a) <u>Duplicated pings</u>: Entries with identical information regarding Vessel, Day and Hour.
- b) Incomplete pings: Pings where any field is missing.
- c) <u>Short pings</u>: Instances where the time interval between one ping and the next is less than one hour.
- d) <u>Long pings</u>: Cases where the time interval between one ping and the next is more than one hour.

**Table 1**. VMS total pings and erroneous entries for the period 2016-2022.

	<b>Total Pings</b>	Duplicated	Incomplete	Short	Long	Wrong (Total)	Wrong (%)
2016	90 294	9 922	0	17 751	5 383	33 056	36.6
2017	64 151	7 933	0	8 352	4 498	20 783	32.4
2018	212 674	81 478	0	30 219	6 813	118 510	55.7
2019	143 031	26 149	0	36 901	5 841	68 891	48.2
2020	142 127	25 372	0	43 638	6 315	75 325	53
2021	127 297	23 050	0	27 734	6 895	57 679	45.3
2022	94 872	10 676	1	13 467	4 798	28 942	30.5

The percentage of erroneous pings ranged from 30.5 to 55.7%. However, it is important to note that not all the errors invalidate the data. Only duplicated and incomplete pings need to be removed from the effort analyses, as short and long pings can be used for the merging as long as the effort analysis considers the duration of the pings and is not just a sum of pings per grid.

# Logbook database

Table 2 shows the total number of hauls recorded in the logbook by year along with the errors identified in this analysis, which can be classified as follows:

- a) Errors in the effort record: These errors result from misrecordings of the start or the end of the haul and they translate into negative efforts (i.e. when the start of the fishing activity is recorded after the end), zero effort (i.e. when the start and the end of the activity are the same or one of them is missing) and high efforts (efforts exceeding 24 hours, often due to errors in recording the day, month or year of the start or end of the haul).
- b) <u>Errors in the position record</u>: These errors pertain to inaccuracies in recording the position of start and/or end of the fishing activity.
- c) <u>Errors in the gear record</u>: These errors, newly identified in this analysis, pertain to inaccuracies in recording the gear used for fishing.

**Table 2.** Logbook hauls and erroneous recordings for the period 2016-2022.

	Total	Mi	isrecorde	d Effort	Misrecorded	Misrecorded	
	hauls	Negative	Zero	Big	Total	positions	gear
2016	7 697	101	12	151	264	9	1 346
2017	6 460	143	59	149	351	26	1 027
2018	8 194	146	7	171	324	11	564
2019	11 358	608	158	260	1 026	156	1 801
2020	12 007	155	139	119	413	2 610	417
2021	8 341	109	918	115	1 142	569	243
2022	8 700	58	1 138	186	1 382	9	256

Hauls with incorrect effort records in the logbook must be removed before merging the datasets, as accurate start and/or end times are crucial for the merging process. However, hauls with erroneous position records can be retained, as position data in subsequent analyses are derived from the VMS database and not from the logbook. Table 3 shows the number of erroneous gear entries in the logbook, and it is clear that these are mainly due to human error in entering the data. The gear is used to characterise the fishing effort by fishery. Only a further analysis, which considers position, season and catch composition, allowed the identification of the correct gear (OTB: otter trawl, LL: longline).

**Table 3.** Logbook misrecorded gears and new gears assigned. Count represents the total for the period 2016-2022. OTB refers to otter trawl gears and LL to longline sets.

Gear type	Count	New gear
	237	LL
ОТВ	2	ОТВ
#N/A	69	
ОТВ	2	ОТВ
1	2	LL
2	7	LL
3	28	LL
4	1	LL
5	6	LL
6	1	LL
???	74	ОТВ
???-2	45	ОТВ
???1	13	ОТВ
???2	290	ОТВ
LLS	259	LL
OBT	1 915	ОТВ
OT	201	
OTB-2	190	ОТВ
OTB2	2 360	ОТВ
OTM	304	
OTW2	34	ОТВ
ТВ	67	ОТВ
TBS	1 254	
ТО	52	ОТВ

# DISCUSSION ON THE GENERAL ANALYSIS OF VMS AND LOGBOOK DATABASES ERRORS

A number of problems have been identified in both the VMS and logbook data, and these errors may have an impact on the subsequent analyses conducted with the VMS, logbooks or the merged VMS and logbooks dataset.

Although VMS pings are designed to be automatically transmitted from the vessel at a frequency of approximately one per hour, technical issues in the transmission system can sometimes lead to deviations from this standard. While Thompson and Campanis (2007) found that such automatic transmission failures are rare in the NAFO Regulatory Area, the results presented in Table 1 indicate that every year around 30% to 50% of the received pings occur at frequencies different from one hour. This suggests that VMS data problems, such as over and under transmission, may have an effect on the analyses that rely on this source of information to estimate fishing effort in the NRA, regardless of the methodology used.

A large number of errors have been identified in the logbook dataset, often due to mistakes made when entering records into logbooks. These errors can have many different consequences. For instance, in hauls where the start time is erroneously recorded after the end time (logbook data), the information from the available pings (VMS data) for these erroneously recorded hauls may be lost when the two databases are merged. In addition, for logbook records with excessively long hauls, the pings included in the merged database (VMS and logbook) may actually correspond to periods when the vessels were not fishing. In these cases, the number of erroneously assigned pings will depend on the duration error of the haul recorded in the logbook.

# ANALYSIS OF THE COVERAGE BASED ON THE SPANISH SCIENTIFIC OBSERVERS TRAWL HAULS

The information collected by the Spanish scientific observers on board trawlers was used to assess the coverage of both the logbook and the VMS, as well as the impact of missing information on the merged datasets.

With regard to the logbook coverage, it is clear that not all fishing trips and hauls documented by the Spanish scientific observers are recorded in the logbook by the skippers. Table 4 provides a summary of the number of trips and hauls recorded by the Spanish scientific observers, as well as the trips and hauls that are missing each year on the logbook. In 2016, all fishing trips with a Spanish scientific observer onboard were recorded in the logbook, while in the other years at least one complete fishing trip was missing, three in 2022. Concerning the total number of hauls, on average, around 300 hauls are missing each year, with the percentage of missing hauls ranging from 22.7% (2019) to 60.2% (2022).

The number of hauls where no pings were received, resulting in exclusion from subsequent analysis, is indicated in Table 5.

**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)		(n) Trips (n) Hauls (n)		Trips	Hauls	Trips	Hauls
2016	7	927	7	691	0	236	0.0	25.5
2017	8	739	6	503	2	236	25.0	31.9
2018	7	685	5	399	2	286	28.6	41.8
2019	6	688	5	532	1	156	16.7	22.7
2020	-	-	-	-	-	-	-	-
2021	8	845	7	498	1	347	12.5	41.1
2022	8	796	5	317	3	479	37.5	60.2

**Table 5.** Number of VMS pings that should be received (i.e. "*Ideal world*" scenario) and number of pings actually received (i.e. "*Real world*" scenario) when filtering VMS pings by the trawl Spanish scientific 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		Missin	g hauls
	Pings (n)		(n)	(%)	(n)	(%)
2016	2016       5 194       4 213         2017       4 597       3 557         2018       4 311       3 776         2019       4 026       2 924         2020       -       -         2021       5 445       4 229		981	18.9	9	1.0
2017			1 040	22.6	15	2.0
2018			535	12.4	7	1.0
2019			1 102	27.4	42	6.1
2020			-	-	-	-
2021			1 216	22.3	115	13.6
2022	5 332	3 966	1 366	25.6	102	12.8

From 2016 to 2018 this represented  $1-2\,\%$  of hauls. In 2019, this percentage increased to 6.1% with 42 missing hauls. In 2021 and 2022, the number of hauls without pings exceeded 100, representing more than 12% of the total hauls recorded by a Spanish scientific observer. Across all years, the total number of missing pings ranges from 535  $-1\,366$ , which represents between 12.4 and 27.4%, depending on the year. Considering that the average duration of a single haul in the trawl fishery is around 5 hours, and VMS pings are recorded every hour, it is most likely that there are more hauls with some missing pings than hauls where all the pings are missing.

Finally, Table 6 illustrates the combined effect of errors when both datasets (VMS and logbook) are merged. The number of hauls that are excluded after datasets are merged increases slightly when compared to the excluded hauls described in Table 4. This is attributed to the fact that, in addition to those hauls that were not recorded in the logbook, hauls which were recorded but have no associated VMS pings are also removed.

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

	Ideal (n)			Real (n)			Difference (%)		
							Trip		
	Trips	Hauls	Pings	Trips	Hauls	Pings	S	Hauls	Pings
2016	7	927	5 194	7	682	3 113	0	26.4	40.1
2017	8	739	4 597	6	497	2 720	25	32.7	40.8
2018	7	685	4 311	5	396	2 528	28.6	42.2	41.4
2019	6	688	4 026	5	500	2 673	16.7	27.3	33.6
2020	-	-	-	-	-	-	-	-	-
2021	8	845	5 445	7	493	2 894	12.5	41.7	46.9
2022	8	796	5 332	5	316	1 968	37.5	60.3	63.1

When compared to Table 5, it is clear that merging the datasets resulted in a significant increase in the number of pings excluded from further analysis. This is because pings for hauls that are not recorded in the logbook are not included in the merged dataset. As shown in Table 6, the percentage of missing pings ranges from 33.6-41.4% between 2016-2019 and 46.9-63.1% between 2021-2022.

# DISCUSSION ON THE ANALYSIS OF THE COVERAGE BASED ON THE SPANISH SCIENTIFIC OBSERVERS TRAWL HAULS

Measuring the extent of errors in the VMS and logbook data is challenging due to the inherent problems in both datasets. In order to assess the possible magnitude of these errors, an analysis of the merged VMS and logbook datasets procedure was carried out. This analysis was based on recreating the "ideal world" scenario using trawl data from Spanish scientific observers. This analysis assumed that the effort actually exerted was accurately recorded and calculated by these scientific observers.

Analysis of the results identified two main sources of missing data:

- a) Misreporting in the logbook: Not all the hauls and/or fishing trips are recorded in the logbook (Table 4). This discrepancy can be attributed to various reasons, including submission issues or inappropriate formats, as highlighted by the NAFO CESAG Working Group (NAFO, 2018b). Within recorded trips, diverse factors contribute to missing information. It has been observed that the last hauls of a fishing trip are sometimes missing. In addition, some logbook entries appear to merge data from several hauls, combining catch and effort data from different hauls.
- b) <u>Misreporting in the VMS system</u>: Each year about 12-27% of the pings that should be associated with the hauls reported by the Spanish scientific observers are missing (Table 5). The cause of these errors should be further investigated in order to correct them and improve the quality of the VMS.

After merging the VMS and logbook datasets, it is clear that the effects of the misreporting are amplified when there is missing information in both data sources. Missing hauls result in pings be discarded, while missing pings may lead to the exclusion of documented hauls from logbooks. Once the datasets are merged, only 40-70% of the original pings are retained, illustrating the magnitude of the potential impact that errors (due to missing pings or missing haul records) can have on subsequent and related analyses.

# **CONCLUSIONS OF THE ANALYSIS**

It is important to note that the conclusions drawn here would only be applicable to the overall NRA trawl data if the sample data used (the Spanish scientific observer data) were representative of the VMS and logbook data provided by all trawl fleets operating in the NRA. This sample represents about 9% of the total NAFO logbook data for the period 2016-2022. However, based on the data provided by the NAFO Secretariat for this analysis, even if the errors quantified for the Spanish fleet are not representative of all the trawl fleets operating in the NRA, the operational problems identified in the VMS and recording errors in the logbook datasets are likely to affect all fleets to some extent.

Problems with VMS data transmission (i.e. including both over- and under-transmission), and in logbook data (i.e. missing trips and/or haul information) can significantly affect any analysis that relies on this information to estimate the fishing effort exerted by the fleet.

The merging of VMS and logbook data shows that the effects of the misreporting are magnified when data coverage is less than 100%. When both datasets were merged, only about 40-70% of the expected pings, according to the "*ideal world*" scenario, were considered. It is important to note that the impact of these problems (in logbook and VMS databases) on the estimation of fishing effort was not the primary objective of the current analysis. Further analysis should be carried out to determine this.

The quality of the information in both the VMS system and the logbooks should be of concern to NAFO. Improving the quality of these datasets is crucial for developing a more comprehensive understanding of effort distribution and directly impacts the accuracy of related analyses (i.e. SAI, fisheries footprint, fishing overlap with VME, assessments, etc).

The analyses carried out by the NEREIDA project are of great practical value in helping to meet specific requests from the NAFO Commission, particularly in the context of the forthcoming reassessment of NAFO demersal fisheries scheduled for 2026.

In conclusion, overcoming the challenges of VMS and logbook data, improving data coverage and overall data quality are essential steps in advancing research on effort allocation and related tasks that are critical for effective fisheries management.

# Sub-task 1.3: Improving the methodology for "Coupling VMS and logbook data"

While the use of a "simple speed filter" is a very common method for extracting VMS points associated with fishing, there will inevitably be some points that are misclassified at a rate that is difficult to quantify. In previous years (NAFO, 2015), a simple speed filter of 1-5 knots (rounded to the nearest integer) was used to filter VMS points and assign them to fishing activities, but this presented challenges in terms of threshold speeds across entire fleets.

Logbook data and VMS are complementary, and the coupling of the two datasets has already been shown to be powerful in describing the spatial distribution of fishing activity at a much finer resolution (NAFO, 2017).

Figure 1 illustrates the flowchart of the main steps involved in the process of linking VMS with logbook data. The whole framework is modular, with each step developed in the open source statistical computing environment R (R Code Team, 2023).

# VMS Data Raw data cleaning Logbook Data Data matching Merged dataset Analyses Results

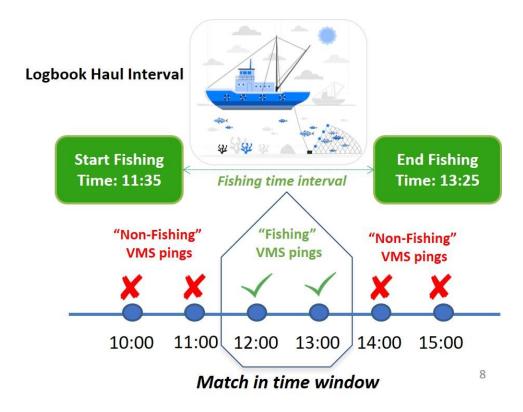
Figure 1. Flowchart of the main steps involved in the process of coupling VMS and logbook data.

Considering the various problems identified with the VMS and logbook databases, a number of analyses were carried out to ensure the quality of the data used to perform the linkage between VMS and logbook data. All of these issues are described in detail in sub-tasks 1.1 and 1.2 and were critical in order to carry out the first important step of the flowchart: "Raw data cleaning".

Once the data cleaning has been carried out, both datasets are ready for "data matching" using the NAFO Vessel ID and the date as common fields between the two

databases. This step is particularly important as all subsequent analyses depend on the success of the match. From the "merged dataset" we can start the "analyses" and obtain the final "results". The use of the haul-by-haul data allows VMS pings to be classified as "fishing" or "non-fishing" based on whether or not they fall within the fishing time intervals reported in the haul-by-haul catch data (match in time window, see Figure 2). This means that the start and end of fishing time stamps from the logbooks are used to extract relevant VMS points, which are then mapped in space to represent fishing effort.

As these VMS points are directly within the reported fishing time interval, they are considered to be associated with fishing activity.



**Figure 2**. Match in time window procedure example. NAFO Vessel ID and Date were used as common fields between both databases (VMS and logbook).

This analysis used VMS data and haul-by-haul catch data (logbook) for the period 2016 to 2022 to produce fishing footprint maps for fishery-specific and cumulative fishing effort (bottom trawl, longline, and both together). The resulting maps are presented in sub-task 1.4 section.

To produce the fishery specific effort maps, VMS points were assigned to a fishery based on the species with the highest retained catch weight in the logbook during the corresponding logbook fishing time interval. This definition of the fishery is based solely on the main species in the catch and in some cases the main species may differ from the main species targeted.

Filtered VMS points were assigned a "ping time" interval to represent the duration of fishing. This value was calculated as the forward time difference between VMS points. VMS points were aggregated on a  $0.05 \times 0.05$  degree grid and the ping time intervals were summed to represent the hours fished in each cell.

# Sub-task 1.4: Mapping of fishery-specific footprint and the overlap with VMEs

The improved method of coupling VMS and logbook data described in sub-task 1.3 section was used to produce yearly cumulative fishing effort maps together with yearly fisheries-specific effort maps. This analysis was carried out to understand the extent of fishing activities within the NRA and to obtain the distribution of fishing effort of the different fisheries for a seven-year period (2016 to 2022). This characterization was carried out using two data sources: Haul by haul logbook information and Vessel Monitoring System (VMS) data. The method developed for this sub-task was first described by Sacau *et al.*, (2020) and later by Garrido *et al.*, (2023).

# **DEMERSAL FISHERIES**

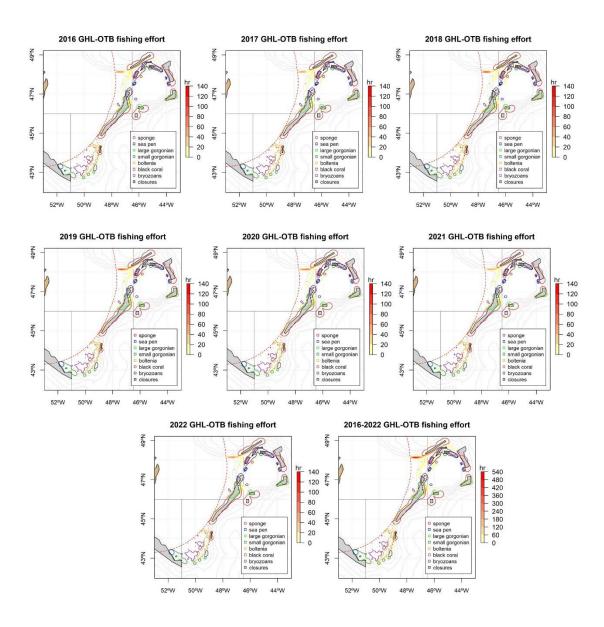
The demersal groundfish fisheries in the NRA for the period 2016-2022 were conducted in Divs. 3LMNO. The semipelagic fisheries of Redfish Divs. 1F2G and of Alfonsino Div. 6G were excluded from this analysis. The demersal groundfish fisheries were separated into different components depending on the main fishing grounds and their target species/stocks identified in the NCEM Annex I.A or I.B and gear. These fisheries were carried out mainly with trawl gear, 89% of the total fishing effort (hr) in the NRA in the period 2016-2022, and to a lesser extent with long lines, 11% of the NRA total fishing effort (hr). To make the different fisheries and cumulative footprint maps, the new merging VMS and logbooks data method, was applied to the 2016-2022 data.

Yearly fishery-specific and cumulative fishing effort maps for 2016 to 2022 and for the whole period (2016-2022) are shown in Figures 3 to 17.

There are two principal demersal trawl fisheries in the NRA that are conducted on widely distributed stocks in the NAFO Regulatory Area: Greenland halibut and Northern squid.

# **Greenland Halibut Trawl 3LMNO (GHL-OTB-3LMNO)**

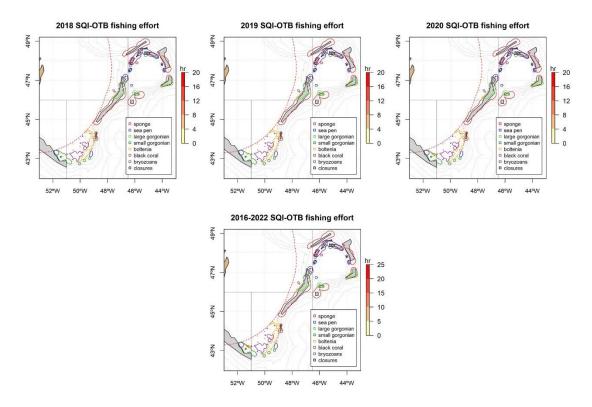
This is one of the main fisheries currently conducted in the NRA. Figure 3 shows the fishery footprint of Greenland halibut in Divs. 3LMNO. This fishery is carried out mainly at depths of 550-1000 m in Divs. 3LMNO using demersal trawl gear with 130 mm codend mesh size. Approximately 29 vessels of different flag states participate in this fishery and the effort represents 32% of the total trawl effort in the NRA. The spatial footprint of this fishery is quite stable from year-to-year. Greenland halibut is the target species (94% of the total catches) and the main by-catch species is Roughead grenadier (1.86%).



**Figure 3**. Greenland halibut Divs. 3LMNO fishery footprint together with the location of the VME polygons in the NRA, colour coded by taxon. Closed areas are indicated in black outline. Fishing activity (from yellow to red) is expressed in hours fished in each cell.

# Northern squid Trawl 3LMNO (SQI-OTB)

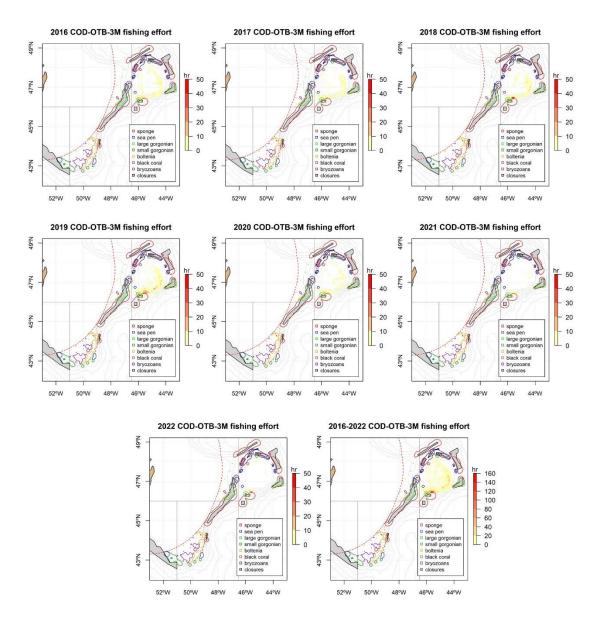
This fishery is conducted sporadically during the second half of the year, depending on the annual availability of the species in the NRA. Figure 4 shows the Northern squid Divs. 3LMNO fishery footprint. In the period 2016-2022 there were only three years (2018, 2019 and 2020) in which a directed fishery for Northern squid occurred. The fishery is carried out mostly at depths of 90-150 m, manly in Divs. 3NO, using demersal trawl gear with 60 mm cod-end mesh size. Records indicate that 14 vessels participate in this fishery and the effort represents 0.3% of the total trawl effort in the NRA. Northern shortfin squid is the target species (81% of the total catches) and the main by-catch species are Silver hake (7.5%), Redfish (3.2%) and Yellowtail flounder (2.7%).



**Figure 4**. Northern squid Divs. 3LMNO fishery footprint together with the location of the VME polygons in the NRA, colour coded by taxon. Closed areas are indicated in black outline. Fishing activity (from yellow to red) is expressed in hours fished in each cell.

# Cod Trawl 3M (COD-OTB-3M)

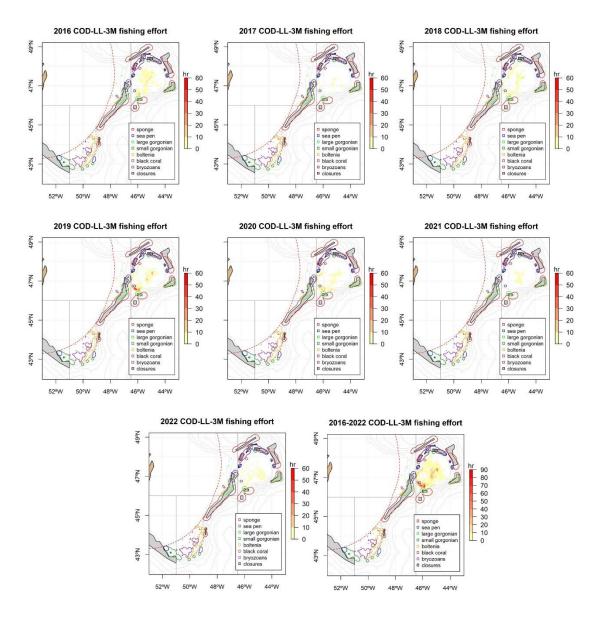
Figure 5 shows the Cod trawl Div. 3M fishery footprint. The fishery is conducted mainly in areas with depths ranging from 150 to 450 m in the south-eastern part of the Flemish Cap bank (Div. 3M) using demersal trawl gear with 130 mm cod-end mesh size. Records indicate that 35 vessels participate in this fishery and the effort represents 8.4% of the total trawl effort in the NRA. Cod is the target species (93% of the total catches) and the main by-catch species are Redfish (4%) and American plaice (1.2%).



**Figure 5**. Cod 3M trawl fishery footprint together with the location of the VME polygons in the NRA, colour coded by taxon. Closed areas are indicated in black outline. Fishing activity (from yellow to red) is expressed in hours fished in each cell.

# Cod longline 3M (COD-LL-3M)

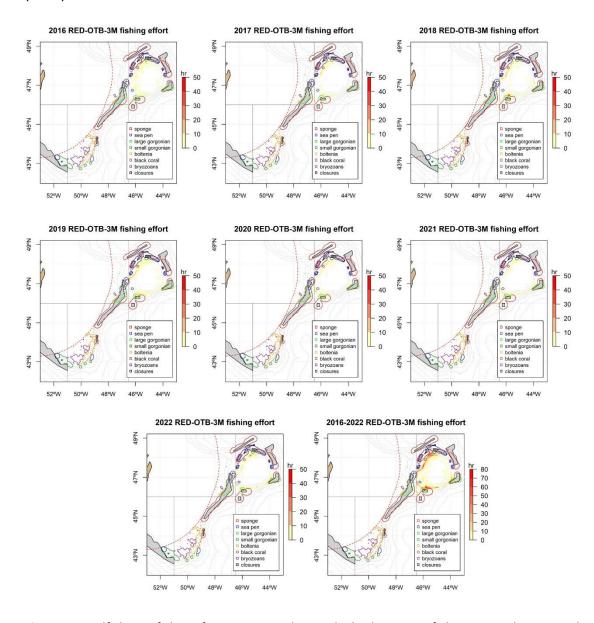
Figure 6 shows the Cod longline Div. 3M fishery footprint which is mainly conducted over areas with depths from 200 to 400 m in the central and south part of the Flemish Cap bank (Div. 3M) with demersal longline gear. The footprint of this fishery is different from that observed in the cod 3M trawl fishery. Records indicate that 22 vessels participate in this fishery and the effort represents 94.3% of the total longline effort in the NRA. Cod is the target species (98.7% of the total catches). By-catch from this fishery is around 1.25% of the total catches.



**Figure 6**. Cod 3M longline fishery footprint together with the location of the VME polygons in the NRA, colour coded by taxon. Closed areas are indicated in black outline. Fishing activity (from yellow to red) is expressed in hours fished in each cell.

# **Redfish Trawl 3M (RED-OTB-3M)**

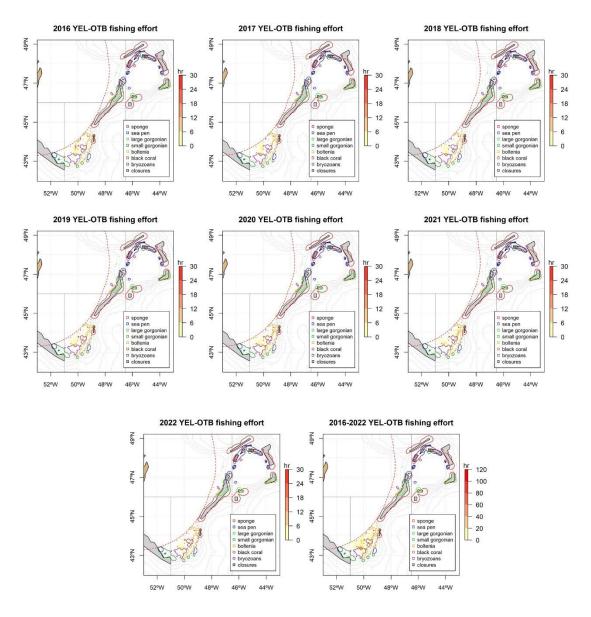
There are three species of Redfish in Division 3M, the deep-sea Redfish (*Sebastes mentella*), Acadian redfish (*Sebastes fasciatus*) and Golden redfish (*Sebastes marinus*) that have been commercially fished and reported collectively as Redfish in fishery statistics. Figure 7 shows the Redfish trawl Div. 3M fishery footprint which is conducted mainly at depths of 250-500 m in Div. 3M using demersal trawl gear with 130 mm codend mesh size. Records indicate that 29 vessels participate in this fishery and the effort represents 9.7% of the total trawl effort in the NRA. Redfish is the target species (92.8% of the total catches) and the main by-catch species are Cod (4.5%) and American plaice (0.9%).



**Figure 7**. Redfish 3M fishery footprint together with the location of the VME polygons in the NRA, colour coded by taxon. Closed areas are indicated in black outline. Fishing activity (from yellow to red) is expressed in hours fished in each cell.

# Yellowtail flounder Trawl 3NO (YEL-OTB-3NO)

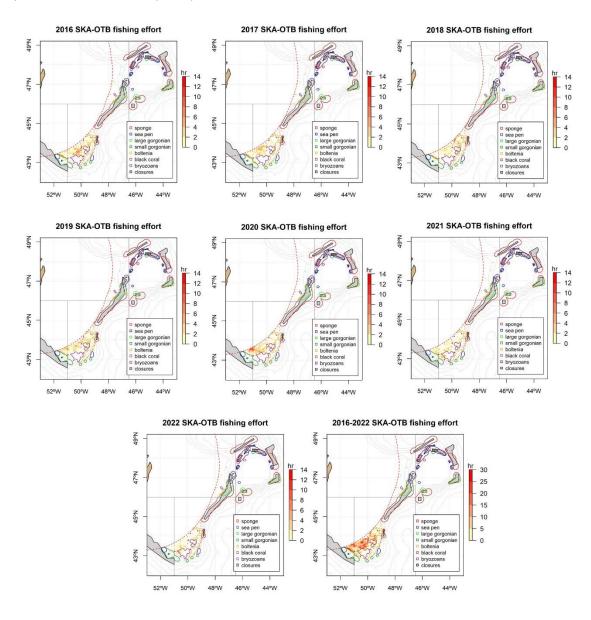
Figure 8 shows the Yellowtail flounder trawl Divs. 3NO fishery footprint which is carried out mainly at depths shallower than 100 m of Divs. 3NO using demersal trawl gear with 130 mm cod-end mesh size. Records indicate that 20 vessels participate in this fishery and the effort represents 2.4% of the total trawl effort in the NRA. Yellowtail flounder is the target species (88.2% of the total catches) and the main by-catch species are American plaice (6%), Skates (2.5%) and Cod (1.1%).



**Figure 8**. Yellowtail flounder 3NO fishery footprint together with the location of the VME polygons in the NRA, colour coded by taxon. Closed areas are indicated in black outline. Fishing activity (from yellow to red) is expressed in hours fished in each cell.

# Skates Trawl 3NO (SKA-OTB-3NO)

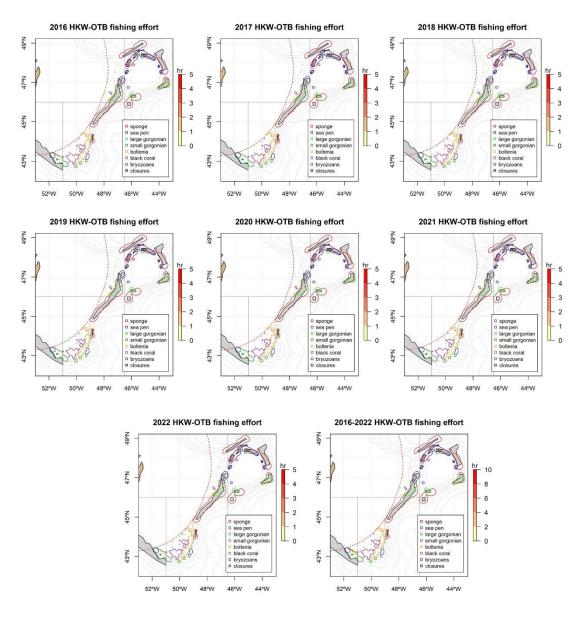
Commercial catches of skates comprise a mix of species (*Amblyraja radiata, Bathyraja spinicauda, Raja hyperborean, Raja senta*, etc). However, Thorny skate (*Amblyraja radiata*) dominates the catches, comprising around 90% of the total. Figure 9 shows the skates trawl NRA Divs. 3NO fishery footprint, conducted mainly at depths shallower than 100 m of Divs. 3NO using demersal trawl gear with 280 mm cod-end mesh size. Records indicate that 26 vessels participate in this fishery and the effort represents 6.6% of the total trawl effort in the NRA. Skates are the target species (85.2% of the total catches) and the main by-catch species are Yellowtail flounder (6%), American plaice (3.5%), Cod (2.8%) and Atlantic halibut (1.1%).



**Figure 9**. Skates 3NO fishery footprint together with the location of the VME polygons in the NRA, colour coded by taxon. Closed areas are indicated in black outline. Fishing activity (from yellow to red) is expressed in hours fished in each cell.

# White hake Trawl 3NO (HKW-OTB)

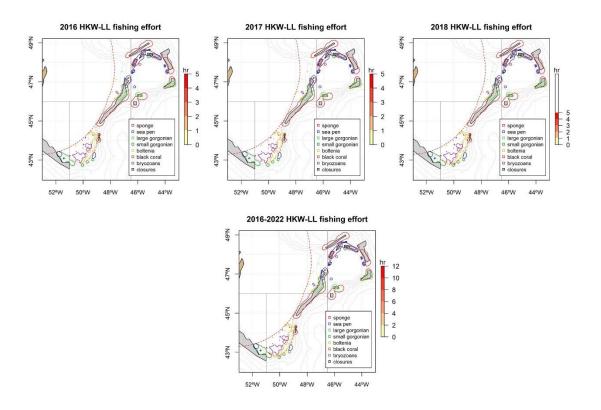
This fishery represents a small percentage of the total effort due to the fact that Divs. 3NO is at the limit of the species distribution and this species appears sporadically in the area. Figure 10 shows the White hake trawl Divs. 3NO fishery footprint. The fishery is carried out mainly at depths between 150-350 m of Divs. 3NO using demersal trawl gear with 130 mm cod-end mesh size. Records indicate that 16 vessels participate in this fishery and the effort represents 0.2% of the total trawl effort in the NRA. White hake is the target species (49.8% of the total catches) and the main by-catch species are Silver hake (17.7%), Redfish (12%) and Witch flounder (5%).



**Figure 10**. White hake 3NO trawl fishery footprint together with the location of the VME polygons in the NRA, colour coded by taxon. Closed areas are indicated in black outline. Fishing activity (from yellow to red) is expressed in hours fished in each cell.

# White hake longline 3NO (HKW-LL)

This fishery represents a small percentage of the total effort because the NRA Divs. 3NO is at the limit of the species distribution and this species appears sporadically in the area. Figure 11 shows the White hake longline Divs. 3NO fishery footprint. The fishery is conducted mainly at depths of 200-350 m in Divs. 3NO using demersal longline gear. Records indicate that 4 vessels participate in this fishery and the effort represents 2.1% of the total longline effort in the NRA. White hake is the target species (59.3% of the total catches) and the main by-catch species are Atlantic halibut (11.9%), Cod (6%), Greenland shark (6%) and Thorny skate (5.7%).



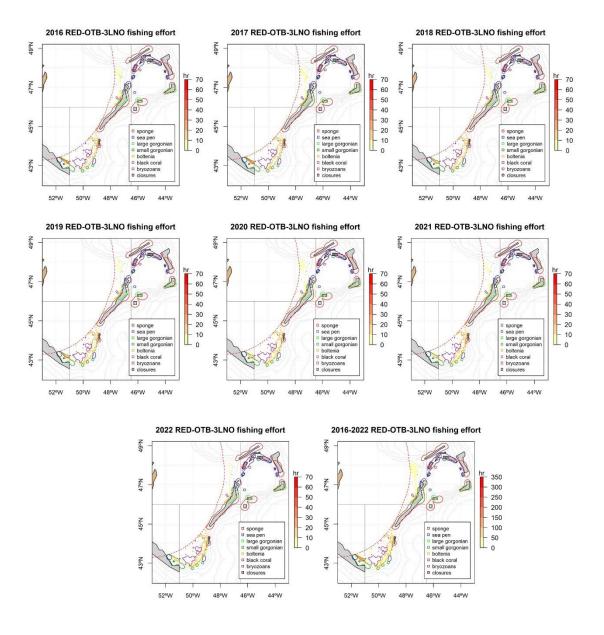
**Figure 11.** White hake 3NO longline fishery footprint together with the location of the VME polygons in the NRA, colour coded by taxon. Closed areas are indicated in black outline. Fishing activity (from yellow to red) is expressed in hours fished in each cell.

# Redfish Trawl 3LN (RED-OTB-3LN)

There are two species of Redfish in Divisions 3L and 3N, the deep-sea Redfish (*Sebastes mentella*) and the Acadian redfish (*Sebastes fasciatus*) that have been commercially fished and reported collectively as Redfish in fishery statistics. Both species are managed as a single stock in Divs. 3LN. Figure 12 shows the Redfish trawl Divs. 3LN fishery footprint, conducted mainly with depths ranging from 250 to 350 m in Divs. 3LN with demersal trawl gear with 130 mm cod-end mesh size. Records indicate that 20 vessels of different flag states participate each year and the effort of this fishery represents 8.5% of the total trawl effort in the NRA. Redfish is the target species (91.4% of the total catches) and the main by-catch species are Cod (2.5%), Atlantic halibut (2.3%) and American plaice (2.15%).

# Redfish Trawl 30 (RED-OTB-30)

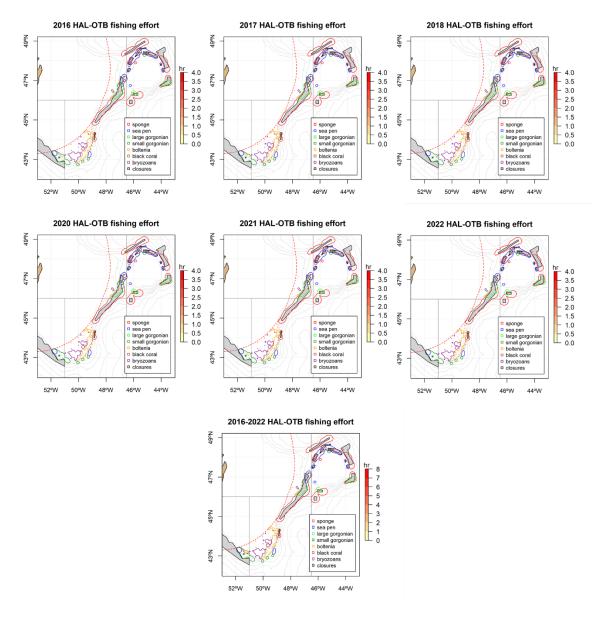
There are two species of Redfish in Division 3O, the deep-sea Redfish (*Sebastes mentella*) and the Acadian redfish (*Sebastes fasciatus*) that have been commercially fished and reported collectively as Redfish in fishery statistics. Both species are managed as a single stock in Div. 3O. Figure 12 shows the Redfish trawl Div. 3O fishery footprint carried out mainly at depths ranging from 200 to 350 m in Div. 3O using demersal trawl gear with 130 mm cod-end mesh size. Records indicate that 18 vessels of different flag states participate each year and the effort of this fishery represents 6.9% of the total trawl effort in the NRA. Redfish is the target species (86.1% of the total catches) and the main by-catch species are Silver hake (3%), American plaice (2.2%), Atlantic halibut (2%) and Cod (1.9%).



**Figure 12**. Redfish 3LNO fishery footprint together with the location of the VME polygons in the NRA, colour coded by taxon. Closed areas are indicated in black outline. Fishing activity (from yellow to red) is expressed in hours fished in each cell.

# **Atlantic halibut Trawl 3LMNO (HAL-OTB)**

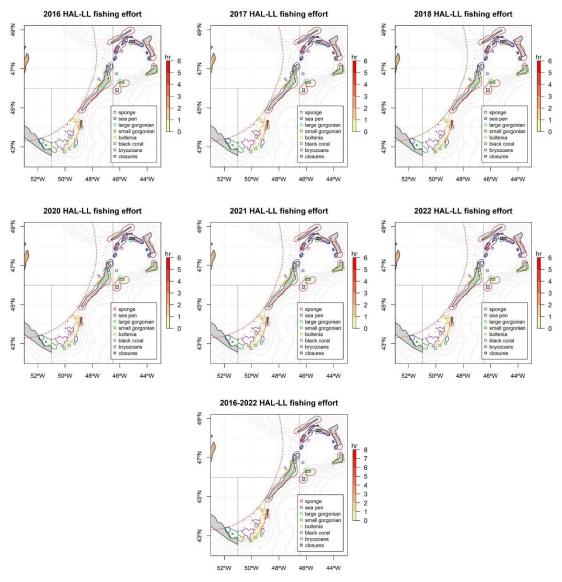
Figure 13 shows the Atlantic halibut trawl NRA footprint carried out mainly at depths ranging from 200 to 400 m in Divs. 3LNO using demersal trawl gear. In 2019 there were not directed trawl hauls to this species. Occasionally trawl hauls targeting this species have been observed in Div. 3M. Records indicate that 20 vessels participate in this fishery and the effort represents 0.2% of the total trawl effort in the NRA. Atlantic halibut is the target species (60% of the total catches) and the main by-catch species are Redfish (14%), White hake (7%), Silver hake (6%) and Witch flounder (4%).



**Figure 13**. Atlantic halibut Divs. 3LMNO trawl fishery footprint together with the location of the VME polygons in the NRA, colour coded by taxon. Closed areas are indicated in black outline. Fishing activity (from yellow to red) is expressed in hours fished in each cell.

# Atlantic halibut Longline 3LMNO (HAL-LL)

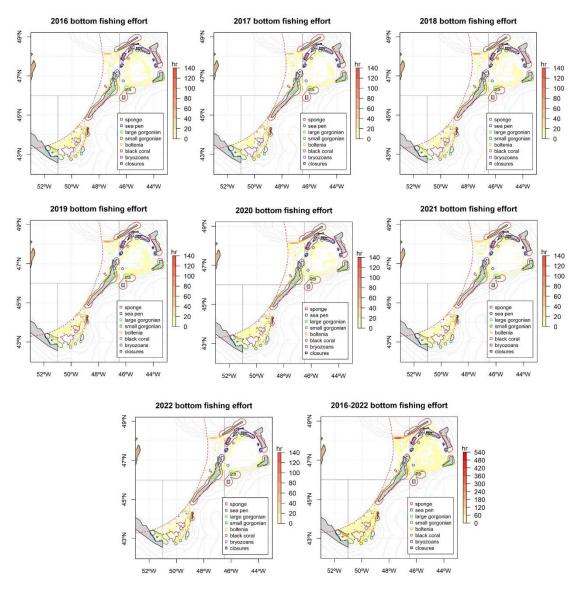
Figure 14 shows the Atlantic halibut longline footprint carried out mainly at depths ranging from 300 to 500 m in Div. 3N using demersal longline gear. In 2019 there were not directed longline hauls to this species. Records indicate that 8 vessels participate each year and the effort of this fishery represents 2.3% of the total longline effort in the NRA. Atlantic halibut is the target species (44.6% of the total catches) and the main bycatch species are Greenland shark (27.6%), Cod (6.5%) and White hake (6.12%).



**Figure 14**. Atlantic halibut Divs. 3LMNO longline fishery footprint together with the location of the VME polygons in the NRA, colour coded by taxon. Closed areas are indicated in black outline. Fishing activity (from yellow to red) is expressed in hours fished in each cell.

# **Cumulative Bottom Trawl fishery footprint**

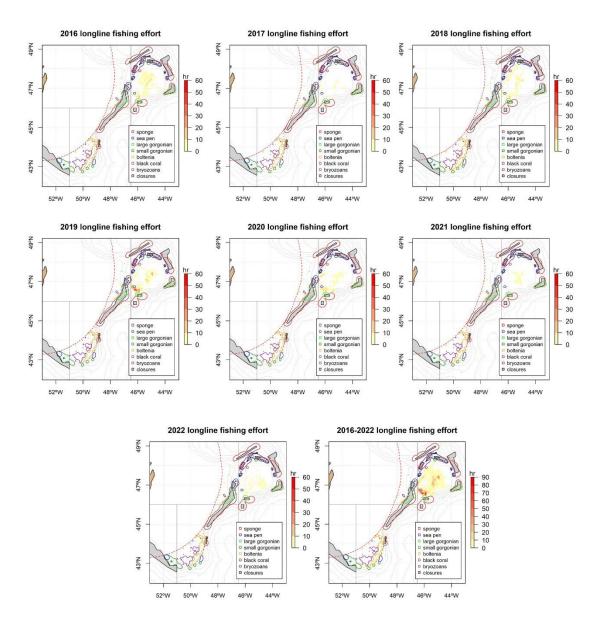
The annual cumulative footprint of the bottom trawl fishery for 2016 to 2022 and for the whole period (2016-2022) is shown in Figure 15.



**Figure 15**. Cumulative bottom trawl fishery footprint together with the location of the VME polygons in the NRA, colour coded by taxon. Closed areas are indicated in black outline. Fishing activity (from yellow to red) is expressed in hours fished in each cell.

# **Cumulative longline fishery footprint**

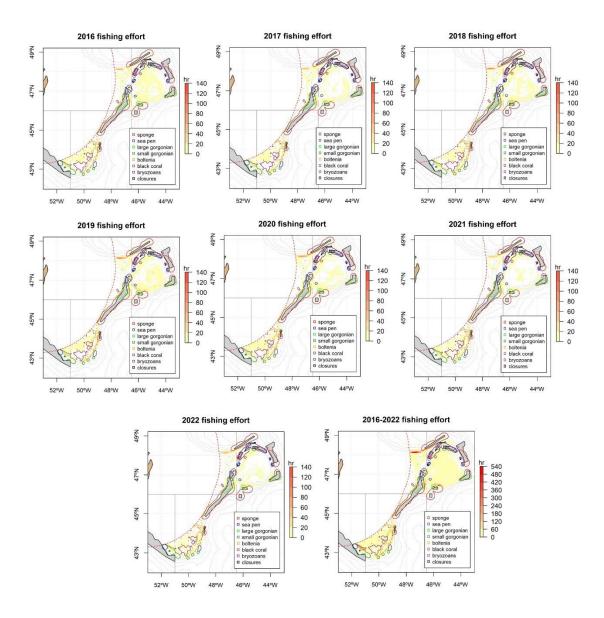
The annual cumulative footprint of the longline fishery for 2016 to 2022 and for the whole period (2016-2022) is shown in Figure 16.



**Figure 16**. Cumulative longline fishery footprint together with the location of the VME polygons in the NRA, colour coded by taxon. Closed areas are indicated in black outline. Fishing activity (from yellow to red) is expressed in hours fished in each cell.

## **Cumulative Bottom Trawl and Longline fishery footprint**

The annual cumulative footprint fishery (Bottom Trawl and Longline) for 2016 to 2022 and for the whole period (2016-2022) is shown in Figure 17.

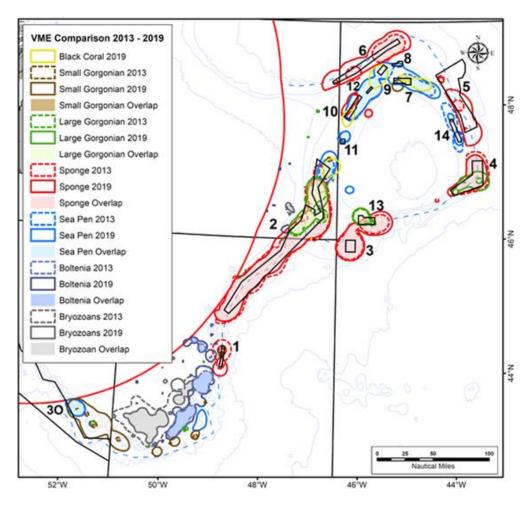


**Figure 17**. Cumulative fishery footprint (Bottom Trawl and Longline) together with the location of the VME polygons in the NRA, colour coded by taxon. Closed areas are indicated in black outline. Fishing activity (from yellow to red) is expressed in hours fished in each cell.

#### **OVERLAP OF DEMERSAL FISHERIES WITH VMEs**

A simple overlay analysis to estimate the area of VME polygons that is overlapped by the 2016 to 2022 cumulative fishing effort and fisheries-specific effort layers was conducted. The fishing effort layers used were calculated with the new "Coupling VMS with Logbook" methodology described in sub-task 1.3.

Figure 18 illustrates the VME polygons generated in 2013 (Kenchington *et al.*, 2014) together with those generated in 2019 (Kenchington *et al.*, 2019) and areas of overlap identified between both years. The overlay analysis done within this section was carried out according to 2019 VME taxa polygons.



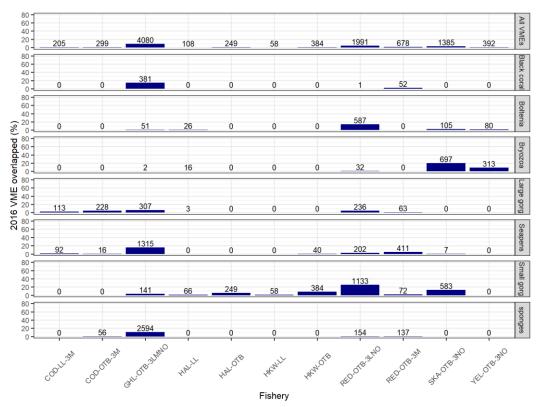
**Figure 18**. Overview map of the location of VME taxa (large-sized sponges, sea pens, small gorgonian corals, large gorgonian corals, erect bryozoans, sea squirts (*Boltenia ovifera*), and black corals) in the NRA, colour coded by taxon. For all taxa the polygons determined from the 2013 analysis are shown in dashed line and compared with those from the 2019 analyses in solid lines. Areas of overlap between both years (2013 and 2019) are shaded. The closed areas are indicated in black outline and their numbers shown near the closure. Dashed blue line is the fishing footprint (NAFO, 2019).

To perform this analysis the following calculations were done: 1) the area (km²) of each of the seven 2019 VME taxa polygons and all VMEs polygons merged; 2) the area (km²) that coincides for all VME combinations, fisheries-specific footprints and cumulative fishing footprint, expressed as the percent VME overlapped by a given fishery. The areas of 2019 VME polygons (km²) are shown in Table 7.

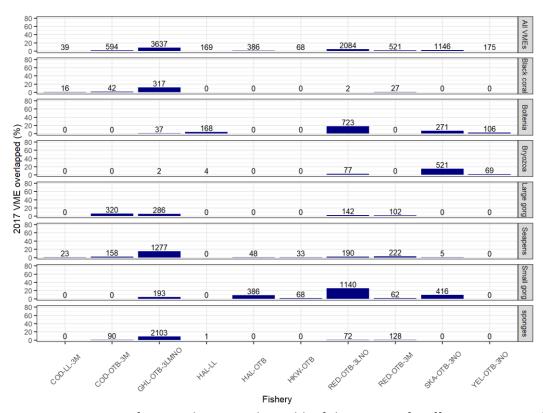
**Table 7**. Area in Km<sup>2</sup> of each of the VME taxa polygons.

2019 VME taxa polygon	Area (km²)
All VME Polygons (merged)	44810.7
Black Corals	2631.1
Boltenia sp.	4076.7
Bryozoans	3491.5
Large Gorgonians	5006.6
Seapens	8497.6
Small Gorgonians	4540.2
Sponges	24217.8

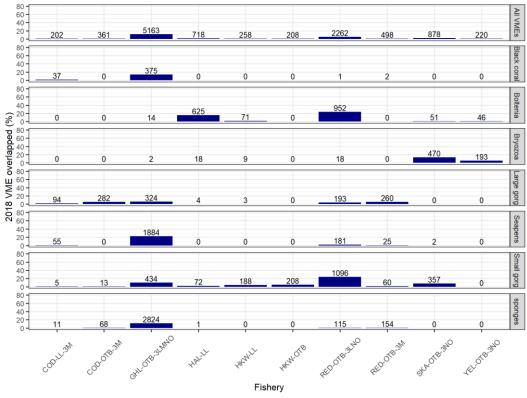
The top panel of the following figures (Figure 19 to Figure 26) represents the area of all VMEs combined, while the bottom seven panels represent the specific VME polygons by taxa. The number on top of each bar indicates the absolute area of VME (km²) that is overlapped by the fishing effort layers. Note that VME polygons are not the same as the VME closure areas.



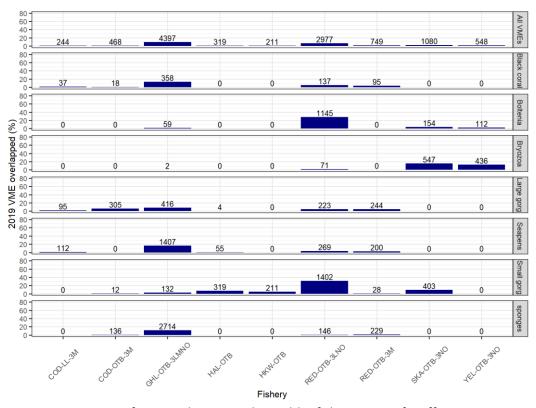
**Figure 19**. Percentage of VME polygon overlapped by fisheries-specific effort areas using the new "Coupling VMS with Logbook" methodology for 2016 year.



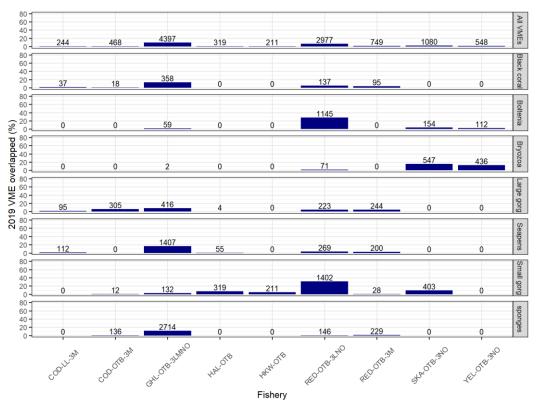
**Figure 20.** Percentage of VME polygon overlapped by fisheries-specific effort areas using the new "Coupling VMS with Logbook" methodology for 2017 year.



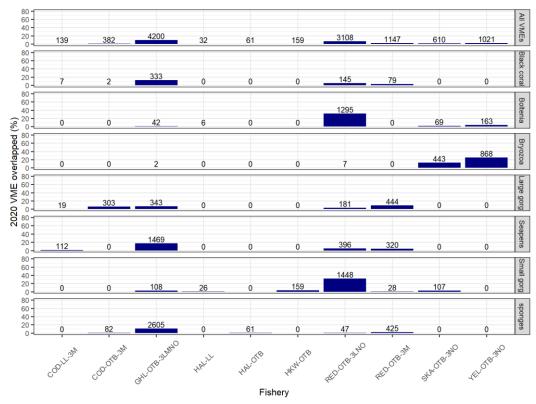
**Figure 21.** Percentage of VME polygon overlapped by fisheries-specific effort areas using the new "Coupling VMS with Logbook" methodology for 2018 year.



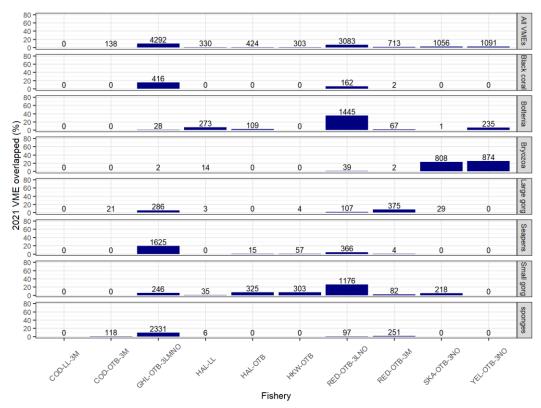
**Figure 22.** Percentage of VME polygon overlapped by fisheries-specific effort areas using the new "Coupling VMS with Logbook" methodology for 2019 year.



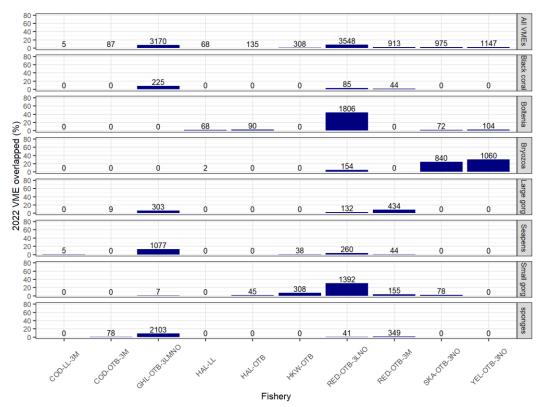
**Figure 23.** Percentage of VME polygon overlapped by fisheries-specific effort areas using the new "Coupling VMS with Logbook" methodology for 2019 year.



**Figure 24.** Percentage of VME polygon overlapped by fisheries-specific effort areas using the new "Coupling VMS with Logbook" methodology for 2020 year.



**Figure 25.** Percentage of VME polygon overlapped by fisheries-specific effort areas using the new "Coupling VMS with Logbook" methodology for 2021 year.



**Figure 26.** Percentage of VME polygon overlapped by fisheries-specific effort areas using the new "Coupling VMS with Logbook" methodology for 2022 year.

Overall, we found that the total VME area was subject to bottom trawl fishing activity in the 7 years considered in this analysis, with an average overlap of 20.1% (see Table 8). The average overlap was lowest for sponges (11.9%), large gorgonians (16.9%) and black coral (17.5%) and increasingly so for sea pens (21.6%), bryozoans (31.7%), Boltenia sp. (33.6%) and small gorgonians (36.1%). There was considerable year-to-year variability in overlap, in terms of the difference between maximum and minimum, for sea pens (from 28.8 % in 2021 to 16.6% in 2022, i.e. 12.2% difference), large gorgonians (from 20.7% in 2020 to 15.1% in 2017, i.e. 5.6% difference), bryozoans (from 53.5% in 2022 to 18% in 2017, i.e. 35.5% difference), Boltenia sp. (from 49% in 2022 to 19% in 2016, i.e. 30% difference), black corals (from 24.5% in 2021 to 12.9% in 2017, i.e. 11.6% difference), small gorgonians (from 41.1% in 2020 to 30.2% in 2016, i.e. 10.9% difference) and sponges (from 14.6% in 2020 to 9.5% in 2017, i.e. 5.1% difference).

**Table 8**. Percentage of VME area overlapped with the cumulative bottom trawl fisheries per year.

Percentage of VME area overlapped (%) with cumulative bottom trawl fisheries								
VME	2016	2017	2018	2019	2020	2021	2022	Average overlap
All VMEs combined	16.9	16	19.5	20	23.6	23.3	21.5	20.1
Black Corals	14.5	12.9	14.4	20.4	22	24.5	13.5	17.5
Boltenia sp.	19	27.3	26.1	34.6	37.3	41.8	49	33.6
Bryozoans	24.4	18	19.5	24.1	36.7	45.9	53.5	31.7
Large gorgonians	15.4	15.1	15.9	18	20.7	15.8	17.3	16.9
Seapens	19.3	17.6	24.3	19.9	24.6	28.8	16.6	21.6
Small gorgonians	30.2	32.1	37.2	34.6	41.1	40.4	36.9	36.1
Sponges	11.9	9.5	12.7	13.1	14.6	11	10.4	11.9

Concerning cumulative longline fisheries, it was found that the total VME area was subject to longline fishing activity in the 7 years considered in this analysis, with an average overlap of 0.9% (see Table 9). The average overlap was lowest for bryozoans (0.3%), small gorgonians (0.9%), large gorgonians (1%) and seapens (1%) and increasingly so for black corals (1.4%), sponges (1.4%) and Boltenia sp. (4.3%). There was considerable year-to-year variability in overlap, in terms of the difference between minimum and maximum, for sea pens (from 3.5 % in 2020 to 0% in 2021, i.e. 3.5% difference), large gorgonians (from 2.3% in 2016 to 0% in 2017 and 2022, i.e. 2.3% difference), bryozoans (from 0.8% in 2018 to 0% in 2019 y 2020, i.e. 0.8% difference), Boltenia sp. (from 6.7% in 2021 to 0% in 2019, i.e. 6.7% difference), small gorgonians (from 6.1% in 2020 to 0% in 2016, 2021 and 2022 i.e. 6.1% difference), small gorgonians (from 4.8% in 2018 to 0% in 2019 and 2022 i.e. 4.8% difference). The overlap with sponges was zero throughout the time series considered (2016 to 2022).

**Table 9**. Percentage of VME area overlapped with the cumulative longline fisheries per year.

Percentage of VME area overlapped (%) with cumulative longline fisheries								
VME	2016	2017	2018	2019	2020	2021	2022	Average overlap
All VMEs combined	0.8	0.5	2.5	0.5	0.8	0.7	0.2	0.9
Black Corals	0	0.6	1.4	1.4	6.1	0	0	1.4
Boltenia sp.	0.6	4.1	17	0	0.2	6.7	1.7	4.3
Bryozoans	0.5	0.1	0.8	0	0	0.4	0.1	0.3
Large gorgonians	2.3	0	2	1.9	0.4	0.1	0	1
Seapens	1.1	0.3	0.6	1.3	3.5	0	0.1	1
Small gorgonians	2.2	0.5	4.8	0	0.6	0.8	0	0.9
Sponges	0	0	0	0	0	0	0	1.4

In general terms (see Figure 19 to Figure 26) the four fisheries that have had the greatest degree of overlap with specific KDE VME polygons are indicated in Table 10:

**Table 10**. Fisheries with the highest percentage of KDE VME polygons overlapped (% of area overlapped is expressed for each year).

Fishery	Year	KDE VME polygon	Percentage of area overlapped (%)
	2016		15.5
	2017		15
Greenland Halibut	2018		22.2
Trawl 3LMNO	2019	Seapens	16.6
(GHL-OTB-3LMNO)	2020		17.3
	2021		19.1
	2022		15.5
	2016		25
	2017		25.1
Redfish Trawl 3LN	2018		24.1
(RED-OTB-3LNO)	2019	Small Gorgonians	30.9
(KED-OTB-SLINO)	2020		31.9
	2021		25.9
	2022		30.7
	2016		20
	2017		14.9
Skates Trawl 3NO	2018		13.5
(SKA-OTB-3NO)	2019	Bryozoans	15.7
(314-016-3110)	2020		12.7
	2021		23.1
	2022		24.1
	2016		9
	2017		2
Yellowtail flounder	2018		5.5
Trawl 3NO	2019	Bryozoans	12.5
(YEL-OTB-3NO)	2020		24.8
	2021		25
	2022		30.4

#### **REFERENCES OF TASK 1**

Campanis, G., Thompson, A., Fischer, J. and Federizon, R. (2008). The Geographical Distribution of the High-Seas Commercial Greenland Halibut Fishery in the Northwest Atlantic. NAFO SCR Doc. 08/01. Serial No. N5483

Campbell, N. and Federizon, R. (2013). Estimating fishing effort in the NAFO regulatory area using vessel monitoring system data. NAFO SCR Doc. 13/001. Serial No. N6144

Garrido I., Sacau M., Durán-Muñoz P., Baldó F., González-Costas F., González-Troncoso, D. (2023). Update on the analysis of VMS and Logbook data to study the bottom

- fishing footprint in the NAFO Regulatory Area: NEREIDA project. NAFO SCR Doc. 23/056. Serial No. N7486. <a href="https://www.nafo.int/Portals/0/PDFs/sc/2023/scr23-056.pdf">https://www.nafo.int/Portals/0/PDFs/sc/2023/scr23-056.pdf</a>.
- Kenchington E, Murillo FJ, Lirette C, Sacau M, Koen-Alonso M, Kenny A, et al., (2014).
  Kernel density surface modelling as a means to identify significant concentrations of vulnerable marine ecosystem indicators. PLoS One 9:e109365.
  https://doi.org/10.1371/journal.pone.0109365
- Kenchington, E., Lirette C., Murillo, .FJ., Beazley, L., and Downie, A.-L. (2019). Vulnerable Marine Ecosystems in the NAFO Regulatory Area: Updated Kernel Density Analyses of Vulnerable Marine Ecosystem Indicators. NAFO SCR Doc. 19/058. Serial No. N7030. https://www.nafo.int/Portals/0/PDFs/sc/2019/scr19-058.pdf
- NAFO (2015). Report of the 8<sup>th</sup> Meeting of the NAFO Scientific Council (SC) Working Group on Ecosystem Science and Assessment (WGESA) [Formerly SC WGEAFM]. NAFO SCS Doc. 15/19. Serial No 6549. 176 pp.
- NAFO (2017). Report of the 10<sup>th</sup> Meeting of the NAFO Scientific Council (SC) Working Group on Ecosystem Science and Assessment (WGESA). NAFO SCS Doc. 17/21. Serial No N6774.
- NAFO (2018a). Report of the 11<sup>th</sup> Meeting of the NAFO Scientific Council Working Group on Ecosystem Science and Assessment (WGESA). NAFO SCS Doc. 18/23. Serial No. N6900.
- NAFO (2018b). Report of the NAFO Joint Commission-Scientific Council Catch Estimation Strategy Advisory Group (CESAG) Meeting. NAFO COM-SC Doc. 18-01. Serial No. N6814
- NAFO (2019). Report of the 12<sup>th</sup> Meeting of the NAFO SC Working Group On Ecosystem Science And Assessment (WGESA) November 2019. NAFO SCS Doc. 19/25. Serial No. N7027.
- NAFO (2024a). Report of the 2024 NAFO Scientific Council Meeting. SCS Doc. 24/16. Serial No. N7556
- NAFO (2024b). NAFO Conservation and Enforcement Measures 2024. NAFO/COM Doc. 24-01. Serial No. N7490.
- R Core Team (2023). R: A language and environment for statistical computing. R Foundation for Statistical Computing. Vienna. Austria. URL https://www.R-project.org/.
- Sacau M., Durán-Muñoz P., Garrido I. and Baldó F. (2020). Improvements in the methodology to study the bottom fishing footprint in the NRA using VMS and logbook data. NAFO SCR Doc. 20/069. Serial No. N7145. <a href="https://www.nafo.int/Portals/0/PDFs/sc/2020/scr20-069.pdf">https://www.nafo.int/Portals/0/PDFs/sc/2020/scr20-069.pdf</a>
- Thompson, A.B. and Campanis, G.M. (2007). Information on Fishing On and Around the Four Closed Seamount Areas in the NRA. NAFO SCR Doc. 07/06. Serial No. N5347.
- WGDEC (2008). Report of the ICES-NAFO Joint Working Group on Deep Water Ecology (WGDEC), 10–14 March 2008, Copenhagen, Denmark. ICES CM 2008/ACOM:45. 126 pp. http://www.ices.dk/reports/ACOM/2008/WGDEC/WGDEC 2008.pdf

#### **ANNEXES OF TASK 1**

#### ANNEX 1 - NAFO SCR Document

Garrido I., Sacau M., Durán-Muñoz P., Baldó F., González-Costas F., González-Troncoso, D. (2023). Update on the analysis of VMS and Logbook data to study the bottom fishing footprint in the NAFO Regulatory Area: NEREIDA project. NAFO SCR Doc. 23/056. Serial No. N7486. <a href="https://www.nafo.int/Portals/0/PDFs/sc/2023/scr23-056.pdf">https://www.nafo.int/Portals/0/PDFs/sc/2023/scr23-056.pdf</a>

## ANNEX 2 - Presentation at the NAFO Scientific Council meeting (June 2024)

Sacau M., Garrido I., Baldó F., González-Troncoso D., González-Costas F., Durán Muñoz, P. (2024). Update on the analysis of VMS and Logbook data to study the bottom fishing footprint in the NAFO Regulatory Area. Nereida Task 1. NAFO Scientific Council meeting June 2024. Oral communication.

# <u>TASK 2</u>. Activities other than fishing in the NAFO Regulatory Area (Divs. 3LMNO): Seabed litter.

#### **INTRODUCTION**

The United Nations Environment Programme (UNEP) defines marine litter as "any persistent, manufactured or processed solid material discarded, disposed or abandoned in the marine and coastal environment". Nowadays, marine litter has been recognized as a worldwide problem affecting the marine environment in several ways such as economic loss, degradation of habitats and impact on biota (Pham et al., 2014). The large quantities of litter reaching the deep ocean floor is a major issue worldwide, yet little is known about its sources, patterns of distribution, abundance and, particularly, impacts on the habitats and associated fauna (UNEP, 2009). Benthic habitats and ecosystems, such as the Vulnerable Marine Ecosystems (VMEs) (FAO, 2009), may be therefore affected or damaged by marine litter (Pham et al., 2014, Canals et al., 2021 and references therein), as the sea bottom is considered a long-term sink for marine litter (Woodall et al., 2014; Egger et al., 2020; Kaandorp et al., 2020).

Marine litter is also a matter of concern for the NAFO Commission and Scientific Council (e.g. NAFO Commission Request #93). To address the concerns about seabed litter in NAFO Regulatory Area (NRA), the Spanish Institute of Oceanography (IEO) started to monitor in year 2006 the spatial and temporal distribution of seabed macrolitter<sup>4</sup> in the Flemish Pass (Division 3L) using data from the EU-Spain groundfish surveys (Durán Muñoz et al., 2020). A pilot study was conducted in Division 3L by analysing an extensive seabed macrolitter database from years 2006-2017 (see García-Alegre et al., 2020). Based on that study, NAFO WGESA<sup>5</sup> recommended to Scientific Council that standardized protocols for marine litter data collection should be implemented by all Contracting Parties as part of their groundfish surveys conducted in the NRA, to facilitate the on-going monitoring and assessment of seabed litter (NAFO, 2019). The preliminary protocol was first implemented in Divs. 3LNO (2018) and Div. 3M (2019) as a pilot experiment, and its application continues to date, providing new records on seabed macrolitter. These records are available in the IEO database and can help to respond to the NAFO Commission Request #9 on seabed litter, by providing updates on the spatial and temporal distribution of seabed macrolitter in the NRA. In addition, further work is needed to improve and standardise methods for collecting seabed macrolitter during the EU groundfish surveys. In this report, the seabed litter we analyzed falls under the category of seabed macrolitter. Therefore, when we refer to seabed litter throughout this report, we are specifically referring to seabed macrolitter that is collected during groundfish surveys.

 $<sup>^2\,\</sup>underline{\text{https://www.unep.org/topics/ocean-seas-and-coasts/regional-seas-programme/marine-litter}}$ 

<sup>&</sup>lt;sup>3</sup> **COM Request #9** (2024): "The Commission requests the SC to monitor and provide regular updates on relevant research related to the potential impacts of activities other than fishing in the Convention Area, subject to the capacity of the Scientific Council" (NAFO, 2024).

<sup>&</sup>lt;sup>4</sup> The terms, macro-, meso- and microlitter are defined respectively as objects larger than 25 mm, which are visible from greater distances; items between 25 and 5 mm, requiring specific methods for standardised sampling; and particles smaller than 5 mm (MSFD GES Technical Subgroup on Marine Litter, 2011).

<sup>&</sup>lt;sup>5</sup> NAFO Working Group on Ecosystem Science and Assessment (WGESA).

#### **OBJECTIVE OF TASK 2**

The aim of Task 2 is to continue the pilot study by García-Alegre *et al.*, 2020 by extending the analysis temporally in Flemish Pass (Div. 3L) and spatially to other areas sampled by EU groundfish surveys: Flemish Cap (Div. 3M) and the Grand Banks (Divs. 3NO). The specific objectives of this research, focused on large debris (i.e. macrolitter), were: (i) to improve the current protocol for seabed litter data collection, (ii) characterize marine seabed litter on the seabed in these regions, (iii) analyze the spatial distribution of seabed litter in Divs. 3LMNO, (iv) determine the main seabed litter sources, and (v) as far as possible, analyse the potential drivers of seabed litter distribution.

This was in response to a request from the NAFO Commission to continue to monitor and provide updates resulting from relevant research related to the potential impact of activities other than fishing (e.g. COM Request #9). A summary of this information was presented to the Scientific Council during the June 2024 meeting (Abalo-Morla *et al.*, 2024).

#### MATERIAL AND METHODS

#### Survey data

Seabed litter data used in this study were collected and gathered from 3 different European groundfish surveys<sup>6</sup>, conducted on board R/V *Vizconde de Eza* between late spring and summer during 2018 – 2023 (Table 1; Figure 1):

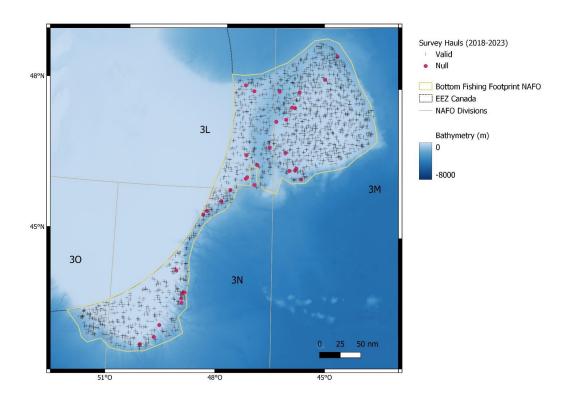
- 1. The EU-Spain 3L groundfish survey, conducted by the Instituto Español de Oceanografía (IEO, CSIC), sampled Div. 3L with a total of 298 tows (291 valid). The gear used in Division 3L was the Campelen 1800 otter trawl net (McCallum and Walsh 1994; Walsh *et al.*, 2001). Depth ranged between 116- 1491 meters. Due to the pandemic COVID-19, during 2020 and 2021 surveys were not conducted in Division 3L. During 2022 the survey was not conducted due to technical issues.
- 2. The EU-Spain and Portugal Flemish Cap groundfish survey, conducted by the Instituto Español de Oceanografía (IEO, CSIC), together with the Instituto de Investigaciones Marinas (IIM, CSIC), and Instituto Português do Mar e da Atmosfera (IPMA), sampled the Flemish Cap (NAFO Div. 3M), with a total of 1101 tows (1087 valid). In Division 3M the bottom trawl gear type used was the Lofoten (Vázquez et al., 2014). Depth ranged between 128 1470 meters.
- 3. The EU-Spain 3NO groundfish survey, conducted by the Instituto Español de Oceanografía (IEO, CSIC), sampled the Grand Bank of Newfoundland (NAFO Divs. 3NO), with a total of 570 tows (558 valid). The bottom trawl gear used in Divisions 3NO was the same as that used in Div. 3L (Campelen 1800 gear type). Depth ranged between 40 1460 meters. Due to the pandemic COVID-19, survey during 2020 there was not conducted in Divisions 3NO.

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<sup>&</sup>lt;sup>6</sup> These surveys are relevant to provide key data on the presence, distribution, and abundance of seabed litter. Although they are primarily intended for fisheries stock assessment, other ancillary ecosystem information is also collected, such as data on Vulnerable Marine Ecosystems indicator species, or seabed litter, which the earliest records dating back to as early as 2006.

**Table 1**. Summary of sampling: years with survey ( $\checkmark$ ); years without survey ( $\ast$ ). Reasons for not conducting the survey were: COVID-19 pandemic (\*) technical issues (\*\*).

	2018	2019	2020	2021	2022	2023
Div. 3L	✓	✓	**	<b>*</b> *	×**	✓
Div. 3M	✓	✓	✓	✓	✓	✓
Divs. 3NO	✓	✓	**	✓	✓	✓



**Figure 1.** Valid (black crosses) and null tows (pink points) conducted during the European groundfish surveys from 2018 to 2023. The bathymetry (in blue scale), the boundaries of the bottom fishing footprint in the NAFO NRA (yellow line), the Canadian Economic Exclusive Zone (EEZ) (dashed black line) and the NAFO Divisions (grey line) are also shown.

### Seabed litter data collection

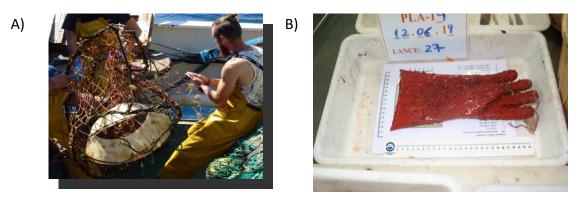
According to the current protocol for seabed litter data collection, after each haul, all collected and retained items by the bottom trawl gear were examined, categorized, counted, weighed, sized, photographed, and recorded on board the research vessel. Any evidence regarding the source of the litter was also noted. For each haul, the trawl gear characteristics, location, date, time, and depth at the start and end of each trawl are also recorded, among other general information.

## <u>Sub-task 2.1: Cross-check groundfish survey data collection forms with the seabed</u> litter database

Litter items retained in the bottom trawl hauls are examined and recorded onboard using the aforementioned standardized seabed litter monitoring protocol. All these data are recorded, by scientists onboard the research vessel, in the corresponding paper data collection form. The objective of this sub-task was to ensure that seabed litter database is revised and according to the records existing on the onboard log sheet forms. To achieve this purpose, a cross-check of the groundfish survey data collection forms with the database for the period 2018-2023 was carried out to ensure that seabed litter database did not contain any typographical errors, in which case they were removed or corrected. Additionally, a comprehensive review, update and standardization of the list of seabed litter categories and codes existing in the database was performed to obtain a standardized master file. That master file contains all the updated categories and specific codes of the records collected to date by the IEO in the NRA. As a result, a revised seabed litter database was obtained, according to onboard forms, and according to the existing seabed litter categories and codes.

## Sub-task 2.2: Cross-check seabed litter database with photo records

Once the seabed litter database was cross-checked with data collection forms, another cross-check exercise was performed against the photo records (Figure 2) to ensure that all the items matched the records in the database. The criteria for counting seabed litter items was done as described in the ICES Manual for Seafloor Litter Data Collection (ICES, 2022). In case of discrepancies between the database and the photograph of the seabed litter item, each record was reviewed and corrected accordingly, assigning the corresponding code in each case. Additionally, whenever the photo quality allowed, more detailed litter codes were assigned to those records initially categorized in more general categories (i.e., a general plastic record was reassigned to a specific plastic bag code). Besides, according to ICES, litter that arises from the survey itself, such as items released from the gear or the vessel during the trawl (e.g., cod-end strings, pieces of net, plastic floats from the trawl gear), were excluded from the analysis (ICES, 2022). As a result, a cross-checked seabed litter database was obtained according to photographic records. Once sub-tasks 2.1 and 2.2 were completed, the database was ready to conduct the next sub-tasks, which are described as follows.



**Figure 2.** Examples of photographic records of seabed litter collected during the EU Groundfish Surveys: A) fishing pot; and B) rubber gloves.

## <u>Sub-task 2.3: Mapping and analysis of composition and spatial distribution of the</u> seabed litter

This sub-task analysed the cross-checked seabed litter database obtained as a result in the sub-tasks 2.1 and 2.2. The analysis of the database provided results that summarize the information on seabed litter (e.g. composition, categories, occurrence, source, density, etc.) in the NRA (Divs. 3LMNO) from data collected during 2018-2023. Moreover, mapping of seabed litter was conducted using QGIS software in order to:

- i) Locate the hauls with absence and presence of litter in the trawl gear and the percentage of presence of litter in the hauls by sampling strata.
- ii) Show the distribution of litter, by haul and by strata, helping to identify possible seabed litter accumulations hot spots.

In order to simplify the analysis, the different seabed litter items (categories) recorded were classified into seven litter group categories based on their material composition, degradability and original activity or use, namely: Plastics, Rubber, Metal, Fisheries related litter, Glass/Ceramics, Organic litter and Other anthropogenic litter (Modified from OSPAR, 2007; and ICES, 2022). The latter included processed wood, textiles, paper/cardboard, clothing, refractory material (with alumina), ropes made of natural fibers, and other anthropogenic litter not fitting into the other litter group categories. Fisheries derived items (i.e. pieces of longlines, nets, bobbins, floats, pots, hooks) were incorporated into a separated group category, as done in previous research (Pham *et al.*, 2014; Lopez-Lopez *et al.*, 2017; García-Alegre *et al.*, 2020). Additionally, it was determined whether synthetic ropes and/or entangled monofilaments could be associated with fisheries or not, and were accordingly assigned to the pertaining litter group category.

To obtain seabed litter densities haul data were standardized as density per square km (both by number of seabed litter items and weight) and represented for each trawl and year and averaged for sampling strata, according to the NAFO stratification scheme (Doubleaday, 1981). These density values were calculated by the swept area, obtained by multiplying the distance trawled by the net and the estimated horizontal opening (Campelen 1800 swept area in Divs. 3LNO; see García-Alegre *et al.*, 2020) or by the haul path estimated by haul locations (Lofoten swept area in Div. 3M).

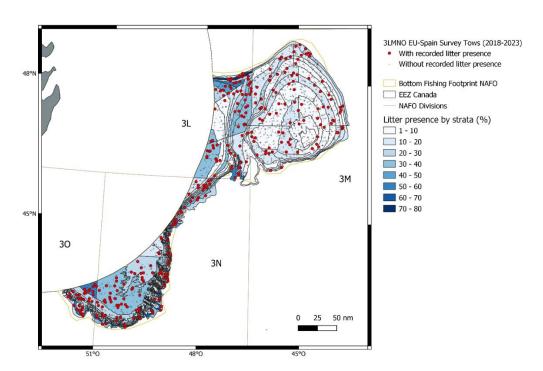
Additionally, available spatial information about bottom fisheries effort (both regulated by NAFO and by the coastal State, Canada) was compiled. Cumulative fishing effort of groundfish fisheries operating in the NRA during 2016-2022 was obtained from the NEREIDA Task 1 (Garrido et al., 2023). Spatial data on queen-snow crab fisheries overlapping with NAFO NRA bottom fisheries footprint was obtained from Statistical Services, Fisheries and Oceans Canada (DFO), and consists of commercial landings data https://gisp.dfofrom 2012 2021. Data is available at: mpo.gc.ca/arcgis/rest/services/FGP/Eastern Canadian Commercial Fishing/MapServe r//24. The analysis of the cross-checked and revised seabed litter database revealed the occurrence, characterization and the spatial distribution of seabed litter in the NRA (Divs. 3LMNO) during 2018-2023. The main achievements are described as follows:

### Occurrence and characterization of seabed litter

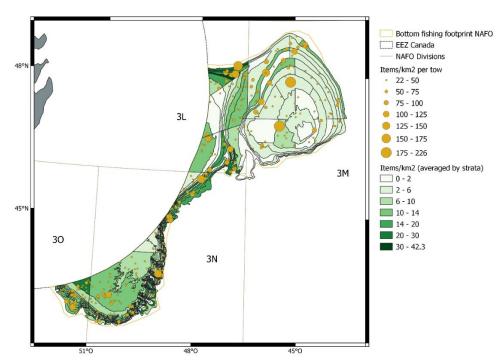
Litter debris was found in a total of 16.7% of the valid trawls performed (Figure 1), accounting for a total of 528 litter items. Plastic and fishing related litter items were the most frequently found in hauls. In most cases fishing-related litter consisted of small fragments of rope and entangled monofilaments, followed by fragments of fishing gear (e.g. hooks, lines, pieces of net, bobbins, floats) or entire fishing gears (e.g. pots, nets). Plastic accounted for 63.6% of the litter items recorded, whilst metal accounted for 12.9% of the total. Remnants of fishing gear (7.8%), organic litter (4.4%), rubber (1.7%) and glass/ceramics (0.4%) were the least common. Items classified as "other anthropogenic litter" accounted for 8.3% of the litter items encountered in sites surveyed and included processed wood, paper/cardboard, clothing, alumina-based refractory material, ropes made using natural fibers, and other uncategorized anthropogenic litter.

#### Spatial distribution of seabed litter

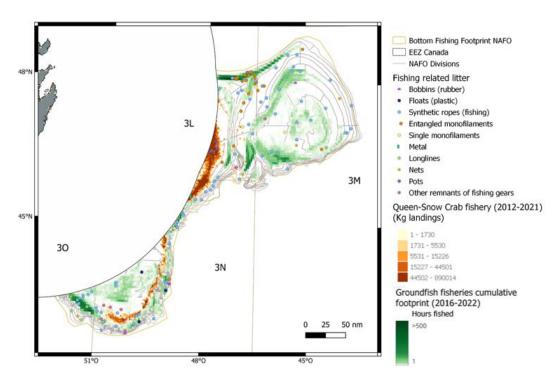
Mapping of seabed litter was conducted to identify possible litter accumulation hotspots. In terms of litter occurrence (Figure 3) and density of marine litter items by haul and by strata (items/km<sup>2</sup>) (Figure 4), the highest densities were found in Divisions 3LNO, mainly on the slopes of the Grand Banks of Newfoundland, and on the northern slopes of the Sackville Spur and southern slopes of Flemish Pass. The spatial distribution of fishing related litter showed that most records of fishing related items might be associated with areas of higher fishing effort, particularly on the northern slopes of the Flemish Pass and the south-western slopes of the Grand Banks of Newfoundland (Figure 5). An uneven distribution of fishing related items was recorded. Although synthetic ropes related with fishing activities were evenly distributed along the Flemish Cap, on the Flemish Pass and the Grand Banks of Newfoundland were mainly recorded on the slopes. Similar distribution was recorded to entangled monofilaments and single monofilaments, but these records were always recorded nearby or on the area covered by the cumulative fisheries effort of the groundfish fisheries. There are few records of bobbins and floats along the study area, both on slopes and plains, but always nearby the areas where groundfish fisheries operates. Few records of nets were located on the south and east of Flemish Cap and Flemish Pass, and in the slopes of the southwestern part of the Grand Banks (Division 30). Longlines were mainly recorded on the slope of the southwest part of the Grand Banks (Division 30), two of them close to the areas operating longline groundfish fisheries. Other remnants of fishing gears were mainly recorded on the southwestern part of the Grand Banks (Division 3N), close to the queensnow crab fishery and the groundfish fisheries operating areas. Pots were found in the western part of the Flemish Pass, close to the Canadian EEZ, over the areas with the highest landing recordings of the queen-snow crab fishery. Therefore, in Division 3L fishery-related litter items were identified as being associated with both NAFO managed and non-managed fishing activities, in accordance with the pilot study (García-Alegre et al., 2020).



**Figure 3.** Occurrence of seabed litter during the EU Surveys conducted in the NRA during 2018-2023. Hauls with litter presence (red points) and hauls with no recorded litter (black crosses) are shown. In the background the percentage of tows with litter presence by sampling strata (according to the NAFO scheme) is shown (in blue scale). The boundaries of the bottom fishing footprint in the NRA (yellow line), the Canadian Economic Exclusive Zone (EEZ) (dashed black line) and the NAFO Divisions (grey line) are also shown.



**Figure 4**. Litter densities (number of items/km²) per tow (yellow points) and averaged by sampling strata (in green scale) recorded during the scientific bottom trawl surveys conducted in the NRA during 2018-2023.



**Figure 5.** Spatial distribution of fishing related litter by items. The cumulative fishing effort of groundfish fisheries operating in the NRA during 2016-2022 (green scale; NEREIDA Task 1) and the effort of the queen-snow crab fisheries (orange scale) are displayed. Data on queen-snow crab fisheries was obtained from Statistical Services, Fisheries and Oceans Canada (DFO) and consists of commercial landings data from 2012 to 2021. Each cell in a 2-minute hexagonal grid (approx.  $10 \text{km}^2$  cell) shows the total weight (kg) of landings summed over the ten-year period. The boundaries of the sampling strata (light grey lines), the boundaries of the bottom fishing footprint in the NAFO NRA (yellow line), the Canadian Economic Exclusive Zone (EEZ) (dashed black line) and the NAFO Divisions (grey line) are also shown.

Although updated information on composition and distribution of seabed litter in the NRA was obtained from the analysis, due to the late start of the contract caused by administrative issues beyond the control of the IEO, the analysis to identify the main sources of seabed litter, as well as the potential drivers of seabed litter distribution in the NRA has not been completed, and it is expected to be presented during the upcoming WGESA meeting scheduled for November 2024.

## <u>Sub-task 2.4: Review of the current standardized protocol for collection of seabed litter data in the EU groundfish surveys</u>

Regarding the current global concern about the importance of monitoring marine litter in a standardized way, the European bottom trawl groundfish surveys conducted within the NRA are relevant to provide key data on the presence, distribution, and abundance of seabed litter of the Flemish Cap (Div. 3M), the Flemish Pass (Div. 3L), and the Grand Banks of Newfoundland (Div. 3NO). Although these surveys are primarily intended for fisheries stock assessment, other ancillary ecosystem information is also collected, such as data on Vulnerable Marine Ecosystems indicator species, or seabed litter, which the earliest records dating back to as early as 2006.

Based on the recommendation of the Scientific Council to the NAFO Commission (NAFO, 2020) that standardized protocols for the collection of seabed litter data should be implemented by all Contracting Parties (CPs) as part of their groundfish surveys, the Spanish Institute of Oceanography (IEO) developed a protocol for seabed litter data collection, to be used in all the EU groundfish surveys in the NRA. The objective of implementing a protocol was to extend the seabed litter data collection started in year 2006 in the Flemish Pass (Div. 3L) (García-Alegre *et al.*, 2020) to the other areas sampled by the EU surveys: Flemish Cap (Div. 3M) and the Grand Banks of Newfoundland (Divs. 3NO), using a common methodology. This preliminary protocol was first implemented in Divs. 3LNO (2018) and Div. 3M (2019) as a pilot experiment. Its application continued to date, when it is being reviewed and improved, as part of the NEREIDA Task 2. Therefore, the development of this sub-task is focused on a review and improvement of the existing standardized protocol for collection of seabed litter data.

Results obtained from sub-tasks 2.1 and 2.2 has allowed us to guide the drafting of the improved protocol and to propose best practices for groundfish surveys according to the needs and gaps identified. On this basis, for example, the criteria for counting litter items for further analysis was carried out as described in the ICES Manual for Seafloor Litter Data Collection (ICES, 2022). Building on the previous protocol, a preliminary improved protocol has been developed, with a new log sheet form to record the seabed litter data (Figure 6), which will be tested during the EU groundfish surveys that will be conducted between June and August 2024. Therefore, this sub-task is currently in process, as it involves a review that will identify the strengths and weaknesses of the new log sheet form and of the original standardized protocol versus the preliminary improved protocol. Such review will help in suggesting new measures and recommendations to implement in the seabed litter data collection during the EU groundfish surveys conducted in NRA.

RESIDUOS:					
CÓDIGO (COD_ARGO)	DESCRIPCIÓN (CATEGORÍA)	CAPTURA (kg)	N° ITEMS	гото	COMENTARIOS
60	RESTOS APAREJOS (REDES,)				
63	PLASTICO (BOLSAS, BOTELLAS,,)				
64	METAL				
68	LÁMINA/HOJA PLÁSTICA				
69	BOLSA PLÁSTICA				
71	CABO SINTÉTICO				
95	ROPA/TRAPOS				
240	RESTOS APAREJOS PROPIO BARCO: CABOS SINTÉTICOS				
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**Figure 6.** New seabed litter collection log sheet form to be used in the EU Groundfish Surveys 2024.

In this context, it should be noted that have a common protocol agreed with other CPs for the collection of seabed litter in the NRA would facilitate the standardisation of monitoring practices. This would help to reduce differences in data collection and classification procedures, which would improve the comparability of the data and allow its assessment on a regional scale. This fact encourages us to prepare and continue working on a new revised protocol, based on a previous review of protocols and manuals used in different areas by different groups (e.g. ICES, 2022). As an initial approach, the aim of the new revised protocol will be to establish common criteria for the surveys in the different Divisions in order to develop a "common practice" and to record data in a standardized way. In this sense, the Diagram 1 shows the expected task flow in the collection of litter data for each haul:



**Diagram 1.** Basic step sequence for recording seabed litter data on board. The concept of Item refers to each object (complete or in fragments) that constitutes a waste recovered from the seabed. The category mainly refers to the type of items, grouped according to the material they are made of, the use of the items or other aspects of their composition (Adapted from ICES, 2022).

The sequence of the different proposed steps to be followed for reporting seabed litter items on board is consistent with the experience developed by IEO scientists at NRA in sampling and collecting seabed litter data, reflecting a common structure and practice also found in other manuals (i.e. ICES, 2022).

According to the reviewed protocol, after each trawl, all seabed litter items collected and retained by the bottom trawl gear shall be examined, categorised, counted,

weighed, sized, photographed and recorded on board the research vessel (Diagram 1). Any evidence of the origin of the litter shall also be recorded as well as other additional information, such as the materials composing the items of litter or the presence of epibionts. For each haul, the characteristics of the trawl gear, location, date, time and depth at the start and end of the haul shall also be recorded, among other data. Recognising that seabed litter data are collected and recorded during groundfish surveys for stock assessment, which may be subject to time constraints and poor weather conditions, the procedures in the manual will intend to be simple and user-friendly, and will be presented accompanied by a visual guide to facilitate a better categorisation of the different items, developed on the basis of the photographic record of the surveys carried out by the IEO in previous years.

In this sub-task, the late start of the contract due to administrative issues, has delayed the achievement of several results on time. The preliminary seabed litter protocol and the new log sheet form are being tested during the groundfish surveys which are currently taking place in the NRA between June and August 2024. Based on the feedback received, the documents will be updated and improved. The final seabed litter protocol and visual guide are expected to be presented at the next WGESA meeting scheduled for November 2024.

#### **REFERENCES OF TASK 2**

- Abalo-Morla, S., Palas Otero, S., Román-Marcote, E., Durán Muñoz, P., Pérez, P., and Sacau, M. (2024). Preliminary results on seabed litter distribution on Flemish Cap (Div. 3M), Flemish Pass (Div. 3L) and Grand Banks of Newfoundland (Divs. 3NO). NAFO SCR Doc. 24/046. Serial No. N7553.
- Canals, M., Pham, C., Bergmann, M., Gutow, L., Hanke, G., van Sebille, E., Angiolil-lo, M., et al., (2021). The quest for seafloor macrolitter: a critical review of background knowledge, current methods and future prospects. Environmental Research Letters 16 023001. <a href="https://doi.org/10.1088/1748-9326/abc6d4">https://doi.org/10.1088/1748-9326/abc6d4</a>
- Durán Muñoz, P., Sacau, M., García-Alegre, A., and Román, E. (2020). Cold-water corals and deep-sea sponges by-catch mitigation: Dealing with groundfish survey data in the management of the northwest Atlantic Ocean high seas fisheries. Marine Policy, 116, 103712. <a href="https://doi.org/10.1016/j.marpol.2019.103712">https://doi.org/10.1016/j.marpol.2019.103712</a>
- Egger, M., Sulu-Gambari, F., Lebreton, L. First evidence of plastic fallout from the North Pacific Garbage Patch. Sci Rep 10, 7495 (2020). <a href="https://doi.org/10.1038/s41598-020-64465-8">https://doi.org/10.1038/s41598-020-64465-8</a>
- FAO (2009). Directrices Internacionales para la Ordenación de las Pesquerías de Aguas Profundas en Alta Mar. Roma, 73p. <a href="http://www.fao.org/3/i0816t/l0816T.pdf">http://www.fao.org/3/i0816t/l0816T.pdf</a>
- García-Alegre A., Román-Marcote E., Gago J., González-Nuevo G., Sacau M., and Durán Muñoz P. (2020). Seabed litter distribution in the high seas of the Flemish Pass area (NW Atlantic). Scientia Marina 84(1).
- ICES (2022). ICES manual for seafloor litter data collection and reporting from demersal trawl samples. ICES Techniques in Marine Environmental Sciences Vol. 67. 16 pp. <a href="https://doi.org/10.17895/ices.pub.21435771">https://doi.org/10.17895/ices.pub.21435771</a>

- Kaandorp, M., Dijkstra, H.A., van Sebille, E. (2020). Closing the Mediterranean marine floating plastic mass budget: inverse modelling of sources and sinks Environ. Sci. Technol. 54, 11980–9. <a href="https://doi.org/10.1021/acs.est.0c01984">https://doi.org/10.1021/acs.est.0c01984</a>
- MSFD GES Technical Subgroup on Marine Litter (2011). Marine Litter: technical recommendations for the implementation of MSFD requirements. *JRC Sc. Techn. Rep.* p 91. <a href="https://data.europa.eu/doi/10.2788/91406">https://data.europa.eu/doi/10.2788/91406</a>
- NAFO (2024). The Commission's Request for Scientific Advice on Management in 2025 and Beyond of Certain Stocks in Subareas 2, 3 and 4 and Other Matters. NAFO Scientific Council. NAFO/SCS Doc. 24/01. No. N7491. <a href="https://www.nafo.int/Portals/0/PDFs/sc/2024/scs24-01.pdf">https://www.nafo.int/Portals/0/PDFs/sc/2024/scs24-01.pdf</a>
- NAFO (2020). Report of the Scientific Council, 21 25 September 2020, via WebEx. NAFO SCS Doc. 20/19. https://www.nafo.int/Portals/0/PDFs/sc/2020/scs20-19.pdf
- NAFO (2019). Report of the 12th Meeting of the NAFO Scientific Council Working Group on Ecosystem Science and Assessment (WGESA). Northwest Atlantic Fisheries Organization. 19-28 November 2019, Dartmouth, Canada. Serial No. N7027 NAFO SCS Document 19/25. <a href="https://www.nafo.int/Portals/0/PDFs/sc/2019/scs19-25.pdf">https://www.nafo.int/Portals/0/PDFs/sc/2019/scs19-25.pdf</a>
- OSPAR (2007). Monitoring of Marine litter in the OSPAR Region. Publication No. 306/2007. London, United Kingdom, 74 pp. Available at: <a href="https://www.vliz.be/imisdocs/publications/ocrd/136746.pdf">https://www.vliz.be/imisdocs/publications/ocrd/136746.pdf</a>
- Pham, C.K., Ramirez-Llodra, E., et al., (2014). Marine litter distribution and density in European seas, from the shelves to deep basins. PLoS One 9: e95839. https://doi.org/10.1371/journal.pone.0095839
- UNEP (2009). Marine Litter: A Global Challenge. Nairobi. 232 p. <a href="https://www.unep.org/resources/report/marine-litter-global-challenge">https://www.unep.org/resources/report/marine-litter-global-challenge</a>
- Woodall, L.C., Sanchez-Vidal, A., Canals, M., Paterson, G.L.J., Coppock, R., Sleight, V., Calafat, A., Rogers, A.D., Narayanaswamy, B.E., Thompson R.C. (2014). The deep sea is a major sink for microplastic debris. R. Soc. Open Sci.1140317. <a href="http://doi.org/10.1098/rsos.140317">http://doi.org/10.1098/rsos.140317</a>

#### **ANNEXES OF TASK 2**

#### ANNEX 3 - NAFO SCR Document

Abalo-Morla, S., Palas Otero, S., Román-Marcote, E., Durán Muñoz, P., Pérez, P., and Sacau, M. (2024) Preliminary results on seabed litter distribution on Flemish Cap (Div. 3M), Flemish Pass (Div. 3L) and Grand Banks of Newfoundland (Divs. 3NO). NAFO SCR Doc. 24/046. Serial No. N7553.

### ANNEX 4 – Presentation at the NAFO Scientific Council meeting (June 2024)

Abalo-Morla, S., Palas Otero, S., Román-Marcote, E., Del Río, J.L., Pérez, P., Durán Muñoz, P., and Sacau, M. (2024). Seabed litter in NAFO Regulatory Area (Divs. 3LMNO): Protocol for data collection and preliminary results on Spatial distribution. NAFO Scientific Council Meeting June 2024. NEREIDA Task 2. Oral communication.

# <u>TASK 3</u>. Activities other than fishing in the NAFO Regulatory Area (Divs. 3LMNO): Offshore oil and gas.

#### **INTRODUCTION**

This section compiles the results of a desk research on activities other than fishing taking place in the NAFO Regulatory Area. The main natural and socioeconomic ecosystem components were mapped. Spatial overlap (user-environment; user-user) and trends (period 2018-2024) were identified, focusing on offshore oil and gas, deep-sea fisheries and Vulnerable Marine Ecosystems (VMEs). In addition, the role of area-based management tools (i.e., NAFO closure No. 10) was emphasized, as well as the implications of multisectoral areas for the process of identifying, assessing and reporting other effective area-based conservation measures (OECMs). Some key findings from the relevant scientific literature on the environmental impact of oil and gas activities, of interest in the context of NAFO, were summarized. Finally, lessons learned (gaps, needs and challenges) were also summarized. A summary of this information was previously presented to the Scientific Council during the June 2024 meeting (Durán Muñoz *et al.*, 2024).

### Activities other than fishing: Oil and gas exploration, production and decommissioning

Oil and gas activities sequentially include the phases of (i) exploration, (ii) production and (iii) decommissioning. Not all phases are always completed, as this depends on multiple factors (e.g. characteristics and viability of discoveries, etc.). Seismic surveys and exploratory drilling are fundamental tools for oil and gas explorations, which can negatively affect the ecosystem (see sub-task 3.3). In recent years, there has been exploration activity in the NAFO Convention Area. For example, on the Grand Banks of Newfoundland, starting in 1999, operators began exploring further afield, and the most recent decade has seen another wave of exploratory activity (Kaiser, 2021).

### A concern for the international community and stakeholders

<u>United Nations General Assembly</u>. United Nations General Assembly (UNGA) Resolution 71/123, adopted in 2016, reflects the international community's concern about the potential impacts of non-fishing activities. Specifically, paragraph 184 states that *Notes with concern that vulnerable marine ecosystems may also be impacted by human activities other than bottom fishing, and encourages in this regard States and competent international organisations to consider taking action to address such impacts*. Although Resolution 71/123, like the previous resolutions, focuses on sustainable fisheries, it also addresses the need to implement conservation measures for Vulnerable Marine Ecosystems (VMEs) in relation to human activities other than bottom fishing. This concern is reiterated in the following resolutions (Table 1).

**Table 1**. UNGA Resolutions on sustainable fisheries that included the issue of the impacts of non-fishing activities, indicating the date of adoption and the number of the *ad-hoc* paragraph about this issue.

<b>UNGA Resolution</b>	Date of adoption	ad-hoc paragraph about impacts of non-fishing activities
71/123	07 December 2016	184
72/72	05 December 2017	188
73/125	11 December 2018	197
74/18	10 December 2019	204
75/89	08 December 2020	203
76/71	09 December 2021	203
77/118	09 December 2022	217
78/68	05 December 2023	226

In this context, it is noteworthy that, the participants of the last United Nations workshop<sup>7</sup> to review the implementation of UNGA resolutions (64/72, 66/68 and 71/123) on sustainable fisheries, acknowledged a concern that management actions taken by RFMO/As were unable to address potential impacts resulting from other activities taking place in the same area, thereby affecting the effectiveness of ecosystem-based approaches. In particular, NAFO's contribution<sup>8</sup> to the review workshop, pointed out that there are a number of non-fishing activities occurring in the Regulatory Area that have the potential to impact fisheries resources and the ecosystem. NAFO also expressed its concern about non-fishing activities (specifically mentioning oil and gas as an example) and confirmed that these remain on the agenda of the NAFO Commission during its annual meetings (e.g., 2023: Commission Request #9)<sup>9</sup>. Moreover, some Contracting Parties expressed concern about drilling for oil and gas having taken place in NAFO closed area 10 (NAFO, 2016) and some stakeholders are also concerned about other marine users competing with fisheries (Guerin, 2019) and who may have impacts on the marine environment and the seafloor (e.g. deep-sea mining, oil and gas).

Convention on Biological Diversity. The Decision 14/8 adopted by the conference of the parties of the Convention on Biological Diversity (CBD)<sup>10</sup>, provides guidance about cross-sectoral coordination in relation to other effective area-based conservation measures (OECMs). Aichi Biodiversity Target 11 refers to effectively and equitably managed, ecologically representative and well-connected systems of protected areas and OECMs. Target 11 focuses on ecosystems. More specifically, it aims to conserve, above all, areas important for biodiversity and ecosystem services (Diz *et al.*, 2018). In this context, mapping is essential to identify which areas are multi-sectoral, in order to further advance the process for nomination and recognizing OECMs (CBD, 2018; NAFO, 2023). According to the FAO handbook for fisheries OECMs, in the case of multi-sectoral areas (Figure 1) (i.e. areas where many uses exist) the optimal approach is to carry out cross-

<sup>7</sup> Held at United Nations headquarters in August 2022. See: <a href="https://digitallibrary.un.org/record/3988731?ln=es">https://digitallibrary.un.org/record/3988731?ln=es</a>

<sup>&</sup>lt;sup>8</sup> See pp.14 *In*: NAFO Input to the 2022 Workshop to discuss the implementation of UNGA resolutions (64/72, 66/68, 71/123). 16 March 2022. NAFO/22-096. 15 pp. <a href="https://www.un.org/depts/los/bfw/NAFO">https://www.un.org/depts/los/bfw/NAFO</a> 2022.pdf

<sup>&</sup>lt;sup>9</sup> NAFO Commission Request #9: 'Continue to monitor and provide updates resulting from relevant research related to the potential impact of activities other than fishing'.

<sup>&</sup>lt;sup>10</sup> De Santo (2018) notes that there is some debate on the CBD's jurisdictional scope in ABNJ. Article 4 of the CBD stipulates that the provisions of the Convention apply (i) in the case of components of biological diversity, in areas within the limits of its national jurisdiction, and (ii) in the case of processes and activities, regardless of where their effects occur, carried out under its jurisdiction or control, within the area of its national jurisdiction or beyond the limits of national jurisdiction.

sectoral identification, assessment and reporting of OECMs (FAO, 2022). García *et al.*, (2020) suggest that a bilateral collaboration between two sectors may be enough to make an OECM operational and even to establish cross-sectoral OECM outcomes. They noted the need for international collaboration in the case of transboundary OECMs (areas where different jurisdictions overlap), suggesting that Regional Fisheries Management Organizations (RFMOs) could be used to promote effective OECMs. They also point out the importance of considering non-fishing impacts (considering the relative magnitude of cumulative non-fishery impacts relative to the fishery impacts), and describing the potential contribution to connectivity.

BBNJ Agreement. The Agreement under the United Nations Convention on the Law of the Sea on the conservation and sustainable use of marine biological diversity of areas beyond national jurisdiction (BBNJ Agreement) was adopted in June 2023. It is organized around four areas: (i) marine genetic resources; (ii) establishment of a network of Area-Based Management Tools (ABMTs); (iii) Environmental Impact Assessments (EIA); and (iv) capacity-building. The Agreement shall be interpreted and applied in a manner that does not undermine relevant legal instruments, frameworks and sectoral bodies. Moreover, it applies to Areas Beyond National Jurisdiction (ABNJ). There are a number of challenges that could influence cross-sectoral aspects in the future, especially those related to the implementation of ABMTs and EIA. Most RFMOs have established areabased measures, such as bottom fishery closures to protect VMEs. Lothian (2024) suggests that these protected habitats are likely to be a priority area for the establishment of ABMTs under the BBNJ Agreement. In this complex scenario, some questions arise: (i) How will existing ABMTs, such as bottom fishing closures implemented by RFMOs, fit with potential ABMTs developed under the BBNJ Agreement? and (ii) Will the BBNJ Agreement interact with existing governance regimes without undermining them? Furthermore, in light of the NAFO case study, an additional question can be asked: How will the issue of multi-sectoral areas be addressed? With regard to EIA, Lothian (2024) also notes that, until the adoption of the BBNJ Agreement, there was no mechanism in place to assess the cumulative impacts of all human activities on deep-sea VMEs. As some sectors already have sectoral impact assessment procedures in place, this raises the question of how the BBNJ Agreement's EIA provisions will interact with and sit alongside the EIA processes established under existing governance regimes, without undermining them. In light of this novel issue, the assessment of cumulative impacts from multiple sectors may become important within RFMOs.

#### **OBJECTIVE OF TASK 3**

This document complements the information from the NEREIDA Task 3, presented to the NAFO Scientific Council in June 2024, in particular, that related to *NAFO Commission's Request #9*, focusing on the interactions between oil and gas activities, deep-sea fisheries and VMEs. It should be noted that this study is not intended to duplicate the work done by the relevant authorities in each sector (e.g., it is not intended to duplicate the work done through existing impact assessment processes). The objective of the NEREIDA tasks related to activities other than fishing is to better understand some of these activities taking place in the NAFO Regulatory Area (NRA), in relation to their potential impact on the fishery resources, the ecosystem and the fishing

activity regulated by NAFO. This work will help to develop approaches related to tackling impacts of non-fishing activities on the marine biological resources and fisheries in the NRA.

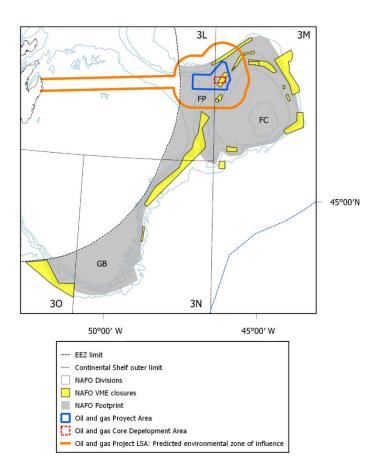
#### **MATERIAL AND METHODS**

## <u>Description of the study area: spatial overlap of oil and gas activities with groundfish</u> <u>fisheries and VMEs in the NAFO Regulatory Area, Divs. 3LMNO</u>

Currently, Division 3LM is the area of greatest concern in terms of spatial overlap between oil and gas activities, fisheries, VMEs and areas closed to bottom fishing. The bottom fisheries of the NRA are described in detail in NAFO (2020). Greenland halibut and redfish fisheries have traditionally fished in the area where oil and gas activities have emerged. The Greenland halibut trawl 3LMNO fishery (GHL OTB 3LMNO) is one of the main relevant fisheries currently conducted in the NRA. The fishery is carried out mainly at depths of 550 – 1,000 m. Records indicate that about 19 vessels of different flag states participate each year and the effort of this fishery represents 33% of the total trawl effort in the NRA. Redfish trawl 3LNO fishery (RED OTB 3LNO) is conducted mainly with depths ranging from 250-350 m in Divs. 3LNO. Records indicate that 20 vessels of different flag states participate each year and the effort of this fishery represents 10% of the total trawl effort in the NRA. Redfish trawl 3M fishery (RED OTB 3M) is conducted mainly at depths of 250-500 m. Records indicate that 19 vessels of different flag states participate each year and the effort of this fishery represents 14% of the total trawl effort in the NRA.

The Bay du Nord oil and gas project area (Figure 1, outlined in blue) is located in the Flemish Pass. It is approximately 4,900 km<sup>2</sup> in size and is defined as the overall geographic area within which planned tiebacks will occur (depth range: ~340 m - 1,200 m). The core development area of this project (Figure 1, outlined in red), encompasses the immediate offshore area ( $\sim$ 470 km<sup>2</sup>) in which project activities and components may occur and includes the area within which direct physical disturbance to the receiving environment may occur (depth range:  $\sim$ 1,000 m - 1,200 m) (Equinor, 2020). Water depth is an important issue for the present study, as it is considered to increase the risk of accidents associated with oil and gas platforms (Muehelenbachs et al., 2013). The actual footprint of project facilities within the core development area is approximately 7 km<sup>2</sup>. The safety zone will be approximately 30 km<sup>2</sup> and the anti-collision zone ranges from approximately 1 km<sup>2</sup> (drilling installation) to 8.5 km<sup>2</sup> (floating production storage and offloading vessel - FPSO). In this case, subsea developments involve connected seabed pipeline systems that direct hydrocarbons from individual wells to a single platform, so the seabed infrastructure footprint will extend beyond the location of the FPSO platform. The local study area (LSA), represents the predicted environmental zone of influence of the project's planned components and activities and project area tiebacks (Figure 1, outlined in orange). For each valuable component (i.e., components of the environment that are of ecological or socioeconomic importance and/or that can serve as indicators of environmental change, and which have the potential to be affected by the project), the LSA will depend on the geographic extent of an environmental disturbance or change and may vary based on its specific nature, timing, or location (Equinor, 2020). The proposed project area is comprised of 40 wells

within five locations in the core development area and up to 20 future wells in undefined locations outside of the core area (IAAC, 2021).



**Figure 1.** Map of the southern part of the NRA showing the location of the study area. The footprint of deep-sea-fisheries (gray shaded area) and the spatial limits of the Bay du Nord oil and gas project (outlined in blue) is showed, as well as the core development area (outlined in red). The predicted environmental zone of influence of this project is outlined in orange<sup>11</sup> (Source: Equinor, 2020). NAFO VME closures are also indicated (yellow shaded areas). (FC: Flemish Cap; FP: Flemish Pass; GB: Grand Banks of Newfoundland).

### Data collection and analysis

The present study is a desk-based research. Publicly available information on the ecosystem components (natural and socio-economic) of the study area was collated and integrated into a GIS. Spatial data were obtained from various sources (websites, reports, documents, etc.). When spatial data was available, the spatial location of each ecosystem component was mapped. In addition, relevant scientific literature on the environmental impact of offshore oil and gas activities was also reviewed, paying special attention to deep waters.

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 $<sup>^{11}</sup>$  Considering marine fish and fish habitat, including species at risk, marine mammals and sea turtles, and special areas. This zone also includes a smaller area of influence on seabirds.

## <u>Sub-task 3.1: Update of maps of the main ecosystem components in NAFO Divs.</u> 3LMNO

This sub-task focused on collating and mapping available information to update the characterization of the existing conditions in the study area. The baseline for this study was a previous research conducted as part of the ATLAS project (Durán Muñoz *et al.*, 2020a). The main biophysical and natural ecosystem components identified within the study area include geomorphological features, fishery resources, marine species (i.e. marine mammals, seabirds and sea turtles), and VMEs, such as cold-water corals and deep-sea sponges (Kenchington *et al.*, 2019a), including its connectivity pathways (Gary *et al.*, 2020; Combes *et al.*, 2021) (Table 2; Figure 2). The main socio-economic components identified are related to fisheries, shipping, the offshore oil and gas industry, undersea cable routes, and marine research (Durán Muñoz *et al.*, 2012, 2020b) (Table 2; Figure 3). All this information was organized and integrated into a GIS using the open source software QGIS (v3.28).

**Table 2.** List of the main natural and socio-economic ecosystem components identified in the NRA (\*: Potential).

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Biophysical/natural	Bathymetry and geomorphological features (e.g. seamounts, knolls).							
components	Substrate types (e.g. rock, gravel, sand, silt, clay).							
	Vulnerable Marine Ecosystems (VMEs).							
	Key species (i.e. marine mammals, sea birds and sea turtles).							
	Ecosystem connectivity (i.e. larval dispersal).							
	Epibenthic assemblages							
	Fisheries resources.							
Socio-economic	Deep sea fisheries (DSF) <sup>12</sup> and bottom fisheries regulated by coastal states							
components	(i.e. pots).							
	Pelagic fisheries (seines, gillnets, trawls and longlines).							
	Shipping (passenger and items)							
	Offshore oil and gas industry							
	Offshore renewables* (windfarms, power cables)							
	Seabed mining*							
	Undersea telecommunication cables							
	Military activities							
	Pollution (marine litter and long-distance pollution; dumping)							
	Bioprospecting* <sup>13</sup>							
	Marine research (surveys)							
	Deep sea conservation and management (closed areas for VME protection;							
	OECMs; EBSAs, etc.)							

NEREIDA surveys, using multibeam echosounder technology, have mapped the main fishing grounds and identified key geological features (e.g., submarine canyons, sedimentary drifts) and environmental variables (e.g., slopes) related to the study of VMEs (Figure 2A; Durán Muñoz et al., 2012). Additionally, over the past few years, new areas with VMEs have been identified both within and outside the fishery footprint

 $<sup>^{12}</sup>$  Bottom fisheries operating in the NRA (bottom trawls and bottom longlines).

<sup>&</sup>lt;sup>13</sup> Biodiversity prospecting or bioprospecting is the systematic search for biochemical and genetic information in nature in order to develop commercially-valuable products for pharmaceutical, agricultural, cosmetic and other applications (<a href="https://sdgfinance.undp.org/sdg-tools/bioprospecting">https://sdgfinance.undp.org/sdg-tools/bioprospecting</a>)

(Murillo et al., 2011; 2012; 2016; Meredick et al., 2017; Wudrick et al., 2020; Abalo-Morla et al., 2023). This information has updated the knowledge about the distribution of VMEs (Figure 2B; Kenchington et al., 2019a) and elucidated connectivity between VMEs (Figure 2C; Gary et al., 2020; Wang et al., 2024). In addition, EU groundfish research surveys (Durán Muñoz et al., 2020b) have elucidated the benthic assemblages (Figure 2D; Murillo et al., 2016). In addition, there are predictions of habitat suitability for commercially important species. (Figure 2E; Morato et al., 2020).

The region also supports breeding and non-breeding seabirds<sup>14</sup> (Figure 2F), sea turtles<sup>15</sup> (Figure 2G), and marine mammals<sup>16</sup> (Figure 2H). The Flemish Pass and slope around the Flemish Cap were identified as important diving areas for female hooded seals (*Cystophora cristata*) during the post-breeding period. Based upon sighting data, the Tail of the Grand Banks was identified as an important area for leatherback turtles. A wide variety of cetaceans also use the Grand Banks outside of the Canadian EEZ, particularly off the Nose of the Grand Banks, and along the Southeast Shoal (Román-Marcote *et al.*, 2020).

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<sup>&</sup>lt;sup>14</sup> Breeding and non-breeding seabirds which are present in the region include species listed as Near Threatened species (NT) by the IUCN, as the sooty shearwater (*Ardenna grisea*), other seabird species listed as Vulnerable (VU), as the Leachs's storm petrel (*Hydrobates* leucorhous), black-legged kittiwake (*Rissa tridactyla*), and Atlantic puffin (*Fratercula arctica*); and seabird species listed as Least Concern (LC), as northern fulmar (*Fulmarus glacialis*), greater shearwater (*Ardenna gravis*), great Skua (*Catharacta skua*), pomarine/parasitic jaegers (*Stercorarius pomarinus/parasiticus*), long-tailed jaeger (*Stercorarius longicaudus*), northern Gannet (*Morus bassanus*), great black-backed gull (*Larus marinus*), lesser black-backed gull (*Larus fuscus*), common tern (*Sterna hirundo*), Wilson's storm-petrel (*Oceanites oceanicus*), razorbill (*Alca torda*), among others (IUCN 2018, 2019, 2021; Román-Marcote *et al.*, 2020).

<sup>&</sup>lt;sup>15</sup> Sea turtles inhabiting the region are the green turtle (*Chelonia mydas*) which is listed as Endangered (EN); the leatherback sea turtle (*Dermochelys coriacea*) and the loggerhead sea turtle (*Caretta caretta*), both listed as Vulnerable by the IUCN (Mortimer and Donnelly, 2008; Wallace *et al.*, 2013; Casale and Tucker, 2017; IUCN, 2019; Seminoff, 2023).

<sup>&</sup>lt;sup>16</sup> Marine mammals inhabiting the region include species listed as Vulnerable by the IUCN, as the sperm whale (*Physeter macrocephalus*), fin whale (*Balaenoptera physalus*), and hooded seals (*Cystophora cristata*); Near Threatened species, as the northern bottlenose whale (*Hyperoodon ampullatus*); Least Concern species as the long finned pilot whale (*Globicephala melas*), humpback whale (*Megaptera novaeangliae*), common minke whale (*Balaenoptera acutorostrata*), harbour porpoise (*Phocoena phocoena*), and atlantic white sided dolphins (*Lagenorhynchus acutus*), and other especies not listed by the IUCN as the killer whale (*Orcinus orca*); among others (Kovacs, 2016; Reeves *et al.*, 2017; IUCN, 2018, 2019, 2021; Román-Marcote *et al.*, 2020).

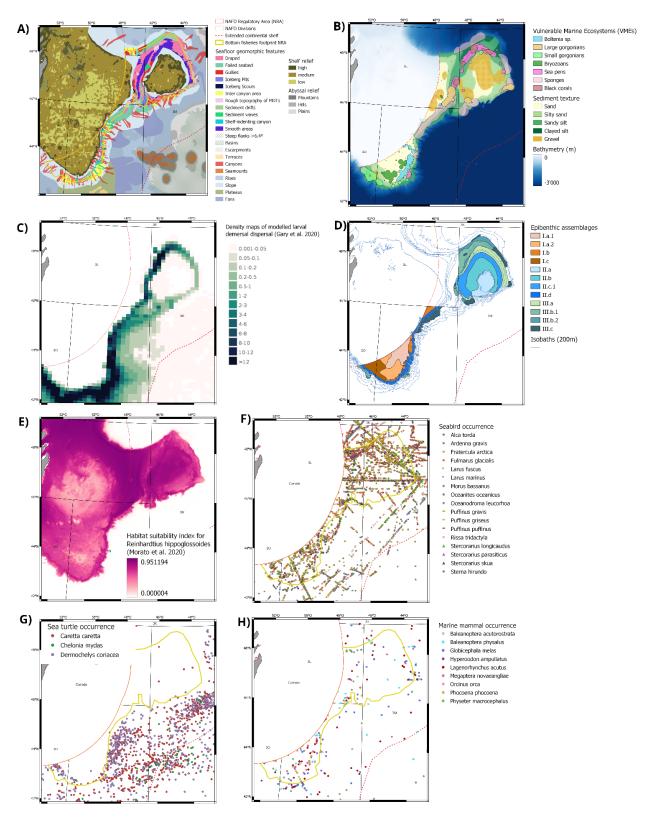


Figure 2.

Figure 2 (caption). Updated cartographic information on the main biophysical/natural components in the study area. A) Seafloor geomorphic features. Shelf and abyssal areas are classified upon its roughness (high, medium and low) (Harris et al., 2014). Geomorphology on the slopes was obtained from the NEREIDA multibeam echosounder technology (Durán Muñoz et al., 2012); B) Bathymetry (blue scale; GEBCO Bathymetric Compilation Group, 2023), sediment texture types according Shepard classification (yellow to green; and orange for gravel, Murillo et al., 2016) and polygons of significant concentrations of VME indicator taxa (Kenchington et al., 2019a); C) Density maps (particles per square km) of modelled particles of larvae released from Flemish Cap (Gary et al., 2020); D) Epibenthic megafaunal assemblages in Divisions 3MNO. Assemblages were grouped into three major groups: (i) Continental shelf of the Tail of Grand Bank; (ii) Shallow waters of Flemish Cap and upper slope of the Tail of Grand Bank; and (iii) Lower slope of Flemish Cap and Tail of Grand Bank (Murillo et al., 2016); E) Fisheries resources: e.g., Habitat suitability index for R. hippoglossoides (Morato et al., 2020); F) Spatial distribution of seabirds; G) Spatial distribution of sea turtles; H) Spatial distribution of marine mammals. Limits of the NAFO Regulatory Area (red lines), NAFO Divisions (black lines) and extended continental shelf (dashed red line) are shown in all maps. Occurrence data for seabirds, sea turtles and marine mammals were obtained from OBIS (https://obis.org/).

The existing and potential human activities identified constitute the socio-economic components in the region. Bottom fisheries occur in the study area. These activities are regulated by NAFO when they take place in the water column of the NRA (e.g., groundfish fisheries) and by the coastal state in the case of fisheries for sedentary species as they occur on the extended continental shelf (e.g., snow crab fishery) (Figure 3A). To meet conservation objectives and prevent significant adverse impacts of NAFO fisheries on VMEs, closed areas for bottom fishing activities have been implemented since 2010 (FAO, 2016). These closed areas are assessed and updated by NAFO as new scientific information becomes available. In addition, there is a closed area for shrimp fishing in Division 3M between June and September (Figure 3B; NAFO, 2021, 2022a, 2024).

Furthermore, since 2008, two areas in the NRA have been declared Ecologically or Biologically Significant Marine Areas (EBSAs). The objective of EBSAs is to highlight important areas that support the healthy functioning of oceans and the many services they provide, and that need protection (<a href="https://www.cbd.int/ebsa/">https://www.cbd.int/ebsa/</a>) (Figure 3B). More recently, in 2018, the Convention of Biological Diversity (CDB) has developed "Other Effective Area-based Conservation Measures" (OECMs)<sup>17</sup>. These areas are of more direct relevance to fisheries management and a better match with the remit of RFMOs than marine protected areas (MPAs) (Thompson and Reid, 2024). At present, OECMs in the region are located under the jurisdiction of the coastal state to protect portions of Significative Benthic Areas (SiBAs) (Figure 3B; Gullage et al., 2022). RFMOs can report OECMs (FAO, 2022) and with this regard there are spatial closures currently adopted by NAFO that are being considered for OECM listing (VME closed areas 1 to 6) (NAFO, 2023). However, during recent years offshore oil and gas activities in NAFO Divs. 3LNM had increased, including exploratory drilling activities on NAFO VME closed areas to bottom

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<sup>&</sup>lt;sup>17</sup> "A geographically defined area other than a Protected Area, which is governed and managed in ways that achieve positive and sustained long-term outcomes for the *insitu* conservation of biodiversity, with associated ecosystem functions and services and where applicable, cultural, spiritual, socio–economic, and other locally relevant values" (CBD, 2018).

fishing (i.e., Areas 2 and 10) (NAFO, 2016; Durán Muñoz and Sacau, 2021; NAFO, 2023; Thompson and Reid, 2024).

Research surveys are also conducted in the NRA, as NAFO's main objective is to ensure the long-term conservation and sustainable use of fishery resources in the Convention Area, while safeguarding the marine ecosystems in which these resources are found (Figure 3C; Abalo-Morla *et al.*, 2023; Durán Muñoz *et al.*, 2012; 2020b). Additionally, industry-DFO collaborative post-season snow crab trap surveys are conducted in Division 3L over the extended continental shelf (AMEC, 2014). Research focused on bioprospecting also has the potential to occur in the region due to its increasing interest (e.g., Rocha *et al.*, 2011; Ledoux and Antunes, 2017; Li *et al.*, 2018; Saminara *et al.*, 2022; Steffen, 2022; Tan, 2023), although no spatial information was found about it in the study area.

Other human activities occurring in the study area include activities related to offshore hydrocarbon exploration and exploitation, and submarine cable routes for telecommunication signals (AMEC, 2014; Durán Muñoz *et al.*, 2020a; NAFO, 2022b; Figure 3D), and shipping (e.g., cargo vessels, oil tankers, passenger vessels; Figure 3E). Potential activities in the area include deep-sea mining (van Dover *et al.*, 2017; Christiansen *et al.*, 2022; Cassota and Goodsite, 2024) and those related to renewable energy, such as wind farms (AMEC, 2014; Tang and Kilpatrick, 2021; Wilber *et al.*, 2022; Danovaro *et al.*, 2024). Military activities related to operations, training, and weapons testing have occurred in the past, creating legacy sites where unexploded ordnance (UXO) may still be present. Currently, military activities primarily consist of routine operations for surveillance and monitoring, law enforcement, natural resource protection, and search and rescue activities (AMEC, 2014). Finally, marine pollution, including marine litter, long-distance pollution, and dumping, occurs in the region (Figure 3F; NAFO, 2019; García-Alegre *et al.*, 2020; Abalo-Morla *et al.*, 2024).

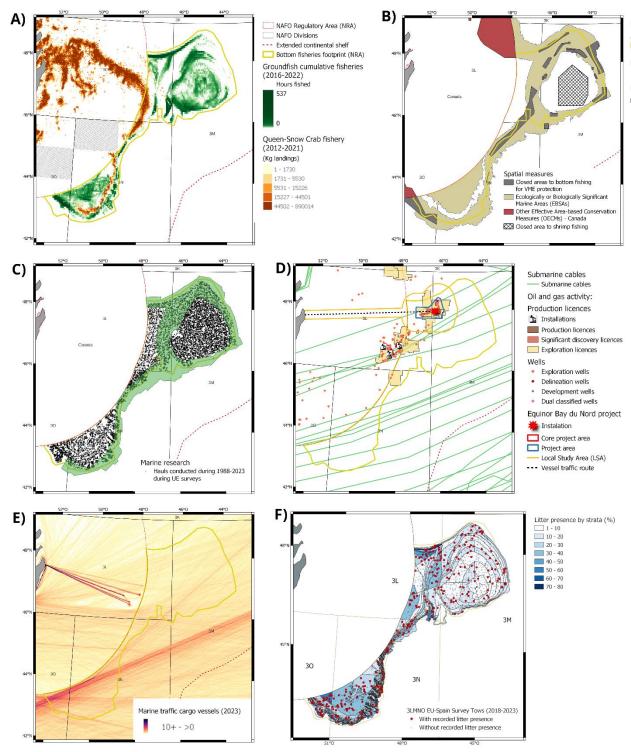


Figure 3.

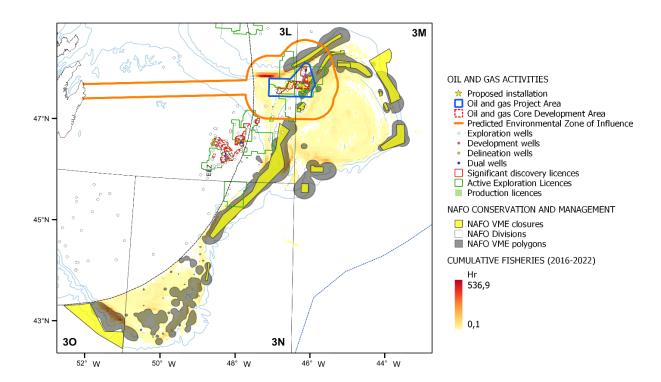
Figure 3 (caption). Updated cartographic information on the main socio-economic components identified in the study area. A) Bottom fisheries: NAFO cumulative bottom fisheries in 2016-2022 (hours fished; green scale) (Task 1 NEREIDA contract) and queen-snow crab fishery during 2016-2021 (kg landings; orange scale). Snow crab data obtained from Fisheries and Oceans Canada available at: https://open.canada.ca/data/en/dataset/502da2ef-bffa-4d9b-9e9ca7425ff3c594; B) Areas closed for VME protection (grey polygons; NAFO, 2024), areas closed for shrimp fishing during 1 June to 31 September in Division 3M (NAFO, 2024), Ecologically and Biologically Significant Marine Areas (EBSA): Slopes of the Flemish Pass and Grand Bank and Southeast shoal and adjacent areas on the Tail of the Grand Bank (beige polygons) (https://www.cbd.int/ebsa/), and Other-Effective Area-based Conservation Measures (OECMs) established in Canadian waters (red polygons) (UNEP-WCMC and IUCN, 2024); C) Marine research: Hauls conducted during the EU surveys during 1988 to 2023 in the NRA (black crosses; González-Costas et al., 2023; Abalo-Morla et al., 2023) and the study area of NEREIDA cruises: 2009-2010 (in green) (Durán Muñoz et al., 2012); D) Oil and gas activities: installation locations, licences (production licences (PL), significant discovery licences (SDL), exploration licences (EL)), wells (delineation wells, development wells, dual classified wells) and available information about the Equinor Bay du Nord project (installation location, project area, core project area, local study area and vessel traffic route). Data available in May 2024 at <a href="https://www.cnlopb.ca/">https://www.cnlopb.ca/</a>. Submarine cables (green lines) obtained from https://www.submarinecablemap.com/; E) Marine traffic: Cargo vessel density map during 2023 (Fisheries and Oceans Canada; https://open.canada.ca/data/en/dataset/5b86e2d2-cec1-4956-a9d5-12d487aca11b); F) Spatial distribution of seabed litter in the NRA (Abalo-Morla et al., 2024). Limits of the NAFO Regulatory Area (red lines), NAFO Divisions (black lines) and extended continental shelf (dashed red line) are shown in all maps.

## <u>Sub-task 3.2: Identify spatial conflicts user-environment and user-user in NAFO Divs.</u> 3LMNO, with focus on offshore oil and gas, DSF and VMEs

Knowing the spatial and bathymetric location of areas where other human activities overlap with VMEs, VME closures and fisheries, is the starting point to better understand potential interactions. This includes: (i) environmental impacts from accidental events or routine activities, (ii) competition for the use of marine space (e.g., loss of fishing opportunities), and (iii) interactions between measures in multiple sectors and transboundary implications of these measures (Molenaar, 2021). This knowledge help to understand whether non-fishing activities may affect the effectiveness of the conservation and management measures adopted by NAFO (e.g., closed areas). Such information is essential to fill the NAFO Ecosystem Summary Sheets (ESS), particularly the sections on (i) human activities other than fisheries and (ii) pollution.

## <u>Distribution of oil and gas activities (licences and wells) and overlap with deep-sea</u> <u>fisheries, VMEs and closed areas</u>

The spatial extent of oil and gas activities (licences and wells) was mapped based on the available information, collected on February 2024 from the Canada-Newfoundland and Labrador Offshore Petroleum Board (C-NLOPB) website. Data on cumulative bottom fisheries (2016-2022 period) was obtained from NEREIDA Project. The map in Figure 4 shows that in the study area, most oil and gas activities, and consequently the spatial overlaps with fisheries, VMEs and VME closures, occur in Division 3LM.



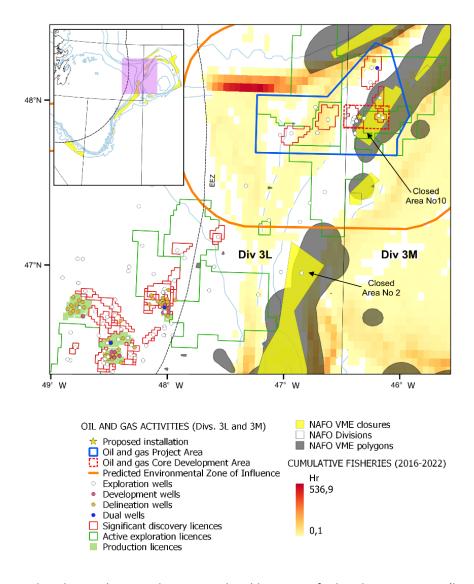
**Figure 4.** Updated map showing the geographical location of oil and gas activities (licences and wells) in NAFO Divs. 3LMNO. Data collected in February 2024 (source: C-NLOPB). Bottom fishing activity (cumulative fishery 2016-2022) is expressed in hours fished in each cell (from yellow to red). Dark color indicates higher value (source: NEREIDA). Most oil and gas activities, and consequently spatial overlaps with fisheries, VMEs, and VME closures occur in Division 3LM.

The map of the Figure 5 reveals that some licences<sup>18</sup> and wells<sup>19</sup> overlap with NAFO-regulated fisheries (fishing grounds), VMEs and areas closed to protect such ecosystems. In summary, the map shows the overlaps between the different users of the marine space, as well as between users and the marine environment. Such overlaps could lead to future conflicts.

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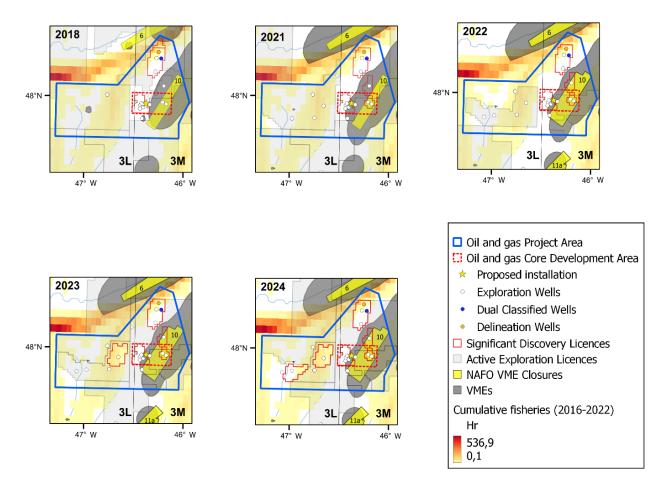
<sup>&</sup>lt;sup>18</sup> A **licence** is the mechanism under the Accord Act by which certain rights are granted in lands in the Canada Newfoundland and Labrador offshore area. According to AMEC (2014), normally, an owner of an **exploration licence** will explore that licence and, upon finding a significant discovery (i.e. accumulation of oil that has potential for sustained production), be issued a **significant discovery licence** to further delineate the discovery in anticipation of finding commercial resources (i.e. discovery that justify the investment and effort to bring the discovery to production) which may lead to the issuance of a **production licence** (for oil production).

<sup>&</sup>lt;sup>19</sup> According to Kaiser (2021), **exploration** and **development** wells are used to find commercial accumulations of hydrocarbons and develop them. Exploration wells are drilled outside known reservoirs, and therefore, exploratory drilling almost always takes place from a mobile offshore drilling unit. Development drilling is different from exploration drilling, since the objective is to produce, while in exploration the objective is to find hydrocarbons, and in appraisal, to delineate the reservoir and gather the necessary data for planning the development. **Delineation** wells are used to determine the areal and vertical extent of reservoirs and have many similarities to exploration wells. **Dual wells** have dual nature.



**Figure 5.** Updated map showing the geographical location of oil and gas activities (licences and wells) in NAFO Divs. 3LM. Data collected in February 2024 (source: C-NLOPB). The yellow star indicates the location of the proposed production installation within the *Bay du Nord Development Project* in the Flemish Pass (outlined in blue). Bottom fishing activity (cumulative fishery 2016-2022) is expressed in hours fished in each cell (from yellow to red). Dark color indicates higher value (source: NEREIDA).

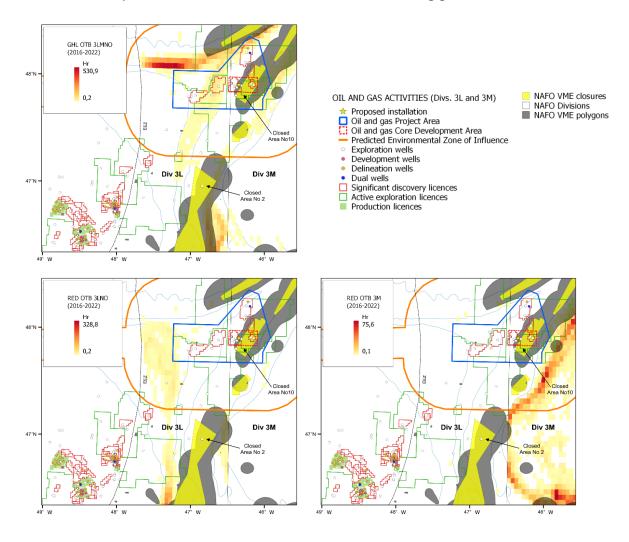
Figure 6 shows the evolution over time of the overlap between oil and gas activities (licences and wells), NAFO-regulated fisheries, VMEs and VME Area Closure No. 10, along the period 2018 - 2024. There has been an increase in overlap due to both the increase in the number of significant discovery licences, the expansion of area closure No. 10 and the redefinition of NAFO VME polygons occurred in 2019. In addition, the number of exploration wells within the project area has also increased during the period analyzed. In this scenario, the potential tension between commitments to protect VMEs and biodiversity, the maintenance of fisheries and the expansion of oil and gas activities is likely to intensify in the near future.



**Figure 6.** Updated map showing the evolution over time of the degree of overlap between oil and gas activities, VMEs and VME Area closure No. 10 (2018 - 2024 period). Source C-NLOPB. Bottom fishing activity (cumulative fishery 2016-2022) is expressed in hours fished in each cell (from yellow to red). Dark color indicates higher value (source: NEREIDA).

## Spatial overlap with the Greenland halibut and redfish bottom fisheries

The international bottom fisheries regulated by NAFO most affected by the overlap with oil and gas activities (wells and licences) is, by far, the Greenland halibut trawl fishery (GHL OTB 3LMNO) and, to a lesser extent, the redfish bottom trawl fisheries (RED OTB 3LNO; RED OTB 3M). Figure 7 shows the overlap of such activities with the mentioned fisheries (2016-2022 period), based on new data from NEREIDA project. The historical footprint of the Greenland halibut trawl fishery is located in the same area where the main oil and gas activities are currently taking place, namely the Flemish Pass area. In the case of the redfish fishery, there is less overlap: There are few active exploration licenses and exploration wells within the current redfish fishing grounds.



**Figure 7.** Map showing the spatial overlap between oil and gas activities (wells and licences) and the bottom fisheries for Greenland halibut and redfish (oil and gas, source: C-NLOPB). Bottom fishing activity (cumulative fishery 2016-2022) is expressed in hours fished in each cell (from yellow to red). Dark color indicates higher value (source: NEREIDA).

## <u>Spatial overlap with VMEs and VME closures: Role in connectivity</u>

Oil and gas activities (licences and wells) in the Flemish Pass, overlap significantly with several patches of VMEs described in Wang *et al.*, (2024), specifically those of sponges (S7), sea pens (SP1) and black corals (BC4). VME patches are partially protected from the impact of bottom fishing through fishing closed areas (Table 3; Figures 8 to 10). Based on the available information, the patches of VME are open to oil and gas activities (e.g., drilling, anchoring). It is important to highlight that the fisheries closure No.10, provides protection to three different VMEs (S7, SP1 and BC4). The closed areas 2, 7 to 12 and 14 show physical connectivity and appear to form a network over Flemish Cap (Kenchington *et al.*, 2019b). In addition, the Closed Areas put in place to protect VMEs also contribute to the protection of 3 of the 12 benthic assemblages (NAFO, 2019) identified in the area by Murillo *et al.* (2016).

**Table 3**. VME patches of sponges, sea pens and black corals, partially protected by NAFO VME Area Closures. Closure Area No. 10 is highlighted in blue.

NAFO VME Closures	VME patches (Wang et al., 2024)		
(NAFO, 2024)	Sponge (S)	Sea pen (SP)	Black coral (BC)
1	S6		
2	S1	SP10	BC3
3	S3		
4	S5		
5	S4, S9		
6	S2		
7		SP1	BC2
8		SP1	
9		SP1	BC1
10	S7	SP1	BC4
11		SP6	
12		SP1	BC1
13	S3		
14		SP5, SP8	BC7

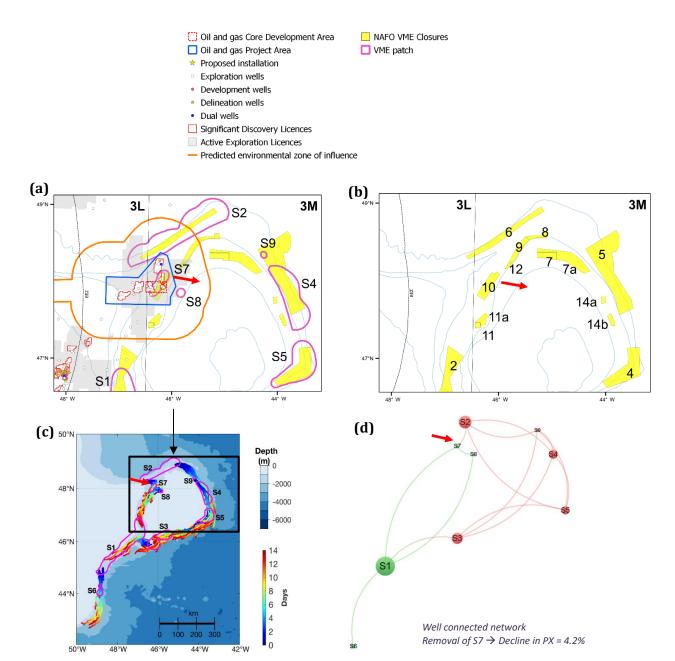
Wang et al., (2024) and the literature herein, suggest that persistence of the sessile benthos over the long term depends on larval supply, and hence on inter-patch connections. Habitat fragmentation has the potential to alter connectivity, affecting population dynamics and ecosystem functioning, and may lead to a loss of biodiversity. They described the connectivity between VME patches in the NRA (Figures 8 to 10), and the effects of habitat loss simulated by systematic removal of whole patches, to determine the importance of each patch to connectivity. According to the authors, sea pens (Figure 9) had the highest degree of connectivity, while black corals (Figure 10) had the least connected network (e.g., BC4 has connections only with 2 black coral patches). Patches serving as source populations to multiple other patches were prevalent in the sea pen network, in which every patch was a source to at least one other, and SP1 had downstream connections to all other patches. In general, the existing networks, including the extant networks of sponge VME (Figure 8), are well connected (e.g., S7 has connections with three sponge patches) and, by inference, those connections are likely

important to the persistence of VME within the study area. These authors concluded that patches of VMEs within the NRA comprise inter-connected networks, such that maintenance of connectivity should be assumed essential to the persistence of the patches and hence of the VMEs. They also analyzed the decline in the Proximity Index (PX)<sup>20</sup>, noted that the existing patches in each network differ in their relative importance for connectivity. On the other hand, connectivity can exacerbate harmful effects caused by anthropogenic activities, such as the spread of pollutants trough a food web or ecosystem (DOSI, 2020; Popova *et al.*, 2019).

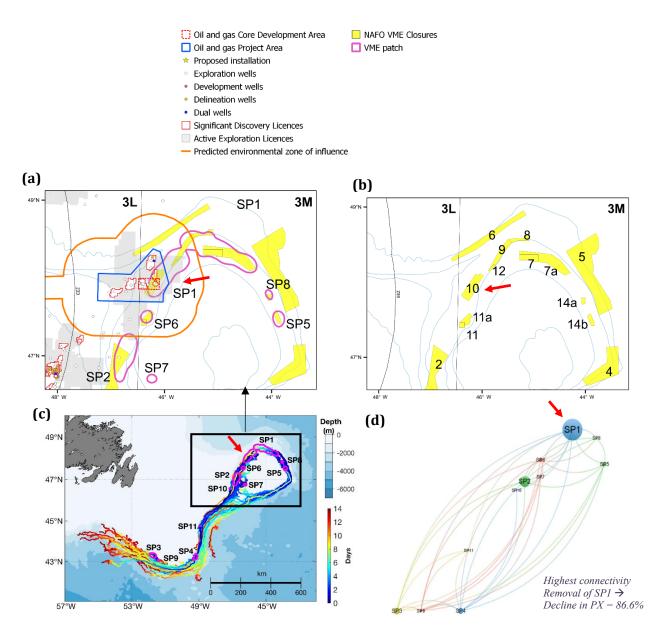
VMEs in closure No. 10 (i.e., sea pens, sponges and black corals) are part of an interconnected network, and hence, impacts on one VME could have cascading effects on other VME areas. In this regard, the effects of non-fishing activities should be further studied in the context of protecting connected VME network, as the development of potentially damaging activities within such area, including oil and gas, may compromises the network (e.g., habitat fragmentation).

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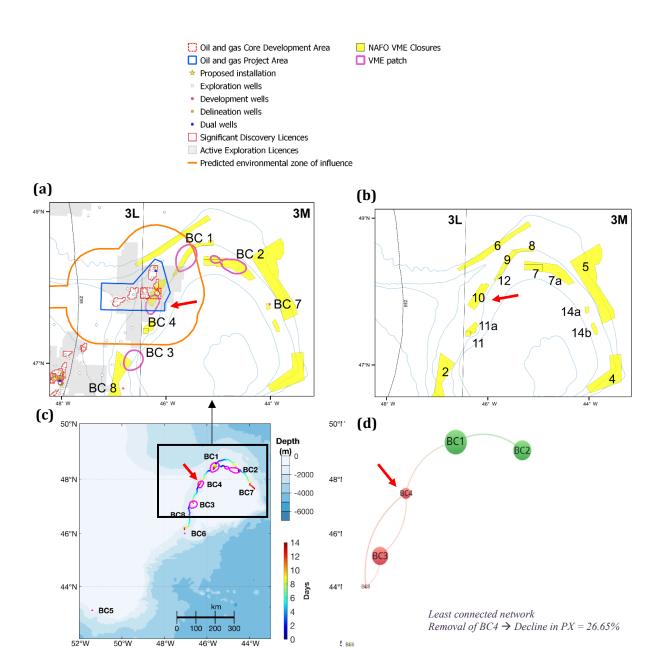
 $<sup>^{20}</sup>$  PX represents the spatial context of habitat patches in relation to their neighbors. It is a suitable metric for detecting network fragmentation. See Wang *et al.*, (2024) and the literature cited therein.



**Figure 8.** Maps of the NAFO Regulatory area showing the spatial interactions between oil and gas activities (licences and wells), sponge VME and fishing closures, as well as the diagrams of connectivity according to Wang *et al.*, 2024. <u>Pannel</u> (a): Spatial overlap between oil and gas activities (licences and wells), sponge VME patches (S) and fishing closures in the Flemish Pass area, in the context of the NAFO network of VME closures shown in <u>Pannel</u> (b). The patches of VME are labeled according to Wang *et al.*, 2024. <u>Pannel</u> (c): Minimum particle trajectories connecting the patches of sponges (S). Source: Wang *et al.*, 2024. Pannel (d): Stylized network map created in VOSviewer, using default settings. Nodes are labelled by patch code and their size is proportional to patch area, within the taxon. Node position represents the patch centroid in geographic space. Source: Wang *et al.*, 2024. Oil and gas activities in the Flemish Pass overlap significantly with a sponge patch (S7). The red arrows indicate the location of such patches in all maps.



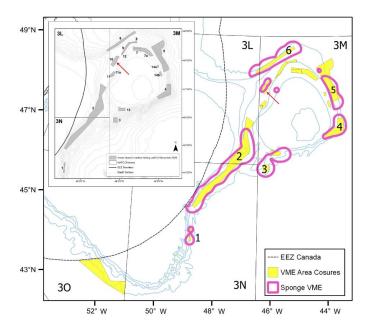
**Figure 9.** Maps of the NAFO Regulatory area showing the spatial interactions between oil and gas activities (licences and wells), sea pen VME and fishing closures, as well as the diagrams of connectivity according to Wang *et al.*, 2024. <u>Pannel</u> (a): Spatial overlap between oil and gas activities (licences and wells), sea pen VME patches (SP) and fishing closures in the Flemish Pass area, in the context of the NAFO network of VME closures shown in <u>Pannel</u> (b). The patches of VME are labeled according to Wang *et al.*, 2024. <u>Pannel</u> (c): Minimum particle trajectories connecting the patches of sea pens (SP). Source: Wang *et al.*, 2024. Pannel (d): Stylized network map created in VOSviewer, using default settings. Nodes are labelled by patch code and their size is proportional to patch area, within the taxon. Node position represents the patch centroid in geographic space. Source: Wang *et al.*, 2024. Oil and gas activities in the Flemish Pass overlap significantly with a sea pen patch (SP1). The red arrows indicate the location of such patches in all maps.



**Figure 10.** Maps of the NAFO Regulatory area showing the spatial interactions between oil and gas activities (licences and wells black coral VME and fishing closures, as well as the diagrams of connectivity according to Wang *et al.*, 2024. Pannel (a): Spatial overlap between oil and gas activities (licences and wells), black coral VME patches (BC) and fishing closures in the Flemish Pass area, in the context of the NAFO network of VME closures shown in Pannel (b). The patches of VME are labeled according to Wang *et al.*, 2024. Pannel (c): Minimum particle trajectories connecting the patches of sea pens (SP). Source: Wang *et al.*, 2024. Pannel (d): Stylized network map created in VOSviewer, using default settings. Nodes are labelled by patch code and their size is proportional to patch area, within the taxon. Node position represents the patch centroid in geographic space. Source: Wang *et al.*, 2024. Oil and gas activities in the Flemish Pass overlap significantly with a black coral patch (BC4). The red arrows indicate the location of such patches in all maps.

## Implications for the process for nomination and recognizing OECMs

To achieve sustained, long-term biodiversity outcomes, a multi-sectoral, integrated and collaborative process for the identification, assessment and reporting of OECMs is considered best practice in areas with multiple uses and pressures (FAO, 2022). In the NAFO context, in the absence of such an approach, the current process of designating and recognizing potential OECMs has focused on areas that support only fishing activities. Consequently, Closed Area No.10 was excluded from the process for nomination of the Sponge VME OECM, due to risks related to oil and gas activities (NAFO, 2023). Area 13 was also excluded, but the draft proforma does not mention the reason (Figure 11).



**Figure 11.** Map showing the six closed areas (1 to 6) comprised in the potential Sponge VME OECM. The box shows the complete NAFO (2024) network of closed areas. The red arrows indicate the location of Closed Area No.10, excluded from the nomination due to risks from oil and gas activities.

Sponge VME within fishing closure No. 10 are part of an interconnected network (Kenchington *et al.*, 2019b; Wang *et al.*, 2024), and it is partially protected from the impacts of bottom fishing (NAFO, 2024). It has relevance in overall conservation objectives, not only for sponges but also for sea pens and black corals (Figures 8 to 10). Impacts on such a VMEs, including impacts from non-fishing activities, could have cascading effects on other areas of VMEs.

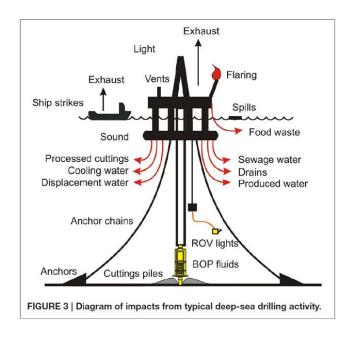
Currently, the existence of oil and gas activities within an area closed to bottom fishing to protect VMEs (i.e., Closure Area No.10), hinders its inclusion in the global OECM database. Consideration of Area 10 would bring greater coherence to the OECM proposal (i.e., integrity of the network of closed areas), but this would require a multi-sectoral approach and international collaboration, as recommended by FAO (2022).

# Sub-task 3.3: Literature review: Environmental effects of offshore (deep-water) oil and gas activities, and existing criteria/methods for studying its potential impacts on VMEs and conflicts with DSF

# <u>Literature on the impacts of oil and gas: Some key findings</u>

A literature review of relevant research on the potential environmental effects of oil and gas activities and the criteria and methods for studying them was carried out. A brief selection of key findings, which might be of interest in the context of NAFO, are summarised below:

 Cordes et al., (2016) carried out a comprehensive review of the impacts of offshore oil and gas industry and the management strategies. According to this review, besides accidental events (e.g., oil spills), routine oil and gas activities can have detrimental environmental effects during each of the main phases of exploration, production, and decommissioning. The authors provide a comprehensive graphical summary of the impacts of the deep-sea drilling activity (Figure 12). They noted that direct impacts of infrastructure installation, including sediment resuspension and burial by seafloor anchors and pipelines, are typically restricted to a radius of  $\sim$ 100 m on from the installation on the seafloor. Discharges of water-based and low-toxicity oil-based drilling muds and produced water can extend over 2 km, while the ecological impacts at the population and community levels on the seafloor are most commonly on the order of 200 – 300 m from their source. These impacts may persist in the deepsea for many years and likely longer for its more fragile ecosystems, such as coldwater corals. The authors also provide the basis for a series of recommendations for the management of offshore oil and gas development. An effective management strategy, aimed at minimizing risk of significant environmental harm, will typically encompass regulations of the activity itself (e.g., discharge practices, materials used), combined with spatial (e.g., avoidance rules and marine protected areas), and temporal measures (e.g., restricted activities during peak reproductive periods. Implementation of these management strategies should consider minimum buffer zones to displace industrial activity beyond the range of typical impacts: at least 2 km from any discharge points and surface infrastructure and 200 m from seafloor infrastructure with no expected discharges.



**Figure 12.** Diagram of impacts from typical deep-sea drilling activity. Source: Cordes *et al.*, (2016).

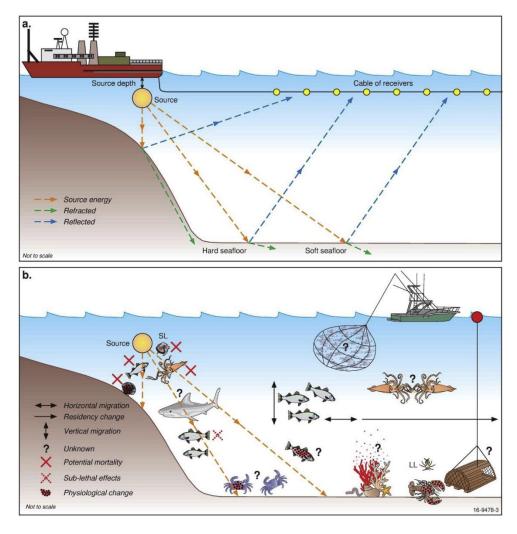
DFO (Gullage et al., 2022) investigated the potential impacts of exploratory drilling activities (positioning, drilling, abandonment and accidental events) to coral and sponge species in the Newfoundland and Labrador (NL) region, as well as the ways in which avoidance and mitigation measures can be applied to reduce them. The impacts described in existing literature suggesting that coral and sponge species may experience changes in behaviour (e.g. feeding, reproduction), fitness, and survival as a result of physical damage, exposure to chemicals, and/or excess sedimentation which result from exploratory drilling activities. While there is limited information available about the specific impacts of exploratory drilling on coral and sponges in the NL region, the literature review found that the effects caused by these activities could be wide-spread and longlasting. The avoidance of exploratory drilling in existing special areas that have been previously delineated based on the presence of coral and/or sponge species in high densities is essential for preserving biodiversity in NL region. This would include Significant Benthic Areas (SiBAs), VMEs, and any sites where the zone of influence from exploratory drilling would overlap SiBA or VME boundaries. The report recommends best practices such as: (i) relocation of exploratory drilling operations from SiBAs and VME habitats, (ii) use of dispersion models, baseline surveys, and visual surveys, (iii) recommendations for drilling and abandonment, and (iv) enhanced follow-up monitoring. Follow-up monitoring can be required to either verify the predicted impacts of exploration activities or determine the effectiveness of mitigation measures which were used during exploration. Baseline surveys may be used to ensure that changes in the chemical and biological aspects of the study area can be accurately recorded. The report outlined several methodologies that have been used in other regions to capture the impacts of oil and gas exploration on corals and sponges.

- According to OSPAR (Marappan et al., 2022), the pressures on the marine environment from oil and gas activities are as follows: (i) Produced water (PW); (ii) Chemicals, including plastics and microplastics; (iii) Naturally occurring radioactive materials; (iv) Drilling fluids and cuttings piles; (v) Installations and pipelines; (vi) Accidental spills; (vii) Atmospheric emissions; (viii) Light; (ix) Noise and (x) Carbon dioxide storage. In line with Cordes et al., (2016), OSPAR recognized that environmental impacts can occur throughout the lifecycle of oil and gas activities. OSPAR has put in place numerous measures aimed at reducing emissions and discharges from oil and gas industry with the OSPAR Maritime Area, particularly since 2000. Such measures have reduced oil in PW discharges and the use and discharge of chemicals and drilling fluids. In addition, with a few exceptions, OSPAR prohibited the disposal of disused offshore installations at sea. Evidence from monitoring and reporting indicates that the overall effect of these measures and their implementation has been to significantly improve the overall quality status of the OSPAR Maritime Area as a whole.
- NOAA (Limpinsel at al., 2023) compiled and reviewed the potential adverse effects of non-fishing activities on Essential Fish Habitats (EFH)<sup>21</sup> in the Alaska region. Sources of potential impacts to EFH offshore were described, including a specific section dedicated to oil and gas exploration and development. Potential impacts include: (i) Noise; (ii) Physical alterations to habitat; (iii) Waste discharges; (iv) Polycyclic aromatic hydrocarbons (PAH); (v) Oil spills, including mayor spills, small spills and chronic releases; (vi) Oil spill response methods (lethal and sublethal effects); and (vii) Platform storage and pipeline decommissioning. The authors also recommend conservation measures designed to avoid and minimize the adverse impacts of oil and gas exploration and development and to promote the conservation, enhancement, and proper function of EFH. Measures focused on the phase of exploration, may be of interest to the NRA: (i) During seismic surveys, use ramp-up procedures to allow fish to move away from the source before exposure to detrimental sound levels occur (NOAA, 2016). Use marine vibroseis instead of airguns when possible. Use the least powerful airguns that will meet the needs of the survey. Survey the smallest area possible to meet the needs of the survey; (ii) Schedule exploration and development activities when the fewest species and least vulnerable life stages are present. Establish appropriate work windows based on multiple season biological sampling. Recommended seasonal work windows are generally specific to regional or watershed-level environmental conditions and species requirements.
- Marine seismic surveys are a fundamental tool for oil and gas explorations. Noise from seismic surveys may affect a range of species (Affati and Camerlenghi, 2023 and references herein), such as marine mammals, fish and invertebrates.

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<sup>&</sup>lt;sup>21</sup> In the United States of America (USA), the federal fisheries law (Magnuson-Stevens Fishery Conservation and Management Act), defines EFH as "those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity", focused on federally managed species. Fisheries management includes the identification, designation and conservation of EFH. EFH not only includes water and hard substrate but also habitat and ecosystem processes that provide water quality, quantity, and nutrient resources essential for survival (e.g., migratory routes, open waters, coral reefs, etc.).

According to Carroll *et al.*, (2017), there is scientific evidence, in the literature, for sound-induced physical trauma and other negative effects on fish and invertebrates; however, the sound exposure scenarios in some cases are not realistic. They suggest that main challenges of seismic impact research are the translation of laboratory results to field populations over a range of sound exposure scenarios and the lack of sound exposure standardisation which hinders the identification of response thresholds. They also provided a graphical summary of the conceptual models showing the physical characteristics and variation related to sound propagation and the possible biological impacts of exposure to low-frequency sound. (Figure 13).



**Figure 13.** Conceptual models showing a) physical characteristics and variation regarding sound propagation through the water column and seabed, and b) potential biological impacts of low frequency sound exposure as described in main text. SL= Scallop larvae; LL = Lobster larvae. References can be found in the original paper: Figs. 3 (fish) and 4 (invertebrates). Figure not to scale. <u>Source</u>: Carroll *et al.*, (2017).

For example, while Meekan *et al.*, (2021) suggest that seismic surveys have little impact on an assemblage of tropical demersal fishes in shallow waters, van der Knaap *et al.*, (2021) observed changes in cod behavior. Cod exhibited disruptions of diurnal feeding activities, unraveling an issue that could potentially hinder

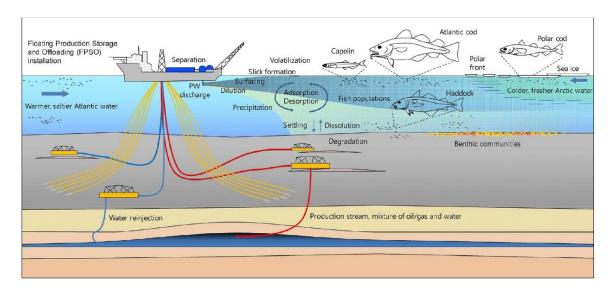
energy budgets leading to consequences at the population level. Although the impact of noise pollution in marine invertebrates is understudied, a recent exhaustive and systematic revision of literature conducted by Solé et al., (2023) provided evidence that anthropogenic noise is detrimental not only to these species but also to the natural ecosystems they inhabit. McCauley et al., (2017) presented evidences suggesting that sound from air gun surveys causes significant mortality to zooplankton populations. The significance and implications of potential large-scale modification of plankton community structure and abundance due to seismic survey operations has enormous ramifications for larval recruitment processes, all higher order predators and ocean health in general. Confirming this result, another recent study of zooplankton found exposure to seismic air guns resulted in increased mortality immediately after exposure (Vereide et al., 2023). A study was conducted with the aim to examine effects of seismic exploration on the commercial snow crab fishery along the Newfoundland (NL) continental slope (Cote, 2020; Hall et al., 2021; Morris et al., 2018; 2020). This research concluded that if seismic surveying impacts commercial snow crab, based on factors considered by the experiments, it is within the range of natural variability. It should be noted that the snow crab fishery only catches large terminally moulted mature male snow crab, and this study<sup>22</sup> did not explore potential impacts on juvenile or female snow crab. Conversely, a new study (Hall et al., 2023) identified biomarkers that were determined to be noise-responsive in both the laboratory and field setting that may be valuable for further studies of environmental stress impacts on snow crab in NL. The transcripts highlighted there were largely associated with stress and immune response, suggesting chronic noise may influence these responses in snow crab. While the identified transcripts may indicate potential mechanisms in which noise can influence snow crab physiology, linking these responses to fitness is still needed to fully understand the longer-term impacts of seismic activity on the snow crab in NL.

• The value of oil and gas infrastructure in secondary production and fisheries, particularly in deep waters, is controversial, but there is some evidence to suggest that this can occur. Infrastructures can also provide hard substratum for colonization by benthic invertebrates. These structures may enhance population connectivity and provide stepping stones for both native and potentially invasive species (Cordes et al., 2016 and references herein). This has been demonstrated for shallow-water invasive corals (e.g., Braga et al., 2021). Evidence for oil and gas structures facilitating vertical and horizontal seascape connectivity exists for larvae and mobile adult invertebrates, fish and megafauna (McLean et al., 2022), but the degree to which these structures represent a beneficial or detrimental net impact remains unclear, is complex and ultimately needs more research to determine the extent to which natural connectivity networks are conserved, enhanced or disrupted.

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<sup>&</sup>lt;sup>22</sup> The snow crab research did not address important questions related to eggs, larvae, or females for which many unanswered questions still remain.

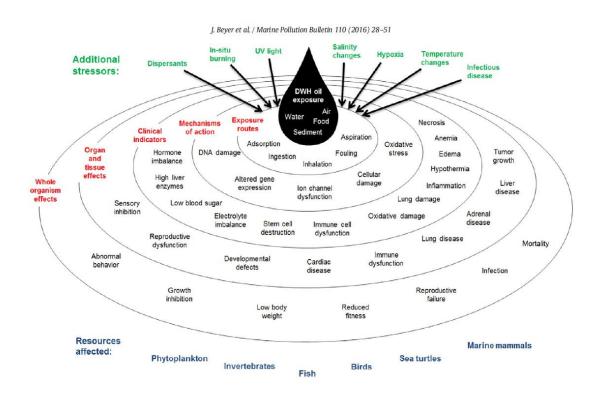
- According to Ronconi et al., (2015), the effects of platforms on birds include both direct and indirect lethal and sub-lethal effects. For seabirds and landbirds (particularly, migrating species), the most frequently observed effect is attraction and sometimes collisions and incinerations associated with lights and flares. Other effects include provision of foraging and roosting opportunities, increased exposure to oil and hazardous environments, increased exposure to predators, or repulsion from feeding sites.
- Environmental effects of oil and gas activities include impacts from routine operational activities such as drilling waste (Larsson and Purser, 2011) and produced water discharges (Neff et al., 2011; 2014), accidental discharges and spills (Cordes et al., 2016), long-term impacts on deep-sea corals (Fisher et al., 2014; Girard and Fisher, 2018) and deep-sea sponges and the habitats they form (Vad et al., 2018). In addition, offshore upstream oil and gas operations involve numerous activities that generate greenhouse gas (GHG) emissions (Watson, 2020): GHG emissions from combustion and venting and flaring are the most significant of those emitted, due to their volume and global impacts resulting in anthropogenic climate change, as well as specific impacts on the marine environment.
- Operational discharges from offshore oil and gas platforms are a continuous source of contaminants to continental shelf ecosystems (Bakke et al., 2013). Drill cuttings (Tornero and Hanke, 2016) and produced water (Beyer et al., 2020; Hansen, 2019; OSPAR, 2021) are the largest operational source of pollution (e.g., crude oil contamination) from the offshore petroleum industry. Beyer et al. (2020) provide a comprehensive graphical summary of the spread of produced water discharges and the exposure of downstream ecosystems (Figure 14). In addition to the natural pollutants in the oil, potentially hazardous production chemicals are also discharged. Effects are generally local (Bakke et al., 2013; OSPAR, 2021) but persistent (Gates et al., 2017). Exposure to produced water at concentrations corresponding to the levels in the plume at close distances from the discharge point, can be detected in fish and mussels in laboratory experiments and in field studies indicating modest impacts (OSPAR, 2021). Haddock and cod larvae subjected to embryonic exposure to produced water extracts were smaller, and displayed signs of cardiotoxicity and body deformations, with more larvae displaying higher severity in haddock compared to cod (Hansen, 2019). Drill cuttings affect Lophelia larvae, but there is an agedependent difference in sensitivity of larvae (Järnegren et al., 2017). They also produce local decline of echinoids (Hughes et al., 2010) and meiofauna, probably related to physical changes in the substrate (Netto et al., 2009). Connectivity can also exacerbate harmful effects of human activities, such as the spread of pollutants trough a food web or ecosystem (DOSI, 2020; Popova et al., 2019).



**Figure 14.** Produced water (PW) discharged from offshore oil and gas production will spread with oceanic currents, forming a continuously diluting plume that exposes downstream ecosystems (illustrated by a simplified Barents Sea system) to the components of PW. <u>Source</u>: Beyer *et al.*, (2020).

- There is evidence for the toxicity of both oil and dispersant on deep-water corals (De Leo et al., 2016 and references herein) and sponges. Global ocean change can affect the resilience of corals to environmental stressors, and the exposure to dispersants may pose a greater threat than oil itself (Weinnig, 2020). Larvae of sponge survived exposure to high concentrations of petroleum hydrocarbons; however, their ability to settle and metamorphose was adversely affected at environmentally relevant concentrations, and these effects were paralleled by marked changes in sponge gene expression and preceded by disruption of the symbiotic microbiome (Luter et al., 2019). The use of dispersants increases the risk posed by hydrocarbon contamination to sponges and should therefore be limited within areas rich in sponges (Vad et al., 2020) or that contain sponge grounds (Vad et al., 2022).
- Oil and gas exploitation introduce toxic contaminants to the surrounding sediment, resulting in deleterious impacts on marine benthic communities. In the North Sea, contamination from oil and gas platforms caused declines in benthic food web complexity, community abundance, and biodiversity at local level (Chen et al., 2024).
- In April 2010 the Deepwater Horizon (DWH) offshore oil rig exploded, releasing an estimated 760 million litres of crude oil into the Gulf of Mexico. As is noted in The First Global Integrated Marine Assessment of UN (Harris *et al.*, 2016), a study of accidental oil spills based on global historical data has shown that the DHW accident was not an outlier, but an accident that can happen every 17 years with an uncertainty interval from 8 to 91 years (5–95%). When the DWH accident was excluded from the data set, the resulting frequency was 23 years with an uncertainty interval from 10 to 177 years (Eckle *et al.*, 2012).

• Effects-oriented studies related to the DWH oil spill (Beyer et al., 2016) demonstrated that the oil was toxic to a wide range of organisms (plankton, invertebrates, fish, birds, and sea mammals), causing a wide array of adverse effects (reduced growth, disease, impaired reproduction, impaired physiological health, and mortality). Both oil exposure and spill response actions caused injuries to a wide range of habitats, species and ecological functions over a vast area. The authors provide a comprehensive graphical summary of the biological effects of the DWH oil spill (Figure 14).



**Figure 14.** Biological effects of the Deepwater Horizon oil spill (DWH). This conceptual figure illustrates the constellation of relationships between oil exposure and toxicological effects in organisms affected by the DWH oil spill. All exposure and effect elements shown in this figure are supported by information in the DWH oil spill research literature. Illustration adapted and extended from DWH NRDA (2015). <u>Source</u>: Beyer *et al.*, (2016).

• Studies on the effects of DWH oil spill, indicate that many years are required for moderately to heavily impacted corals to recover, and that some coral colonies may never recover. As a consequence of the DWH blowout (Fisher et al., 2016), oil was incorporated into the pelagic food web, and a reduction in planktonic grazers led to phytoplankton blooms. Fish larvae were killed. Cetaceans were killed, and many avoided the area of the spill. In the benthic realm, there was a large loss of diversity of soft-bottom infauna, which were still not recovering a year after the DWH oil spill. Colonial octocorals that are anchored to the hard seafloor and are especially vulnerable to anthropogenic impact, died as a result of being covered with flocculent material containing oil and dispersant. Soft and

hard-bottom effects of the oil spill were found as much as 14 km away from the wellhead site.

- The coexistence of fisheries and oil and gas activities can create competition and conflicts as Arbo and Thuy (2016) suggest. The potential issues include limited access to valuable areas, damage of gear and pipelines, navigational hazards due to installations and increased traffic congestion, etc. Environmental and resource use conflicts are frequently about the access to and use of natural resources and space and the distribution of the associated benefits and costs. They can also be about the harm that different co-located activities inflict upon each other through operational or ecosystem impact. They concluded that resolving use conflicts is a central issue in the context of ecosystem-based management, especially in densely used areas. For the industries involved, this is important for avoiding intractable conflicts, but it is also important for the health of the ecosystems. The potential development of new offshore oil and gas activities in fishing areas is a controversial issue not only in the Northwest Atlantic. For example, Misund and Olsen (2013) examined the issue of opening up the Lofoten-Vesterålen areas (Norway) to offshore oil and gas exploration. They reviewed the arguments for and against and concluded that these valuable areas should not be opened to such activity due to their great biological importance, as they host main spawning grounds for important fish stocks (e.g. cod), in addition to sensitive benthic habitats, seabird colonies and marine mammal populations.
- A study in the Gulf of Mexico revealed that, incidents, such as blowouts, injuries, and oil spills, are positively correlated with deeper water (Muehlenbachs et al., 2013). Climate change may affect oil and gas facilities and operations (e.g., damage to pipelines and platforms) both in coastal areas and in the outer continental shelf, due to more intense storms and higher winds and waves (Burkett, 2011).

Sub-task 3.4: Description of the institutional landscape for DSF and oil and gas sectors and identify gaps and opportunities for collaboration between management authorities, with focus on VME protection

## Management of deep-sea fisheries and oil and gas activities in the study area

Table 4 summarizes the institutional framework for deep-sea fisheries and oil and gas activities in the NRA. There is no integrated management of human activities in the study area and each sector is managed independently.

**Table 4.** Summary of the management framework in the study area regarding deep-sea fisheries and offshore oil and gas.

Sector of activity	Deep-sea fisheries (NAFO managed stocks)	Offshore oil and gas (e.g., exploration, exploitation)	
Management authority	NAFO <sup>23</sup>	C-NLOPB <sup>24</sup> ; IAAC <sup>25</sup>	
Zoning and jurisdiction	High seas (international water column); Areas beyond national jurisdiction	Continental shelf (seabed and subsoil); Areas within national jurisdiction	
Spatial boundary	NAFO Regulatory Area (NRA)	Canada-Newfoundland and Labrador offshore area (Offshore Area)	
Operational level	International (12 Contracting Parties): NAFO (Regional Fisheries Management Organization)	Coastal State: C-NLOPB (Board); IAAC (Agency)	
General management objectives	NAFO: Long term conservation and sustainable use of the fishery resources and to safeguard the marine ecosystems.	C-NLOPB: To facilitate the exploration for and development of the petroleum resources, including safety, environmental protection, resource management and industrial benefits. IAAC: Impact assessment process. Deliver high-quality impact assessments that contribute to informed decision-making on major projects in support of sustainable development.	
Management and assessment tools	NAFO Conservation and Enforcement Measures, including bottom fishing closures to protect VMEs and delineation of existing bottom fishing areas (footprint) to regulate bottom fisheries that cause a Significant Adverse Impact (SAI) on VMEs; NAFO Road Map to Ecosystem Approach Framework; Assessment of bottom fisheries (SAI assessment).	C-NLOPB management mandate under the Accord Acts; Licences and authorizations; Strategic Environmental Assessments (SEA); Regional Assessment under IAAC; Environmental Assessments (EAs):  • Accords Acts EAs: Required and led by the C-NLOPB under the Accords Acts.  • Designated projects EAs: For projects requiring EAs triggered under IAA <sup>26</sup> 2019 and previously CEAA <sup>27</sup> 2012. They are managed by the IAAC.	

<sup>&</sup>lt;sup>23</sup> Northwest Atlantic Fisheries Organization (source: https://www.nafo.int/).

<sup>&</sup>lt;sup>24</sup> The Canada-Newfoundland and Labrador Offshore Petroleum Board (C-NLOPB) was initiated in 1985 to manage resources in the Newfoundland Labrador offshore area on behalf of the Newfoundland Labrador and Canadian governments (source: https://www.cnlopb.ca).

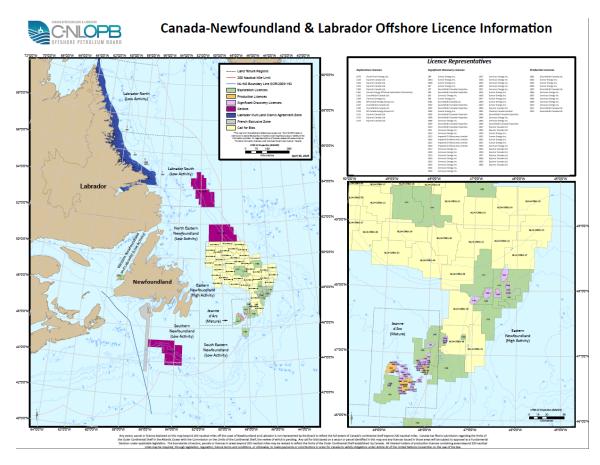
<sup>&</sup>lt;sup>25</sup> In 1994, the Canadian Environmental Assessment Agency was established to prepare for the implementation of the Canadian Environmental Assessment Act, 1992 (CEAA 1992). In 2019, the Impact Assessment Act (IAA) was enacted which created the Impact Assessment Agency of Canada (IAAC) (federal body) and repealed the Canadian Environmental Assessment Act, 2012 (source: https://www.canada.ca/en/impact-assessment-agency.html).

<sup>&</sup>lt;sup>26</sup> Impact Assessment Act.

<sup>&</sup>lt;sup>27</sup> Canadian Environmental Assessment Act.

Bottom fisheries in the NRA (high seas; Figure 1) are managed by NAFO, including the delineation of existing bottom fishing areas (footprint) to regulate bottom fisheries that cause a Significant Adverse Impact (SAI) on VMEs, and the implementation of bottom fishing closures to protect VMEs. NAFO conduct assessments of the risk of Significant Adverse Impacts (SAIs) from bottom fishing activities on VMEs every five years.

Offshore oil and gas activities in the Newfoundland and Labrador Offshore Area (continental shelf; Figure 15) are managed by the Canada-Newfoundland and Labrador Offshore Petroleum Board (C-NLOPB), an independent joint agency of the Governments of Canada and Newfoundland and Labrador.



**Figure 15.** Map of the Newfoundland and Labrador Offshore Area showing licence information. Source: C-NLOPB web site. See: <a href="https://www.cnlopb.ca/exploration/">https://www.cnlopb.ca/exploration/</a>. Accessed on 27/06/2024.

The C-NLOPB manages the petroleum resources on behalf of the Government of Canada and the Government of Newfoundland and Labrador. The Board's responsibilities<sup>28</sup> include: (i) granting and administering offshore areas interests, (ii) authorizing seismic and drilling programs; and (iii) declaring significant and commercial discoveries. The C-NLOPB assesses<sup>29</sup> the potential environmental effects of petroleum related work or activity proposed for the Offshore Area. In accordance with their responsibilities under the Accord Acts and the hoc section of the Impact Assessment Act (IAA 2019), the C-NLOPB undertakes an Environmental Assessment (EA) of petroleum activities proposed

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<sup>&</sup>lt;sup>28</sup> See: https://www.gov.nl.ca/iet/energy/petroleum/offshore/cnlopb/

<sup>&</sup>lt;sup>29</sup> See: https://www.cnlopb.ca/assessments/

for the Offshore Area for which an EA, pursuant to IAA 2019, is not required. EAs required and led by the C-NLOPB are referred to as Accord Act EAs. In accordance with its responsibilities under ad hoc section of the IAA 2019, the C-NLOPB provides specialist or expert information or knowledge to the Impact Assessment Agency of Canada (IAAC) for designated projects requiring environmental assessment triggered under the IAA 2019, and for projects initiated under the previous legislation, Canadian Environmental Assessment Act (CEAA 2012) and continuing under IAA 2019. Designated Projects under IAA 2019 and previously CEAA 2012 are managed by the IAAC. C-NLOPB maintains a publicly accessible record of oil spills and other incidents (Table 5).

**Table 5.** Summary of relevant offshore oil spills and other incidents in the NW Atlantic. 2015-2023 period. The complete list can be consulted on the C-NLOPB website<sup>30</sup> (sources: a: C-NLOPB website; b: NAFO).

Date	Incident description	Observations	Source
20/07/2020	Unauthorized Discharge (Hibernia Platform)	Produced water discharge (mixture of seawater from the reservoir/used in injection, drilling and production fluids). The volume of the discharge and its composition are being determined	
18/06/2020	Unauthorized discharge (SeaRose FPSO)	1,098 litres of an anti-microbial agent (X-Cide 450) was released along with 1,916,000 litres of water that were intended for reservoir injection.	
17/08/2019	Hibernia Oil Spill	Estimated volume of oil on the water was 2,184 L at that time	а
17/07/2019	Hibernia Oil Spill	Oil expressed on the water could be in the order of 12,000 L. It occurred inside Canadian EEZ, but the analysis indicated that the oil was extended outside the EEZ and into the NAFO Regulatory Area	a, b <sup>31</sup>
16/10/2018	White Rose Field Oil Spill	250,000 L of oil were released to the environment	a
27/04/2018	Unauthorized discharge of Synthetic Based Mud (SBM) (Transocean Barents platform)	28,000 L of SBM was released to the environment	а
29/03/2017	Near Miss - Iceberg Approaches Close to the SeaRose Floating Production, Storage and Offloading (FPSO) Vessel	A medium size iceberg came within 180 meters of the FPSO (about 340,000 barrels of crude oil on board at that time)	a
15/07/2016	Unauthorized discharge/Impairment of safety critical equipment (Henry Goodrich drilling)	Approximately 1,800 L of hydraulic fluid was released to the environment	а
15/02/2016	Unauthorized discharge of glycol (West Aquarius)	1,317 L of glycol was released to the sea	а
30/09/2015	Unauthorized discharge of methanol (Terra Nova field)	3,000 L of methanol was released to the sea	a

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 $<sup>^{30}</sup>$  Hydrocarbon spills that are equal to or under one litre, unauthorized gaseous releases and unauthorized discharges are reported in aggregate on a quarterly basis on the C-NLOPB website.

<sup>&</sup>lt;sup>31</sup> Letter from Fisheries and Oceans Canada sent to NAFO, 23 July 2019 (Ref.NAFO/19-205)

Date	Incident description	Observations	Source
31/08/2015	Major hydrocarbon gas release (Southern drill center)	8,938 kg of natural gas was released to the sea	
28/07/2015	Major hydrocarbon gas release (Terra Nova FPSO)	10,000 kg of gas was released	
03/03/2015	Spill from the P78 (Mizzen) oil well, located in the northern Flemish Pass (approx. 11 km west of NAFO Closure 10A)	14,000 L of synthetic-based drilling mud was spilled	a, b <sup>32</sup>

## Gaps and opportunities for collaboration

There is little collaboration between sectors in trying to implement consistent areabased management tools to protect VMEs (e.g., area closures). This can be seen for example in the case of Area No. 10. This area is currently closed to bottom fishing, but is open to other human activities and some exploration wells have been drilled for hydrocarbons (See sub-task 3.2). In this regard, Diz et al., (2018) suggest that these particular closures, are not effective for the purposes of CBD Aichi Biodiversity Targets 11-10 on avoidance or minimization of anthropogenic impacts on ecosystems vulnerable to climate change and ocean acidification. Furthermore, Gullage et al., (2022) indicate that the avoidance of exploratory drilling in existing special areas that have been previously delineated (e.g., VMEs), is essential for preserving biodiversity in the region. They recommend, as best practices, the relocation of exploratory drilling operations from VME and other existing special areas.

In this case, cross-sectoral collaboration could probably be beneficial for improving VME conservation in the long term. A collaboration to identify VMEs, and to assess the potential impacts of both sectors, could lead to more effective and coherent spatial protection measures. For example, Bravo *et al.*, (2023) proposed criteria for carrying out impact assessments at different phases of development of offshore oil and gas activities, adapted to the specific features of such industry, from the criteria recommended by FAO (2009) for impact assessments in deep-sea fisheries, and supplemented with the focus on ecosystem services.

There is also scope for possible cross-sectoral collaborations in sharing data from different sources. In the same way that information on fishing effort (from vessel monitoring system) and distribution of fisheries resources and VMEs (from fisheries research surveys) can be useful for planning oil and gas activities (e.g., avoidance of exploratory drilling in existing special areas such as VMEs), information from ground-truthing surveys (visual surveys) of the oil and gas industry can be useful for improving knowledge of VMEs for conservation purposes.

Finally, cross-sectoral collaboration could help advance the process of identifying, assessing and reporting OECMs, including multi-sectoral areas (See sub-task 3.2). Cross-sectoral collaboration would enable a multi-sectoral, integrated and collaborative OECM process, as recommended by FAO (2O22), when several uses exist.

<sup>&</sup>lt;sup>32</sup> SCS Doc. 16/21 See: https://www.nafo.int/Portals/0/PDFs/sc/2016/scs16-21.pdf?ver=2017-06-20-114008-080

Sub-task 3.5: Identify gaps in research and priority challenges regarding scientific monitoring and mitigation of potential impacts of activities other than fishing in NAFO Divs. 3LMNO

## **Lessons learned**:

- Information on the monitoring of oil spills and discharges (including transboundary spills), geophysical surveys (e.g. seismic) and drilling activity in the study area (Table 5), as well as their impacts and the mitigation measures implemented, is scarce or difficult to find.
- The available information on scientific research on oil and gas activities in the study area, is generally focused on the Grand Banks of Newfoundland (e.g. drilling monitoring programmes and studies on the effects of seismic surveys on snow crab).
- There are also some studies on effects of noise on groundfish, as well as
  development of methods to assess abandoned wells (Grand Bank and
  Newfoundland slope), but these studies are ongoing and their results are not yet
  available. It is important to have the results of these investigations available
  when they are completed.
- However, little information is available on the deep waters of the Flemish Pass and Flemish Cap (Divisions 3LM), which is an area of great interest in the context of NAFO fisheries, VMEs and closed areas, and which has supported significant oil and gas exploration activity in recent years.
- Although there is relevant information in the literature on different offshore and coastal areas subject to routine oil and gas activities and accidental events, there is little specific scientific data to determine the exact impact of such activities on commercial fishery resources or their important habitats in the NAFO Convention Area. This is an information gap that would need to be filled in order to properly assess the impact of oil and gas activities on fisheries.
- Access to data and analysis from oil and gas monitoring programmes carried out in the NAFO Convention Area would be necessary (e.g., monitoring and good practices in geophysical surveys, exploratory drilling, routine activities, discharges, etc.). Experts in marine environmental impact assessment of activities other than fishing (e.g. oil and gas) are also needed to assess such information.
- Information is needed on methodologies for calculating cumulative impacts, as well as the data and experts needed to prepare such assessments.
- It will be necessary to develop monitoring programs and indicators that could be used to assess the possible threats of oil and gas activities on VMEs and fishery resources.

- The available mapping information is very useful and necessary to visualise the
  distribution of oil and gas activities, to monitoring the evolution over time
  (trends), to assess overlaps and to reveal possible conflicts user-user and userenvironment. Although this information is not sufficient to fully assess impacts,
  it is important that it continues to be included in the Ecosystem Summary Sheets.
- Cross-sectoral collaboration is needed to successfully address the potential impacts of activities other than fishing.

#### **REFERENCES OF TASK 3**

- Abalo-Morla, S., Palas Otero, S., Román-Marcote, E., Durán Muñoz, P., Pérez, P., and Sacau, M. (2024). Preliminary results on seabed litter distribution on Flemish Cap (Div. 3M), Flemish Pass (Div. 3L) and Grand Banks of Newfoundland (Divs. 3NO). NAFO SCR Doc. 24/046. Serial No. N7553.
- Abalo-Morla S., Neves, B.M., Hayes V., Sacau, M., Command, R.J., and Durán Muñoz, P. (2023). New preliminary data on VME encounters in NAFO Regulatory Area (Divs. 3LMNO) from EU; EU-Spain and Portugal Groundfish Surveys (2023) and Canadian surveys (Fall 2022 & Spring 2023). NAFO SCR Doc. 23/055. Serial No. N7485. https://www.nafo.int/Portals/0/PDFs/sc/2023/scr23-055.pdf
- Affatati, A. and Camerlenghi, A. (2023). Effects of marine seismic surveys on free-ranging fauna: a systematic literature review. Front. Mar. Sci. 10:1222523. https://doi.org/10.3389/fmars.2023.1222523
- AMEC (2014). Eastern Newfoundland Strategic Environmental Assessment. Final Report for Canada-Newfoundland and Labrador Offshore Petroleum Board.
- Arbo, P. and Thuy P.T.T. (2016). Use conflicts in marine ecosystem-based management The case of oil versus fisheries. Ocean & Coastal Management. 122. 77-86. https://doi.org/10.1016/j.ocecoaman.2016.01.008.
- Bakke, T., Klungsøyr, J., and Sanni, S. (2013). Environmental impacts of produced water and drilling waste discharges from the Norwegian offshore petroleum industry. *Marine environmental research*, *92*, 154-169.
- Bravo, M.E., Brandt, M.I.., van der Grient, J.M.A., Dahlgren, T.G., Esquete, P., Gollner, S., Jones, D.O.B., Levin, L.A., McClain, C.R., Narayanaswamy, B.E., Sutton, T., Victorero, L., and Cordes, E.E. (2023). Insights from the management of offshore energy resources: Toward an ecosystem-services based management approach for deepocean industries. Front. Mar. Sci. 9:994632. https://doi.org/10.3389/fmars.2022.994632.
- Braga, M. D. A., Paiva, S. V., de Gurjão, L. M., Teixeira, C. E. P., Gurgel, A. L. A. R., Pereira, P. H. C., and de Oliveira Soares, M. (2021). Retirement risks: Invasive coral on old oil platform on the Brazilian equatorial continental shelf. Marine Pollution Bulletin, 165, 112156.
- Beyer, J., Goksøyr, A., Hjermann, D. Ø., and Klungsøyr, J. (2020). Environmental effects of offshore produced water discharges: A review focused on the Norwegian continental shelf. *Marine environmental research*, 162, 105155

- Beyer, J., Trannum, H. C., Bakke, T., Hodson, P. V., and Collier, T. K. (2016). Environmental effects of the Deepwater Horizon oil spill: a review. *Marine pollution bulletin*, *110*(1), 28-51.
- Burkett, V. (2011). Global climate change implications for coastal and offshore oil and gas development. *Energy policy*, 39(12), 7719-7725
- Carroll, A.G., Przeslawski, G., Duncan, A., Gunning, M.and Bruce, B. (2017). A critical review of the potential impacts of marine seismic surveys on fish & invertebrates, Marine Pollution Bulletin, 114(1): 9-24. https://doi.org/10.1016/j.marpolbul.2016.11.038
- Casale, P., and Tucker, A.D. (2017). *Caretta caretta* (amended version of 2015 assessment). The IUCN Red List of Threatened Species 2017: e.T3897A119333622. https://dx.doi.org/10.2305/IUCN.UK.2017-2.RLTS.T3897A119333622.en. Accessed on 29 May 2024.
- Cassotta, S. and Goodsite, M. (2024). Deep-seabed mining: an environmental concern and a holistic social environmental justice issue. Front. Ocean Sustain. 2:1355965. <a href="https://doi.org/10.3389/focsu.2024.1355965">https://doi.org/10.3389/focsu.2024.1355965</a>
- CBD (2018). Decision 14/8 Protected areas and Other Effective Area-based Conservation Measures. 14th Meeting of the Conference of the Parties to the Convention on Biological Diversity, 17-29 November, Sharm El-Sheikh, Egypt. CBD/COP/DEC/14/8: 19 pp. <a href="https://www.cbd.int/doc/decisions/cop-14/cop-14-dec-08-en.pdf">https://www.cbd.int/doc/decisions/cop-14/cop-14-dec-08-en.pdf</a>.
- Chen, Z., Cameron, T. C., Couce, E., Garcia, C., Hicks, N., Thomas, G. E., *et al.*, (2024). Oil and gas platforms degrade benthic invertebrate diversity and food web structure. *Science of the Total Environment*, *929*, 172536.
- Christiansen, S., Durussel, C., Guilhon, M., Singh, P., and Unger, S. (2022). Towards an ecosystem approach to management in areas beyond national jurisdiction: REMPs for deep seabed mining and the proposed BBNJ instrument. Front. Mar. Sci. 9:720146. https://doi.org/10.3389/fmars.2022.720146
- Combes, M., Vaz S., Grehan, A., Morato, T., Arnaud-Haond, S., Dominguez-Carrió, C., Fox, A., González-Irusta, J.M., Johnson, D., Callery, O., Davies, A., Fauconnet, L., Kenchington, E., Orejas, C., Roberts, J.M., Taranto, G., Meno,t L. (2021). Systematic Conservation Planning at an Ocean Basin Scale: Identifying a Viable Network of Deep-Sea Protected Areas in the North Atlantic and the Mediterranean, Frontiers in Marine Science, 8. <a href="https://doi.org/10.3389/fmars.2021.611358">https://doi.org/10.3389/fmars.2021.611358</a>
- Cordes, E.E., Jones, D.O.B., Schlacher, T.A., Amon, D.J., Bernardino, A.F., Brooke, S., Carney, R., DeLeo, D.M., Dunlop, K.M., Escobar-Briones, E.G., Gates, A.R., Génio, L., Gobin, J., Henry, L.-A., Herrera, S., Hoyt, S., Joye, M., Kark, S., Mestre, N.C., Metaxas, A., Pfeifer, S., Sink, K., Sweetman, A.K., Witte, U. (2016). Environmental impacts of the deep-water oil and gas industry: a review to guide management strategies. Frontiers in Environmental Science 4. https://doi.org/10.3389/fenvs.2016.00058.
- Cote, D., Morris, C. J., Regular, P. M., & Piersiak, M. G. (2020). Effects of 2D seismic on snow crab movement behavior. Fisheries research, 230, 105661.

- Danovaro, R., Bianchelli, S., Brambilla, P., Brussa, G., Corinaldesi, C., Del Borghi, A., Dell'Anno, A., Fraschetti, S., Greco, S., Grosso, M., Nepote, E., Rigamonti, L., and Boero, F. (2024). Making eco-sustainable floating offshore wind farms: Siting, mitigations, and compensations, Renewable and Sustainable Energy Reviews, 197, 114386. https://doi.org/10.1016/j.rser.2024.114386
- De Leo, D. M., Ruiz-Ramos, D. V., Baums, I. B., and Cordes, E. E. (2016). Response of deep-water corals to oil and chemical dispersant exposure. *Deep Sea Research Part II: Topical Studies in Oceanography*, 129, 137-147.
- De Santo, E. M. (2018). Implementation challenges of area-based management tools (ABMTs) for biodiversity beyond national jurisdiction (BBNJ). Marine Policy, 97, 34-43
- DWH-NRDA (2015). Deepwater Horizon Natural Resource Damage Assessment (NRDA) DRAFT 2015 section 4. Injury to Natural Resources. DWH-NRDA, p. 685.
- Diz, D., Johnson, D., Riddell, M., Rees, S., Battle J., Gjerde, K., Hennige, S., and Roberts, J.M. (2018). Mainstreaming marine biodiversity into the SDGs: The role of other effective area-based conservation measures (SDG 14.5), Marine Policy, 93: 251-261. https://doi.org/10.1016/j.marpol.2017.08.019.
- DOSI (2020). Ecological Connectivity: Implications for Ocean Governance. DOSI policy brief position paper. Available online at: https://www.dosi-project.org/wp-content/uploads/DOSI-Connectivity\_brief\_Feb2020.pdf
- Durán Muñoz, P., Abalo-Morla, S., Palas Otero, S., and Sacau, M. (2024). Preliminary results from a desk-based study on activities other than fishing in the NRA: Interactions between oil and gas activities, deep-sea fisheries and VMEs NEREIDA Task 3. NAFO SCR Doc. 24/047. Serial No. N7554.
- Durán Muñoz, P., and Sacau, M. (2021). Information on activities other than fishing (offshore oil and gas) in the NAFO Convention Area: Implications for the development of the Ecosystem Summary Sheets (Divisions 3LNO and 3M). NAFO SCR Doc. 21/051. pp 9.
- Durán Muñoz, P., Sacau, M., Román-Marcote, E., and García-Alegre, A. (2020a). A theoretical exercise of Marine Spatial Planning in the Flemish Cap and Flemish Pass (NAFO Divs. 3LM): implications for fisheries management in the high seas. NAFO SCR Doc. 20/022. pp 25.
- Durán Muñoz, P., Sacau, M., García-Alegre, A., and Román, E. (2020b). Cold-water corals and deep-sea sponges by-catch mitigation: Dealing with groundfish survey data in the management of the northwest atlantic ocean high seas fisheries. Marine Policy, 116(103712). <a href="https://doi.org/10.1016/j.marpol.2019.103712">https://doi.org/10.1016/j.marpol.2019.103712</a>
- Durán Muñoz, P., Sayago-Gil, M, Murillo, FJ, Del Rio, JL, López-Abellán, LJ, Sacau, M and Sarralde, R (2012). Actions taken by fishing Nations towards identification and protection of vulnerable marine ecosystems in the high seas: the Spanish case (Atlantic Ocean). Marine Policy 36, 536-543.
- Eckle, P., Burgherr, P., and Michaux, E. (2012). Risk of large oil spills: a statistical analysis in the aftermath of Deepwater Horizon. Environmental Science and Techonology 46:13002-13008.

- Equinor Canada Ltd. (2020). Bay du Nord Development Project Environmental Impact Statement. Prepared by Wood Environment & Infrastructure Solutions and Stantec Consulting. St. John's, NL Canada. July 2020.
- FAO (2022). A handbook for identifying, evaluating and reporting other effective areabased conservation measures in marine fisheries. Rome. <a href="https://doi.org/10.4060/cc3307en">https://doi.org/10.4060/cc3307en</a>
- FAO (2016). Vulnerable Marine Ecosystems: Processes and Practices in the High Seas. FAO Fisheries and Aquaculture Technical Paper No. 595. Rome: Food and Agriculture Organization of the United Nations (FAO). <a href="http://www.fao.org/3/a-i5952e.pdf">http://www.fao.org/3/a-i5952e.pdf</a>
- Fisher, C. R., Montagna, P. A., & Sutton, T. T. (2016). How did the Deepwater Horizon oil spill impact deep-sea ecosystems? Oceanography, 29(3), 182-195.
- Fisher, C.R., Hsing, P.Y., Kaiser, C.L., Yoerger, D.R., Roberts, H.H., Shedd, W.W., Cordes, E.E., Shank, T.M., Berlet, S.P., Saunders, M.G., Larcom, E.A., Brooks, J.M. (2014). Footprint of Deepwater Horizon blowout impact to deep-water coral communities. Proc Natl Acad Sci U S A. 2014 Aug 12;111(32):11744-9. https://doi.org/10.1073/pnas.1403492111.
- García, S., Rice, J., Charles, A., and Diz, D. (2020). OECMs in Marine Capture Fisheries: Systematic approach to identification, use and performance assessment in marine capture fisheries. Fisheries Expert Group of the IUCN Commission on Ecosystem Management, Gland, Switzerland. European Bureau of Conservation and Development, Brussels, Belgium: 87 p. Available at www.ebcd.org/feg.
- Gary, S.F., Fox, A.D., Biastoch, A., Roberts, J.M., and Cunningham, S.A. (2020). Larval behaviour, dispersal and population connectivity in the deep sea. Sci. Rep. 10:10675. https://doi.org/10.1038/s41598-020-67503-7
- Gates, A. R., Benfield, M. C., Booth, D. J., Fowler, A. M., Skropeta, D., and Jones, D. O (2017). Deep-sea observations at hydrocarbon drilling locations: Contributions from the SERPENT Project after 120 field visits. *Deep Sea Research Part II: Topical Studies in Oceanography*, 137, 463-479.
- GEBCO Bathymetric Compilation Group 2023 (2023). The GEBCO\_2023 Grid a continuous terrain model of the global oceans and land. NERC EDS British Oceanographic Data Centre NOC. <a href="https://doi.org/10.5285/f98b053b-0cbc-6c23-e053-6c86abc0af7b">https://doi.org/10.5285/f98b053b-0cbc-6c23-e053-6c86abc0af7b</a>
- Girard, F. and Fisher, C. (2018). Long-term impact of the Deepwater Horizon oil spill on deep-sea corals detected after seven years of monitoring. Biological Conservation 225, 117-127. https://doi.org/10.1016/j.biocon.2018.06.028.
- González-Costas, F., Ramilo, G., Román, E., Lorenzo, J., González-Troncoso, D., Sacau, M., Duran, P., Del Rio, J.L., Blanco, R, and Garrido, I. (2024). Spanish Research Report for 2023. Serial No N 7504. NAFO SCS Doc. 24/08
- Guerin, B. (2019). Long Distance Fleet Advisory Council (LDAC) Strategic Report №1
  Performance Review 2016-2018. <a href="https://ldac.eu/images/LDAC web-compressed Performance Review.pdf">https://ldac.eu/images/LDAC web-compressed Performance Review.pdf</a>

- Gullage L, Hayes V, Neves BM, Wells N, Cyr F, Murillo FJ (2022). Avoidance and Mitigation of Coral and Sponge Species During Exploratory Drilling Activities Offshore Newfoundland and Labrador. DFO Can. Sci. Advis. Sec. Res. Doc. 2022/059. vii + 141 p. <a href="https://publications.gc.ca/collections/collection-2022/mpo-dfo/fs70-5/Fs70-5-2022-059-eng.pdf">https://publications.gc.ca/collections/collection-2022/mpo-dfo/fs70-5/Fs70-5-2022-059-eng.pdf</a>
- Hall, J. R., Lehnert, S. J., Gonzalez, E., Hanlon, J. M., Kumar, S., Morris, C. J., and Rise, M. L. (2023). Snow crab (*Chionoecetes opilio*) hemocytes and hepatopancreas transcriptomes: identification, validation, and application of immune-relevant biomarkers of exposure to noise. Frontiers in Marine Science, 10, 1198036.
- Hall, J. R., Lehnert, S. J., Gonzalez, E., Kumar, S., Hanlon, J. M., Morris, C. J., and Rise, M. L. (2021). Snow crab (*Chionoecetes opilio*) hepatopancreas transcriptome: Identification and testing of candidate molecular biomarkers of seismic survey impact. Fisheries Research, 234, 105794.
- Hansen, B. H., Sørensen, L., Størseth, T. R., Nepstad, R., Altin, D., Krause, D., et al., (2019). Embryonic exposure to produced water can cause cardiac toxicity and deformations in Atlantic cod (Gadus morhua) and haddock (Melanogrammus aeglefinus) larvae. *Marine environmental research*, 148, 81-86.
- Harris, P., Alo, B., Bera, A., Bradshaw, M., Coakley, B., Grosvik, B. E., Lourenço, N., Renya Moreno, J., Shrimpton, M., Simcock, A., and Singh, A. (2016). Offshore hydrocarbon industries. The First Global Integrated Marine Assessment. United Nations, New York.
- Harris P.T., Macmillan-Lawler M, Rupp J, and Baker EK (2014). Geomorphology of the oceans. Marine Geology, 352: 4-24. <a href="https://doi.org/10.1016/j.margeo.2014.01.011">https://doi.org/10.1016/j.margeo.2014.01.011</a>
- Hughes, S. J. M., Jones, D. O. B., Hauton, C., Gates, A. R., and Hawkins, L. E. (2010). An assessment of drilling disturbance on *Echinus acutus* var. norvegicus based on in-situ observations and experiments using a remotely operated vehicle (ROV). *Journal of Experimental Marine Biology and Ecology*, 395(1-2), 37-47.
- IAAC (2021). Environmental Assessment Report Bay du Nord Development Project. December 2021. Assessment Agency of Canada, Ottawa, Ontario. 225 pp.
- IUCN (2021). The IUCN Red List of Threatened Species 2021.
- IUCN (2019). The IUCN Red List of Threatened Species 2019.
- IUCN (2018). The IUCN Red List of Threatened Species 2018.
- Järnegren, J., Brooke, S., and Jensen, H. (2017). Effects of drill cuttings on larvae of the cold-water coral Lophelia pertusa. *Deep Sea Research Part II: Topical Studies in Oceanography*, 137, 454-462.
- Kaiser, M.J. (2021). A Review of Exploration, Development, and Production Cost Offshore Newfoundland. Natural Resources Research, 30: 1253–1290. <a href="https://doi.org/10.1007/s11053-020-09784-3">https://doi.org/10.1007/s11053-020-09784-3</a>
- Kenchington, E., Lirette C., Murillo, .FJ., Beazley, L., and Downie, A.-L. (2019a). Vulnerable Marine Ecosystems in the NAFO Regulatory Area: Updated Kernel Density Analyses of Vulnerable Marine Ecosystem Indicators. NAFO SCR Doc. 19/058. Serial No. N7030. https://www.nafo.int/Portals/0/PDFs/sc/2019/scr19-058.pdf

- Kenchington, E., Wang, Z., Lirette, C., Murillo, F. J., Guijarro, J., Yashayaev, I., et al. (2019b). Connectivity modelling of areas closed to protect vulnerable marine ecosystems in the northwest Atlantic. Deep Sea Research Part I: Oceanographic Research Papers, 143: 85 103. https://doi.org/10.1016/j.dsr.2018.11.007.
- Kovacs, K.M. (2016). *Cystophora cristata*. The IUCN Red List of Threatened Species 2016: e.T6204A45225150. https://dx.doi.org/10.2305/IUCN.UK.2016-1.RLTS.T6204A45225150.en. Accessed on 29 May 2024.
- Larsson, A. I., and Purser, A. (2011). Sedimentation on the cold-water coral Lophelia pertusa: cleaning efficiency from natural sediments and drill cuttings. Marine Pollution Bulletin, 62(6), 1159-1168.
- Ledoux, J.B. and Antunes, A. (2017). Beyond the beaten path: improving natural products bioprospecting using an eco-evolutionary framework the case of the octocorals. Critical Reviews in Biotechnology, 38(2), 184–198. <a href="https://doi.org/10.1080/07388551.2017.1331335">https://doi.org/10.1080/07388551.2017.1331335</a>
- Limpinsel, D., McDermott, S., Felkley, C., Ammann, E., Coxe, S., Harrington, G.A., Kelly, S., Pirtle, J.L., Shaw, L., and Zaleski, M. (2023). Impacts to Essential Fish Habitat from Non-Fishing Activities in Alaska: EFH 5-year review from 2018-2023. National Marine Fisheries Service, Alaska Region, Juneau, Alaska. U.S. Dep. Commerce, NOAA Tech. Memo. NMFS-F/AKR-30. https://doi.org/10.25923/9z4h-n860
- Li, F., Janussen, D., Peifer, C., Pérez-Victoria, I., and Tasdemir, D. (2018). Targeted isolation of tsitsikammamines from the antarctic deep-sea sponge Latrunculia biformis by molecular networking and anticancer activity. Mar Drugs, 16:1–17; <a href="http://doi.org/10.3390/md16080268">http://doi.org/10.3390/md16080268</a>
- Lothian, S. (2024). The BBNJ Agreement: Through the Prism of Deep-Sea Vulnerable Marine Ecosystems, Ocean Development & International Law, https://doi.org/10.1080/00908320.2023.2296400
- Luter, H. M., Whalan, S., Andreakis, N., Abdul Wahab, M., Botté, E. S., Negri, A. P., & Webster, N. S. (2019). The effects of crude oil and dispersant on the larval sponge holobiont. *Msystems*, 4(6), 10-1128.
- Marappan, S., Stokke, R., Malinovsky, M.P., and Taylor, A. (2022). Assessment of impacts of the offshore oil and gas industry on the marine environment. In: OSPAR, 2023: The 2023 Quality Status Report for the North-East Atlantic. OSPAR Commission, London.
- McCauley, R. D., Day, R. D., Swadling, K. M., Fitzgibbon, Q. P., Watson, R. A., and Semmens, J. M. (2017). Widely used marine seismic survey air gun operations negatively impact zooplankton. *Nature ecology & evolution*, 1(7), 0195.
- McLean, D. L., Ferreira, L. C., Benthuysen, J. A., Miller, K. J., Schläppy, M. L., Ajemian, M. J., et al., (2022). Influence of offshore oil and gas structures on seascape ecological connectivity. Global change biology, 28(11), 3515-3536.
- Meekan, M. G., Speed, C. W., McCauley, R. D., Fisher, R., Birt, M. J., Currey-Randall, L. M., et al., (2021). A large-scale experiment finds no evidence that a seismic survey impacts a demersal fish fauna. Proceedings of the National Academy of Sciences, 118(30), e2100869118.

- Meredyk, S. (2017). Physical characterization and benthic megafauna distribution and species composition on Orphan Knoll and Orphan Seamount, NW Atlantic. M.Sc. thesis, Memorial University of Newfoundland, Canada. Available at: <a href="http://research.library.mun.ca/id/eprint/12552">http://research.library.mun.ca/id/eprint/12552</a>
- Misund, O. A., and Olsen, E. (2013). Lofoten–Vesterålen: for cod and cod fisheries, but not for oil?. ICES Journal of Marine Science, 70(4), 722-725.
- Molenaar, E. (2021). Multilateral Creeping Coastal State Jurisdiction and the BBNJ Negotiations. The International Journal of Marine and Coastal Law 36: 5–58.
- Morato, T., González-Irusta, J.-M., Dominguez-Carrió, C., et al., (2020). Climate-induced changes in the suitable habitat of cold-water corals and commercially important deep-sea fishes in the North Atlantic. Glob Change Biol. 26:2181–2202. <a href="https://doi.org/10.1111/gcb.14996">https://doi.org/10.1111/gcb.14996</a>
- Morris, C. J., Cote, D., Martin, B., and Kehler, D. (2018). Effects of 2D seismic on the snow crab fishery. Fisheries Research, 197, 67-77.
- Morris, C. J., Cote, D., Martin, S. B., and Mullowney, D. (2020). Effects of 3D seismic surveying on snow crab fishery. Fisheries Research, 232, 105719.
- Muehlenbachs, L., Cohen, M.A., and Gerarden, T. (2013). The impact of water depth on safety and environmental performance in offshore oil and gas production. Energy Policy 55:699–705. https://doi.org/10.1016/j.enpol.2012.12.074
- Mortimer, J.A. and Donnelly, M. (2008). *Eretmochelys imbricata*. The IUCN Red List of Threatened Species 2008: e.T8005A12881238. https://dx.doi.org/10.2305/IUCN.UK.2008.RLTS.T8005A12881238.en. Accessed on 29 May 2024.
- Murillo, F.J., Serrano, A., Kenchington, E., and Mora, J. (2016). Epibenthic assemblages of the Tail of the Grand Bank and Flemish Cap (northwest Atlantic) in relation to environmental parameters and trawling intensity. Deep-Sea Res. I, 109: 99–122.
- Murillo, F.J., Durán Muñoz, P., Cristobo, F.J. Ríos, P. González, C. Kenchington, E., and Serrano, A. (2012). Deep-sea Sponge Grounds of the Flemish Cap, Flemish Pass and the Grand Banks of Newfoundland (Northwest Atlantic Ocean): distribution and species composition. Marine Biology Research 8, 842-854.
- Murillo, F.J., Durán Muñoz, P., Altuna, A., and Serrano, A. (2011). Distribution of deepwater corals of the Flemish Cap, Flemish Pass and the Grand Banks of Newfoundland (Northwest Atlantic Ocean): interaction with fishing activities. ICES Journal of Marine Science 68, 319–332.
- NAFO (2024). Northwest Atlantic Fisheries Organization Conservation and Enforcement Measures 2024. NAFO/COM Doc. 24/01: 195pp.
- NAFO (2023). Report of the Scientific Council, 02 -15 June 2022, Halifax, Canada. NAFO SCS Doc. 23/18.
- NAFO (2022a). Northwest Atlantic Fisheries Organization. Conservation and Enforcement Measures, 2022, NAFO/COM Doc. 22-01, Serial No. N7254, 200pp. https://www.nafo.int/Portals/0/PDFs/COM/2022/comdoc22-01.pdf

- NAFO (2022b). Report of the NAFO Commission and its Subsidiary Bodies (STACTIC and STACFAD). 44th Annual Meeting of NAFO, 19-23 September 2022 Porto, Portugal. NAFO/COM Doc. 22-27. Serial No. N7362. <a href="https://www.nafo.int/Portals/0/PDFs/COM/2022/comdoc22-27.pdf">https://www.nafo.int/Portals/0/PDFs/COM/2022/comdoc22-27.pdf</a>
- NAFO (2021). Report of the Scientific Council Working Group on Ecosystem Science and Assessment, 16 25 November 2021, Dartmouth, Nova Scotia, Canada. NAFO SCS Doc. 21/21, Serial No. N7256. <a href="https://www.nafo.int/Portals/0/PDFs/sc/2021/scs21-21.pdf">https://www.nafo.int/Portals/0/PDFs/sc/2021/scs21-21.pdf</a>
- NAFO (2020). Report of the 13<sup>th</sup> Meeting of the NAFO Scientific Council (SC) Working Group on Ecosystem Science and Assessment, 17-26 November 2020, Dartmouth, Nova Scotia, Canada. NAFO SCS Doc. 19/23.
- NAFO (2019). Report of the 12th Meeting of the NAFO Scientific Council Working Group on Ecosystem Science and Assessment (WGESA). Northwest Atlantic Fisheries Organization. 19-28 November 2019, Dartmouth, Canada. NAFO SCS Document 19/25. <a href="http://hdl.handle.net/10261/325825">http://hdl.handle.net/10261/325825</a>
- NAFO (2016). Report of the NAFO Joint Fisheries Commission Scientific Council Working Group on Ecosystem Approach Framework to Fisheries Management (WGEAFFM). FC-SC Doc. 16/03 (Revised), Serial No. N6612. <a href="https://www.nafo.int/Portals/0/PDFs/fc-sc/2016/fc-scdoc16-03REV.pdf">https://www.nafo.int/Portals/0/PDFs/fc-sc/2016/fc-scdoc16-03REV.pdf</a>
- Neff, J., K. Lee, E.M. DeBlois and Janes, G.G. (2014). Environmental Effects of offshore drilling in a cold ocean ecosystem: A 10-year monitoring study at the Terra Nova offshore oil development off the Canadian east coast. Deep Sea Research II: Topical Studies in Oceanography 110: 1-3. https://doi.org/10.1016/j.dsr2.2014.10.018.
- Neff, J.M., K. Lee and DeBlois, E.M. (2011). Produced water: overview of composition, fates and effects. In: Produced Water: Environmental Risks and Advances in Mitigation Technologies. K. Lee and J.M. Neff (eds.), Springer Press, NY. pp. 3-54.
- Netto, S. A., Gallucci, F., and Fonseca, G. (2009). Deep-sea meiofauna response to synthetic-based drilling mud discharge off SE Brazil. *Deep Sea Research Part II: Topical Studies in Oceanography*, 56(1-2), 41-49.
- NOAA (2016). Effects of oil and activities in the Arctic Ocean. Final environmental impact assessment.
- OSPAR (2021). Report on impacts of discharges of oil and chemicals in produced water on the marine environment. Offshore Oil & Gas Industry Series. Publication Number:804/2021. OSPAR Commission.
- Popova, E., Vousden, D., Sauer, W.H.H., Mohammed, E. Y., Allain, V., Downey-Breedt, N., Fletcher, R., Gjerde, K.M., Halpin, P.N., Kelly, S., Obura, D., Pecl, G., Roberts, M., Raitsos, D.E., Rogers, A., Samoilys, M., Sumaila, U.S., Tracey, S., and Yool, A. (2019). Ecological connectivity between the areas beyond national jurisdiction and coastal waters: Safeguarding interests of coastal communities in developing countries, Marine Policy 104: 90-102.

- Reeves, R., Pitman, R.L., and Ford, J.K.B. (2017). *Orcinus orca*. The IUCN Red List of Threatened Species 2017: e.T15421A50368125. https://dx.doi.org/10.2305/IUCN.UK.2017-3.RLTS.T15421A50368125.en. Accessed on 29 May 2024.
- Rocha, J., Peixe, L., Gomes, N.C.M., and Calado, R. (2011). Cnidarians as a source of new marine bioactive compounds--an overview of the last decade and future steps for bioprospecting. Mar Drugs. 2011;9(10):1860-1886. https://doi.org/10.3390/md9101860
- Román-Marcote, E., Durán Muñoz, P., and Sacau, M. (2020). Preliminary information from EU-Spain surveys in Div 3L regarding Commission request #18: "Provide information to the Commission at its next annual meeting on sea turtles, seabirds, and marine mammals that are present in NAFO Regulatory Area based on available data". NAFO SCR Doc. 20/023REV, Serial No N7069. 8 pp. https://www.nafo.int/Portals/0/PDFs/sc/2020/scr20-023REV.pdf
- Ronconi, R. A., Allard, K. A., and Taylor, P. D. (2015). Bird interactions with offshore oil and gas platforms: Review of impacts and monitoring techniques. *Journal of Environmental Management*, 147, 34-45.
- Samirana, P.O., Jenie, R.I., Murti, Y.B., and Setyowati, E.P. (2022). Application of metabolomics on marine sponges and sponge-associated microorganisms: A review. J Appl Pharm Sci, 12(07):018–033. https://dx.doi.org/10.7324/JAPS.2022.120702
- Seminoff, J.A. (2023). Chelonia mydas (amended version of 2004 assessment). The IUCN Red List of Threatened Species 2023: e.T4615A247654386. https://dx.doi.org/10.2305/IUCN.UK.2023-1.RLTS.T4615A247654386.en. Accessed on 29 May 2024.
- Solé, M., Kaifu, K., Mooney, T. A., Nedelec, S. L., Olivier, F., Radford, A. N., *et al.*, (2023). Marine invertebrates and noise. Frontiers in Marine Science, 10, 1129057.
- Steffen, K. (2022). Genomics and metabolomics in the North Atlantic deep-sea sponge Geodia barretti. Digital Comprehensive Summaries of Uppsala Dissertations from the Faculty of Pharmacy 305. 73 pp. Uppsala: Acta Universitatis Upsaliensis. ISBN 978-91-513-1365-8. Available at: <a href="http://uu.diva-portal.org/smash/get/diva2:1619143/FULLTEXT01.pdf">http://uu.diva-portal.org/smash/get/diva2:1619143/FULLTEXT01.pdf</a>
- Tan, L.T. (2023). Impact of Marine Chemical Ecology Research on the Discovery and Development of New Pharmaceuticals. Marine Drugs.; 21(3):174. https://doi.org/10.3390/md21030174
- Tang, G. and Kilpatrick, R. (2021). Offshore Wind Technology Scan. A review of offshore wind technologies and considerations in the context of Atlantic Canada. Natural Resources Canada, CanmetENERGY-Ottawa, Renewable and Electrical Energy Division. Available at: <a href="https://publications.gc.ca/collections/collection-2022/rncan-nrcan/M154-147-2021-eng.pdf">https://publications.gc.ca/collections/collection-2022/rncan-nrcan/M154-147-2021-eng.pdf</a>
- Thompson, A.B. and Reid, K. (2024). Review of the implementation of the International Guidelines for the Management of Deep-sea Fisheries in the High Seas. FAO Fisheries and Aquaculture Technical Paper, No. 703. Rome, FAO. <a href="https://doi.org/10.4060/cd0243en">https://doi.org/10.4060/cd0243en</a>

- Tornero, V. and Hanke, G. (2016). Chemical contaminants entering the marine environment from sea-based sources: A review with a focus on European seas. *Marine Pollution Bulletin*, 112 (1-2), 17-38.
- UNEP-WCMC and IUCN (2024). Protected Planet: The World Database on Other Effective Area-based Conservation Measures (WD-OECM) [Online], May 2024, Cambridge, UK: UNEP-WCMC and IUCN. Available at: <a href="https://www.protectedplanet.net">www.protectedplanet.net</a>.
- Vad, J., Duran Suja, L., Summers, S., Henry, T. B., and Roberts, J. M. (2022). Marine sponges in a snowstorm–extreme sensitivity of a sponge Holobiont to marine oil snow and chemically dispersed oil pollution. Frontiers in Microbiology, 13, 909853.
- Vad, J., Dunnett, F., Liu, F., Montagner, C. C., Roberts, J. M., and Henry, T. B. (2020). Soaking up the oil: Biological impacts of dispersants and crude oil on the sponge Halichondria panicea. *Chemosphere*, 257, 127109.
- Vad, J., Kazanidis, G., Henry, L.A., Jones, D.O.B., Tendal, O.S., Christiansen, S., Henry, T.B., and Roberts, J.M. (2018). Potential Impacts of Offshore Oil and Gas Activities on Deep-Sea Sponges and the Habitats They Form. In Advances in Marine Biology 79, Elsevier, pp. 33-60. https://doi.org/10.1016/bs.amb.2018.01.001.
- van der Knaap, I., Reubens, J., Thomas, L., Ainslie, M. A., Winter, H. V., Hubert, J., Martin, and Slabbekoorn, H. (2021). Effects of a seismic survey on movement of free-ranging Atlantic cod. *Current Biology*, *31*(7), 1555-1562.
- van Dover, C.L., Ardron, J.A., Escobar, E., Gianni, M., Gjerde, K.M., Jaeckel, A, et al., (2017). Biodiversity loss from Deep-Sea mining. Nat. Geosci. 10, 464–465. https://doi.org/10.1038/ngeo2983
- Vereide, E. H., Mihaljevic, M., Browman, H. I., Fields, D. M., Agersted, M. D., Titelman, J., and de Jong, K. (2023). Effects of airgun discharges used in seismic surveys on development and mortality in nauplii of the copepod Acartia tonsa. Environmental Pollution, 327, 121469.
- Wallace, B.P., Tiwari, M., and Girondot, M. (2013). *Dermochelys coriacea*. The IUCN Red List of Threatened Species 2013: e.T6494A43526147. https://dx.doi.org/10.2305/IUCN.UK.2013-2.RLTS.T6494A43526147.en. Accessed on 29 May 2024.
- Wang, S., Kenchington, E., Murillo, F. J., Lirette, C., Wang, Z., Koen-Alonso, M., Kenny, A. Sacau, M., and Pepin, P. (2024). Quantifying the effects of fragmentation of connectivity networks of deep-sea vulnerable marine ecosystems. Diversity and Distributions, e13824.
- Watson, S. M. (2020). Greenhouse gas emissions from offshore oil and gas activities—Relevance of the Paris Agreement, Law of the Sea, and Regional Seas Programmes. Ocean & coastal management, 185, 104942.
- Weinnig, A.M., Gómez, C.E., Hallaj, A., and Cordes, E.E. (2020). Cold-water coral (*Lophelia pertusa*) response to multiple stressors: High temperature affects recovery from short-term pollution exposure. Scientific Reports, 10(1), 1768.

Wilber, D.H., Brown, L., Griffin, M., DeCelles, G.R., and Carey, D.A. (2022) Demersal fish and invertebrate catches relative to construction and operation of North America's first offshore wind farm, ICES Journal of Marine Science, 79(4):1274–1288. https://doi.org/10.1093/icesjms/fsac051

Wudrick, A., Beazley, L., Culwick, T., Goodwin, C., Cárdenas, P., Xavier, J., and Kenchington, E. (2020). A Pictorial Guide to the Epibenthic Megafauna of Orphan Knoll (northwest Atlantic) Identified from In Situ Benthic Video Footage. Can. Tech. Rep. Fish. Aquat. Sci. <a href="https://publications.gc.ca/collections/collection-2020/mpodfo/Fs97-6-3375-eng.pdf">https://publications.gc.ca/collections/collection-2020/mpodfo/Fs97-6-3375-eng.pdf</a>

#### **ANNEXES OF TASK 3**

#### ANNEX 5 - NAFO SCR Document

Durán Muñoz, P., Abalo-Morla, S., Palas Otero, S., and Sacau, M. (2024) Preliminary results from a desk-based study on activities other than fishing in the NRA: Interactions between oil and gas activities, deep-sea fisheries and VMEs - NEREIDA Task 3. NAFO SCR Doc. 24/047. Serial No. N7554.

## ANNEX 6 – Presentation at the NAFO Scientific Council meeting (June 2024)

Durán Muñoz, P., Abalo-Morla, S., Palas, S., and Sacau, M. (2024). A desk-based study on activities other than fishing in NAFO Regulatory Area. NEREIDA Task 3. NAFO Scientific Council Meeting June 2024. Oral communication.

# 5- OUTREACH ACTIVITIES

Although not part of the initial activities outlined in the NEREIDA contract, some scientific outreach activities have been undertaken. The work of the NEREIDA project has been disseminated to a wide audience, including NAFO scientists and managers, stakeholders, academia and the general public, in particular school children. The outreach activities carried out are described below.

## 5.1- NAFO related meetings

#### **YEAR 2023**

- An informal group of the Joint Commission—Scientific Council Working Group on Ecosystem Approach Framework to Fisheries Management (WGEAFFM) on "Other Effective Area-Based Conservation Measures\_(OECMs)" was held via Webex (20<sup>th</sup> March 2023). During the meeting, a presentation was given to initiate the discussions, highlighting that the NAFO VME and seamount closures have the potential to be put forward as OECMs. In addition, it was noted that there were cross-sectoral issues affecting the VME closed area No. 10 due to oil and gas activities, that hinder its nomination as an OECM. Based on the discussions, the group agreed to suggest to the WGEAFFM to continue work on the review of NAFO ABMTs ("Area-Based Management Tools") for selection and nomination as OECMs.
- The NAFO Scientific Council meeting (SC-June) was held in Halifax, Canada (2<sup>nd</sup>-15<sup>th</sup> June 2023). The research on non-fishing activities conducted by the IEO during 2022, was briefly summarized in the Spanish Research Report (González-Costas *et al.*, 2023). Such information was presented to the SC and included in the SC report (NAFO, 2023a), both in the grey box and in the explanatory text related to the Commission Request #12. The IEO then held a **meeting** in Vigo (7<sup>th</sup> July 2023) with Spanish stakeholders (fisheries sector and fisheries administration) to present the main results of the SC.
- A meeting of the NAFO WGEAFFM was held in Edinburgh (UK) (20<sup>th</sup> –22<sup>nd</sup> July 2023). During this meeting the issue of non-fishing activities was addressed, including the nomination of NAFO OECMs and the difficulties encountered in multi-sectoral areas such as the VME closed area No.10 (NAFO, 2023b). There was also a very interesting discussion on whether or not the SC should continue to advice on the potential impacts of non-fishing activities, but no consensus was reached.
- The NAFO Scientific Council meeting (SC-September) was held in Halifax (18<sup>th</sup>-22<sup>nd</sup> September 2023). During the presentation of the WGEAFFM report, the cochairs, noted that this WG, did not reach consensus on the inclusion of a request to the SC to provide advice on the potential impact of activities other than fishing in the Convention Area for next year. This gives an idea of the great controversy that this issue raises within NAFO (NAFO, 2023c).
- During the 2023 NAFO Working Group on Ecosystem Science and Assessment (WGESA) held in Halifax (14<sup>th</sup>-23<sup>rd</sup> November 2023) the reasons that justify the

need to conduct studies on non-fishing activities occurring or planned in the NRA were analysed and discussed, in relation to the international commitments (e.g., UNGA Resolution 71/123, adopted in 2016) and the stakeholders concerns. It was concluded that there is a strong rationale for addressing such studies in the context of NAFO. A preliminary updated map of the geographic location of oil and gas activities in NAFO Divisions 3LM, based on new spatial data from public sources, was also presented. It was noted that the spatial overlap between *Significant Discovery Licenses* and NAFO fisheries in Division 3L has increased due to the recent increase in the number of such licenses in this area (NAFO, 2023d).

#### **YEAR 2024**

- The coordination meeting between DG MARE and NAFO scientists took place via videoconference, on 25<sup>th</sup> and 26<sup>th</sup> of January 2024. Besides DG MARE participants, scientists from IEO Spain, IPMA Portugal and Lithuania attended the meeting. During this meeting, the research conducted under the NEREIDA project was briefly presented.
- The NAFO Scientific Council meeting (SC-June) was held in Halifax (31st May 13th June 2024). As usual, this year, the research about non-fishing activities conducted by the IEO during 2023, was briefly summarized in the Spanish Research Report (González-Costas et al., 2024). This information was also presented to the SC, and included in the SC report (NAFO, 2024), both in the grey box and in the explanatory text related to the Commission Request #9. In addition, a meeting was carried out between the IEO scientists and the Spanish stakeholders, including representatives from the fishing sector and fisheries administration. The meeting took place in Vigo (June 20th, 2024) to communicate the main results and concerns expressed by the SC.

### 5.2- Collaboration with stakeholders

## 33<sup>rd</sup> Meeting of the LDAC Working Group (7<sup>th</sup> March 2024)

The Long-Distance Fleet Advisory Council (LDAC) is an EU fisheries body representing stakeholders from the fishing sector, including catching, processing, and marketing sectors, as well as trade unions, environmental NGOs, consumers, and civil society. It comprises over 50 members from 12 EU coastal Member States and is recognized under the CFP Regulation (EU) No 1380/2013 for its European Interest objectives. LDAC's mission involves advising European Institutions and Member States on matters concerning Fisheries Agreements with Third Countries, relations with Regional Fisheries Organizations (RFOs), and international organizations where the EU Fleet operates, along with business relations and the global fishing products market. Its primary aim is to advocate for marine biodiversity conservation and sustainable fishing resource utilization. An informative presentation<sup>33</sup> was prepared for LDAC Working Group 2: "North Atlantic RFMOs and Fishing Agreements" on 7 March 2024. The aim was to provide an overview of the implementation of the Ecosystem Approach Framework to Fisheries Management in NAFO. Following the presentation, several comments and

<sup>&</sup>lt;sup>33</sup>Presentation available at: <a href="https://ldac.eu/images/Presentation\_Ecosysten\_approach\_framework\_MarSacau\_IEO.pdf">https://ldac.eu/images/Presentation\_Ecosysten\_approach\_framework\_MarSacau\_IEO.pdf</a>

questions were raised by the attendees, which were useful in the drafting of the LDAC recommendations in the ecosystem section.

#### Article in the maritime-fishing sector magazine "Industrias Pesqueras"

Industrias Pesqueras (IP), is an independent media published in Vigo since 1927, and one of the leading magazines in the maritime-fishing sector in the Iberian Peninsula. 38% of its readers are shipyards and ancillary industry. 23% are fishing vessel owners. 20% are marketers and 9% processors of fishery products. By geographical distribution, 35% of the diffusion corresponds to Spain, 29% to Europe, 20% to America and 14% to Africa. It is also a reference publication for the Portuguese fishing sector. Continuing with the previous articles on interactions between high seas fisheries and non-fishing activities, a new outreach paper was published in IP<sup>34</sup> (Durán Muñoz, 2024), as this topic continues to be of great concern to Fishermen. It summarized (i) the state of the art in the NAFO area and (ii) the contribution of EU funded projects (ATLAS, NEREIDA), (iii) the problems identified regarding oil and gas, (iv) the threats to fisheries management and conservation of VMEs, as well as (v) future challenges, emphasizing (vi) the importance of research on the impacts of non-fishing activities in the context of sustainable high seas fisheries, according to the resolution 71/123 of the United Nations General Assembly and the Convention on Biodiversity.

#### 5.3- Dissemination and transfer of scientific knowledge

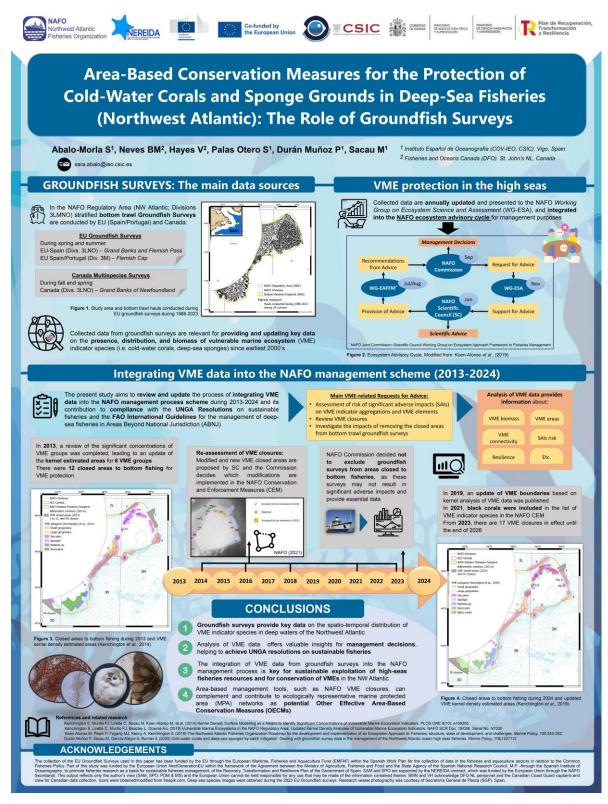
#### IX International Symposium of Marine Sciences (10-12<sup>th</sup> July, 2024)

The IX International Symposium of Marine Sciences was held from July 10 to 12, 2024, at the Port Authority of Valencia (Spain), being a very important event of marine sciences in Spain, of great relevance in the European panorama. Two posters were presented at this meeting, both made in collaboration with Canadian scientists. The first poster updated information on the process of integrating VME data into the NAFO management scheme (Abalo-Morla *et al.*, 2024). Data from groundfish surveys provided a spatial and temporal data series that allowed the identification of VMEs. These data have been used by NAFO to support area-based management measures (i.e. areas closed to bottom fishing) aimed at avoiding significant adverse impacts of deep-sea commercial fishing on VME. The data obtained have the potential to help prevent adverse impacts through spatial management (i.e., closed areas nominated as Other Effective Area-based Conservation Measures (OECMs)) caused by other human activities of increasing concern, such as deep-sea mining and offshore oil and gas exploration and exploitation, which may affect VMEs (Poster 1).

The second poster (Sacau et al., 2024) described how NAFO has actively pursued an ecosystem-based approach to fisheries management since 2007, known as the "Roadmap". This dynamic framework guides sustainable fishing practices, including marine environment protection and biodiversity conservation. It emphasizes integrating scientific information into the management decision-making processes. Key aspects include defining management units, hierarchical exploitation rate setting, and

<sup>&</sup>lt;sup>34</sup>See in: <a href="https://industriaspesqueras.com/noticia">https://industriaspesqueras.com/noticia</a> impresa-79455-seccion-Extra%20Abril%201927-2024%20Investigaci%C3%B3n

considering impacts on benthic communities. Despite being a work in progress, NAFO has made significant strides, implementing measures such as bottom fishing closures to protect Vulnerable Marine Ecosystems (VMEs). This overview discussed the Roadmap's structure, current implementation status, and encountered conflicts and challenges (Poster 2).



Poster 1.











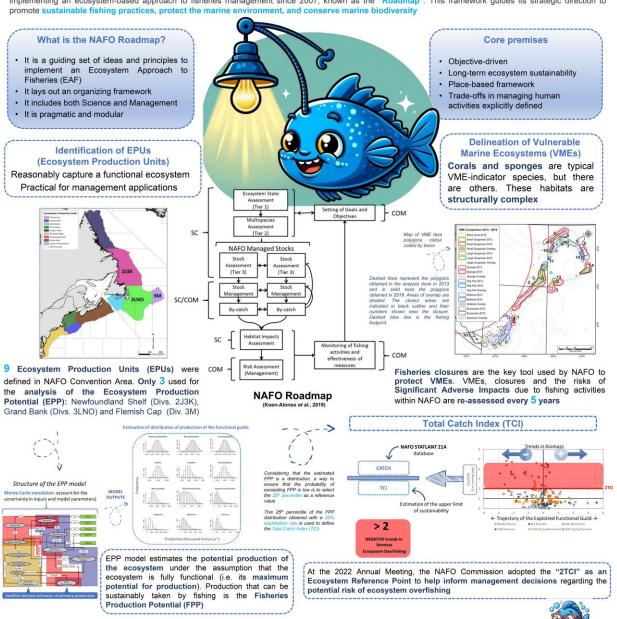
#### **Biodiversity and Marine conservation:** Implementing the Ecosystem Approach Framework in **NAFO** fisheries management

Sacau M1, Durán Muñoz P1 and Koen-Alonso M2

- <sup>1</sup> Instituto Español de Oceanografia (COV-IEO, CSIC). Vigo, Spain.
- <sup>2</sup> Fisheries and Oceans Canada (DFO), St. John's NL, Canada.



The Northwest Atlantic Fisheries Organization (NAFO) manages fisheries in waters beyond national jurisdiction in the Northwest Atlantic and has been implementing an ecosystem-based approach to fisheries management since 2007, known as the "Roadmap". This framework guides its strategic direction to



#### **ACKNOWLEDGEMENTS**

Reference: Koen-Alonso, M., Pepin, P., Fogarty, M. J., Kenny, A., and Kenchington, E. 2019. The Northwest Atlantic Fisheries Organization Roadmap for the development and implementation of an Ecosystem Approach to Fisheries: structure, state of development, and challenges. Marine Policy, 100: 342-352.

#### Poster 2.

#### **Interactive school workshops on VMEs**

Building on the experience gained in the previous European projects, i.e. ATLAS (see: <a href="https://www.eu-atlas.org/news/project-news/european-researchers-night-2019.html">https://www.eu-atlas.org/news/project-news/european-researchers-night-2019.html</a>), the IEO-Vigo team organized, respectively, two interactive school workshops at Aralde-Sobrán School (Vilagarcía de Arousa, Spain, February 07<sup>th</sup>, 2024) and CEIP Santa Mariña (Vigo, Spain, February 21<sup>st</sup>, 2024), in collaboration with the teachers (Figure 1). The aim of these workshops was to raise awareness of ocean conservation among the younger generations. Scientific and technical information on the research carried out under the NEREIDA contract was provided in a playful and interactive way, adapted to the age of the schoolchildren. Combining education with entertainment, young students and their teachers had the opportunity to learn about the main species that inhabit these vulnerable ecosystems, as well as their importance and the main threats they face, with emphasis on the impacts of seabed litter and oil and gas activities. In addition, the main impact mitigation measures currently in place were addressed in a simple and understandable manner.



**Figure 1**. Interactive school workshops on VMEs: (a) Introduction to VMEs, threats, and indicator species. Importance and protection; (b) Observation of deep-sea species; (c) Discovering deep-sea species in their habitat; (d) Identification of important areas for their protection due to high diversity and/or density of vulnerable species. Identification of areas/species with threats and proposals for protection measures.

#### 5.4- References for the outreach activities

- Abalo-Morla, S., Neves, B.M., Hayes, V., Palas Otero, S., Durán Muñoz, P., and Sacau, M. (2024) Area-Based Conservation Measures for the protection of Cold-Water Corals and Sponge Grounds in Deep-Sea Fisheries (Northwest Atlantic): The Role of Groundfish Surveys. IX International Symposium on Marine Sciences. Valencia (Spain), 10-12th July 2024.
- Durán Muñoz, P. (2024) Interacciones entre la pesca de fondo y otras actividades en alta mar: ¿Podrían las actividades emergentes, amenazar los logros de la gestión pesquera? Industrias pesqueras. Nº2204:47-48. <a href="https://industriaspesqueras.com/noticia">https://industriaspesqueras.com/noticia</a> impresa-79455-seccion-Extra%20Abril%201927-2024%20Investigaci%C3%B3n
- González Costas, F., Ramilo, G., Román, E., Lorenzo, J., González-Troncoso, D., Sacau, M., Durán Muñoz, P., del Río, J.L., and Blanco, R. (2023). Spanish Research Report for 2022. NAFO SCS Doc. 23/06. Serial No. N7380. https://www.nafo.int/Portals/0/PDFs/sc/2023/scs23-06.pdf
- González Costas, F., Ramilo, G., Román, E., Lorenzo, J., González-Troncoso, D., Sacau, M., Durán Muñoz, P., del Río, J.L., Blanco, R., and Garrido, I. (2024). Spanish Research Report for 2023. NAFO SCS Doc. 24/08. Serial No. N7504.
- NAFO (2023a) Report of the Scientific Council Meeting June 02 15 June 2023, Halifax, Nova Scotia, Canada. NAFO SCS Doc. 23/18, Serial No. N7438. <a href="https://www.nafo.int/Portals/0/PDFs/sc/2023/scs23-18.pdf">https://www.nafo.int/Portals/0/PDFs/sc/2023/scs23-18.pdf</a>
- NAFO (2023b). Report of the NAFO Joint Commission—Scientific Council Working Group on Ecosystem Approach Framework to Fisheries Management (WGEAFFM) Meeting, 20 22 July 2023, Halifax, Nova Scotia, Canada. NAFO COM-SC Doc. 23/04, Serial No. N7441. <a href="https://www.nafo.int/Portals/0/PDFs/COM-SC/2023/com-scdoc23-04.pdf">https://www.nafo.int/Portals/0/PDFs/COM-SC/2023/com-scdoc23-04.pdf</a>
- NAFO (2023c). Report of the Scientific Council Meeting September, 18 22 September 2023, Halifax, Nova Scotia, Canada. NAFO SCS Doc. 23/22, Serial No. N7481. <a href="https://www.nafo.int/Portals/0/PDFs/sc/2023/scs23-22.pdf">https://www.nafo.int/Portals/0/PDFs/sc/2023/scs23-22.pdf</a>
- NAFO (2023d). Report of the Scientific Council Working Group on Ecosystem Science and Assessment, 14 23 November 2023, Halifax, Nova Scotia, Canada. NAFO SCS Doc. 23/25, Serial No. N7484. <a href="https://www.nafo.int/Portals/0/PDFs/sc/2023/scs23-25.pdf">https://www.nafo.int/Portals/0/PDFs/sc/2023/scs23-25.pdf</a>
- NAFO (2024). Report of the Scientific Council Meeting June, 31 May 13 June 2024, Halifax, Nova Scotia, Canada. NAFO SCS Doc. 24/16, Serial No. N7556
- Sacau, M., Durán Muñoz, P., and Koen-Alonso, M. (2024). Biodiversity and marine conservation: implementing the Ecosystem Approach Framework in NAFO Fisheries Management. Valencia (Spain), 10-12<sup>th</sup> July 2024.

#### **6- DELIVERABLES**

- ✓ Abalo-Morla, S., Palas Otero, S., Román-Marcote, E., Durán Muñoz, P., Pérez, P., and Sacau, M. (2024). Preliminary results on seabed litter distribution on Flemish Cap (Div. 3M), Flemish Pass (Div. 3L) and Grand Banks of Newfoundland (Divs. 3NO). NAFO SCR Doc. 24/046. Serial No. N7553
- ✓ Abalo-Morla, S., Palas Otero, S., Román-Marcote, E., Del Río, J.L., Pérez, P., Durán Muñoz, P., and Sacau, M. (2024). Seabed litter in NAFO Regulatory Area (Divs. 3LMNO): Protocol for data collection and preliminary results on Spatial distribution. NAFO Scientific Council Meeting June 2024. Oral communication.
- ✓ Abalo-Morla, S., Neves, B.M., Hayes, V., Palas Otero, S., Durán Muñoz, P., and Sacau, M. (2024) Area-Based Conservation Measures for the protection of Cold-Water Corals and Sponge Grounds in Deep-Sea Fisheries (Northwest Atlantic): The Role of Groundfish Surveys. IX International Symposium on Marine Sciences. Valencia (Spain), 10-12th July 2024. Poster communication.
- ✓ Durán Muñoz, P., Abalo-Morla, S., Palas Otero, S., and Sacau, M. (2024). Preliminary results from a desk-based study on activities other than fishing in the NRA: Interactions between oil and gas activities, deep-sea fisheries and VMEs NEREIDA Task 3. NAFO SCR Doc. 24/047. Serial No. Doc. 24/047.
- ✓ Durán Muñoz, P., Abalo-Morla, S., Palas, S., and Sacau, M. (2024). A desk-based study on activities other than fishing in NAFO Regulatory Area. NAFO Scientific Council Meeting June 2024. Oral communication.
- ✓ Garrido, I., Sacau, M., Durán-Muñoz, P., Baldó, F., González-Costas, F., and González-Troncoso, D. (2023). Update on the analysis of VMS and Logbook data to study the bottom fishing footprint in the NAFO Regulatory Area: NEREIDA project. NAFO SCR Doc. 23/056. Serial No. N7486. <a href="https://www.nafo.int/Portals/0/PDFs/sc/2023/scr23-056.pdf">https://www.nafo.int/Portals/0/PDFs/sc/2023/scr23-056.pdf</a>
- ✓ Sacau, M., Garrido, I., Baldó, F., González-Troncoso, D., González-Costas, F., Durán Muñoz, P. (2024). Update on the analysis of VMS and Logbook data to study the bottom fishing footprint in the NAFO Regulatory Area. Nereida Task 1. NAFO Scientific Council Meeting June 2024. Oral communication.
- ✓ Sacau, M., Durán Muñoz, P., and Koen-Alonso, M. (2024). Biodiversity and marine conservation: implementing the Ecosystem Approach Framework in NAFO Fisheries Management. IX International Symposium on Marine Sciences. Valencia (Spain), 10-12th July 2024. Poster communication.

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#### 8- ANNEXES

Aforementioned annexes of each task are included below.









## **ANNEXES**

# NEREIDA: RESEARCH IN SUPPORT OF THE REASSESSMENT OF NAFO BOTTOM FISHERIES IN 2022

Project number: 101074766







# Annexes Task 1

#### ANNEX 1 - NAFO SCR Document

Garrido I., Sacau M., Durán-Muñoz P., Baldó F., González-Costas F., González-Troncoso, D. (2023). Update on the analysis of VMS and Logbook data to study the bottom fishing footprint in the NAFO Regulatory Area: NEREIDA project. NAFO SCR Doc. 23/056. Serial No. N7486. <a href="https://www.nafo.int/Portals/0/PDFs/sc/2023/scr23-056.pdf">https://www.nafo.int/Portals/0/PDFs/sc/2023/scr23-056.pdf</a>

#### ANNEX 2 – Presentation at the NAFO Scientific Council meeting (June 2024)

Sacau M., Garrido I., Baldó F., González-Troncoso D., González-Costas F., Durán Muñoz, P. (2024). Update on the analysis of VMS and Logbook data to study the bottom fishing footprint in the NAFO Regulatory Area. Nereida Task 1. NAFO Scientific Council meeting June 2024. Oral communication.

#### **ANNEX 1. NAFO SCR Document**

NOT TO BE CITED WITHOUT PRIOR REFERENCE TO THE AUTHOR(S)



Serial No. N7486 NAFO SCR Doc. 23/056

### Update on the analysis of VMS and Logbook data to study the bottom fishing footprint in the NAFO Regulatory Area: NEREIDA project

By

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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 applying the ecosystem approach is to assess the impact of the fishing activity in the ecosystems by defining the fishing footprint. The NEREIDA project, funded by the European Union through the NAFO Secretariat, addresses specific requests from the NAFO Commission in these regards and its findings are significant for the 2026 re-assessment of NAFO bottom fisheries.

There are two methodologies used to study the fishing effort and footprint in the NAFO Regulatory Area. 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 aim of this study is to analyse the quality and coverage of the VMS and logbook data used in these two methods. Data gathered through the IEO Scientific Observer Program on board fishing vessels were used to assess both the coverage and accuracy of the data employed in studying fishing effort and footprint.

The findings reveal that both VMS and logbook databases contain errors, and that the effects of misreporting are amplified when these datasets are merged. Data from scientific observers allowed these errors to be quantified, with results indicating that approximately 40-70% of the original pings are retained for further analysis with the merging approach.

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



However, these findings highlight that this improvement relies on the availability of high quality data with sufficient coverage.

The quality of information, both in the VMS system and in the logbooks, should be of concern to NAFO. Improving the quality of these data is crucial for better understanding the distribution of fishing effort and it directly impacts the accuracy of related analyses (i.e. Significant Adverse Impacts, fisheries footprint, fishing overlap with Vulnerable Marine Ecosystems, assessments, etc.).

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

#### 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 conducting a study on the environmental impact of the fishing activity is the delineation of the fishing footprint (NAFO, 2009). At the 2020 NAFO Working Group on Ecosystem Science and Assessment (WG-ESA), an analysis of VMS and logbook data was presented to study the quality of the data used to delineate the bottom fishing footprint in the NAFO Regulatory Area (NRA) (Garrido *et al.*, 2020). During the 2023 WG-ESA, these analyses were updated, and the results are presented in this work. Conducted under the NEREIDA project, supported by the European Union through the NAFO Secretariat, this analysis is specifically crafted to fulfil specific requests from the NAFO Commission, with particular importance for the upcoming re-assessment of NAFO bottom fisheries scheduled for 2026, on which the distribution of the fishing effort and the overlap of NAFO fisheries with Vulnerable Marine Ecosystems (VMEs) will be characterized.

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 accurately display the 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. Vessel data is transmitted and received at specific time intervals, and each transmission of information is referred to as a "ping". The information received by the FMCs is then forwarded to the NAFO Secretariat in the cases where the vessels are working in the NAFO Regulatory Area (NRA).

Applying a speed filter is a very common method for identifying VMS pings associated with fishing activities (Thompson and Campanis, 2007; WGDEC, 2008; Campanis *et al.*, 2008, Campbell and Federizon, 2013). This approach involves filtering VMS pings through a straightforward speed filter directly related to fishing speeds. Thus, only the VMS records with a high likelihood of being associated with fishing effort are assigned as fishing activities. However, this procedure presents challenges in terms of threshold speeds across entire fleets/gears, leading to a misclassification of some pings at a rate that is difficult to quantify accurately (NAFO, 2017).

Use of the haul-by-haul data from logbooks permits VMS pings to be categorized as "fishing" or "non-fishing" based on whether they fall within fishing time intervals reported in the haul-by-haul data, instead of categorizing 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 and to delineate the fishing footprint. 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 merging the datasets has already proven powerful for describing the spatial distribution of fishing activity with higher accuracy and precision than if each dataset was assessed independently (NAFO, 2018; NAFO, 2019).



The approach to track fishing effort by merging VMS and logbook data, which 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 VMEs and fishing footprint (NAFO, 2017).

In 2019, the WG-ESA developed the guidelines to create standard data products to study the fishing 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 (speed-filtered & logbook filtered). Comparisons were made with data collected by the IEO Scientific Observer Program on board of trawl fishing vessels, as the information collected by these scientific observers is considered representative of the real effort exerted by the Spanish fleet. This analysis serves as a follow-up to the one conducted in 2020 (Garrido *et al.*, 2020).

#### Material

#### **Vessel Monitoring System (VMS)**

The NAFO 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 ping rate which has improved 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 logbook data.

VMS data used in this study were supplied by the NAFO Secretariat, who is responsible for collecting and maintaining these data from fishing vessels operating in the NRA. In addition to being an integral part of the NAFO's Monitoring, Control and Surveillance (MCS) scheme, the VMS data are also used in various scientific applications by NAFO (e.g. for the assessment of Significant Adverse Impacts (SAIs) on VMEs and in some fish stock assessments<sup>1</sup>).

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, 2023 REV).

#### 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, 2023 REV).

The current logbook data format<sup>2</sup> (NAFO, 2023 REV) was implemented by NAFO in 2016, and was an improvement over 2015, when the haul data records included only 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 the NAFO Secretariat.

#### **IEO Scientific Observer Program**

<sup>&</sup>lt;sup>2</sup> https://www.nafo.int/Fisheries/ReportingRequirements/LogbookInfo



<sup>&</sup>lt;sup>1</sup> https://www.nafo.int/Fisheries/ReportingRequirements/VMS

The Instituto Español de Oceanografía (IEO, CSIC) employs scientific observers who are onboard during fishing operations conducted by the Spanish commercial fleet within the NRA. Around 30 % of the annually effort deployed by the Spanish fleet is sampled by the *IEO Scientific Observer Program*. The collection of these data falls under the responsibility of IEO, under the European Union Fisheries Data Collection Framework<sup>3</sup>. 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.

It is important to note that the Spanish fleet is made up exclusively of trawlers, so the conclusions drawn at any point from the information obtained by the IEO observers may only be extended to the trawling fleet.

It is also important to highlight that due to administrative issues, the information recorded by Spanish scientific observers in the year 2020 is not considered in this analysis.

The data used for the analysis presented in this document correspond to the period from 2016 to 2022. This time interval aligns with the availability of the current format of the haul-by-haul catch data, ensuring the inclusion of the latest and most relevant information in the analysis.

#### Methodology

The analysis of the data was completed using the open-source statistical computing environment R (R Core Team, 2023). The implementation of this analysis involved the use of a script developed by Corinna Favaro from Fisheries and Oceans Canada (DFO). Originally developed for merging VMS and logbook data, the script was later modified and used in the overlay analysis of VME and fishing footprint under the NAFO NEREIDA project (NEREIDA, 2020). Further information about the script and the methodology can be found in Garrido et al. (2020).

#### General analysis of VMS and logbook databases errors

In many instances, both data sources (i.e. VMS and logbook) contain erroneous entries, namely: points with incomplete timestamps; incorrect vessel positions; duplicated records; headings outside compass range, etc. Following a deep review of the databases, a process of removal or flagging of erroneous entries was undertaken. Upon completion of the data cleaning procedure, the VMS and haul-by-haul datasets are joined using vessel identification and date as common fields between both datasets. This step holds particular significance, as the success of all subsequent analyses relies on accurately linking these datasets. The joined dataset only contains the pings (VMS data) of each vessel that coincide with the time reported as fishing in the logbook data, excluding pings from periods when vessels were not fishing.

Further analysis was conducted to identify potential errors in the merged dataset. These errors may be due to problems with the data in the logbooks or due to problems in the VMS data. Compared to the automated nature of VMS records, it is reasonable to assume that errors are more prevalent in the logbooks which rely on user input.

#### Analysis of the coverage based on the Spanish Scientific Observers trawl hauls

Given the potential presence of errors from both data sources, a subset of records in the joined database (VMS and logbooks) were selected for vessels which had a Spanish scientific observer on board. This selection aimed

<sup>&</sup>lt;sup>3</sup> The EU's data collection framework (DCF) outlines the EU countries' obligations to collect, manage and make available a wide range of fisheries and aquaculture data needed for scientific advice (e.g. in the context of RFMOs such as NAFO). Member States' data collection activities are financially supported by the EU. https://oceans-and-fisheries.ec.europa.eu/fisheries/scientific-input/scientific-advice-and-data-collection\_en#data-collection.



to assess the representativeness of errors in each data source, based on the assumption that the real effort exerted in these selected hauls was the one reported by scientific observers on board. Comparisons of the data sets were based on common fields, specifically the vessel ID and date.

To measure the coverage of the VMS and logbook data, an "ideal world" scenario was recreated, representing all the VMS pings in all the hauls with the presence of a Spanish scientific observer. By comparing the outcomes derived from this "ideal world" with the results obtained from the available data, it became possible to estimate the coverage of the VMS, logbook, and the merged VMS and logbook data information.

#### "Ideal world" scenario

In creating the "ideal world" scenario, an artificial database termed Hourly Ping Data (HPD) was generated. This database was constructed by generating a ping for every hour throughout the analysed period (January 1st, 2016 to December 31st, 2022). The HPD database only includes information on date and time. Thus, when merged with the observers' records or logbooks, the same ping was assigned to every vessel conducting fishing activities at the same time within the NRA. This approach simplified the ping registry for all the analysed vessels.

The creation of the "ideal world" scenario involved merging the HPD with the dataset containing information from Spanish scientific observers. This integration enabled the derivation of the number of fishing trips, the count of hauls, the duration of each haul (measured in hours) and the expected number of VMS fishing pings. These were calculated under the assumption that the coverage of both VMS and logbook data was complete for these scientific observers' hauls.

#### Coverage of VMS

The coverage of the VMS system was evaluated by directly filtering the VMS dataset and the HPD by the records from the Spanish scientific observers, indicating the start and end of each haul. Since the "ideal world" scenario 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 incorrect pings identified using this approach are then due to erroneous records in the VMS system.

#### Coverage of logbook

To analyse the haul coverage of the logbooks, the HPD dataset was filtered based on logbook entries, and, subsequently, hauls with the presence of a Spanish scientific observer were isolated. The outcomes of this analysis were then compared to the "ideal world" scenario, where HPD dataset was directly merged with these scientific observers' records. The differences in the results can be attributed solely to differences in the records of the Spanish scientific observers and the skippers, highlighting, among other things, the number of hauls and fishing trips that are not documented in the logbooks.

#### Analysis of the performance of merging VMS and logbook datasets

Once the missing hauls and trips were identified, the performance of merging VMS and logbook data was analysed. This analysis involved comparing the outcomes from the "ideal world" scenario, where the HPD was directly merged with the records from Spanish scientific observers, with the results obtained from the "real world" scenario. In the "real world," the actual VMS data were merged with logbook entries and subsequently filtered based on records from scientific observers.

As a result, it became possible to assess the combined effect that a simultaneous lack of information in both datasets may have on the estimates of the effort deployed.



#### **Results**

#### General analysis of VMS and logbook databases errors

#### Errors in the VMS data

Table 1 presents the total number of pings and the number of erroneous entries in the VMS database by year. The identified errors include:

- a) **Duplicated pings**: Entries with identical information regarding Vessel, Day and Hour.
- b) **Incomplete pings**: Pings where any field is missing.
- c) Short pings: Instances where the time interval between one ping and the next is less than one hour.
- d) **Long pings**: Cases where the time interval between one ping and the next is more than one hour.

The percentage of incorrect pings ranges between 30.5 and 55.7%. However, it is important to note that not all the errors invalidate the data. Only duplicated and incomplete pings need to be removed from the effort analyses, since short and long pings can be used for the merging as long as the effort analyses considers the duration of the pings and is not only a sum of pings by grid.

#### Errors in the logbook data

Table 2 shows the total number of hauls recorded in the logbook by year along with the errors identified in this analysis, which can be classified as follows:

- a) **Errors in the effort record**: These errors result from misrecordings of the start or the end of the haul and they translate into negative efforts (i.e. when the start of the fishing activity is recorded after the end), zero effort (i.e. when the start and the end of the activity are equal or either is missing) and big efforts (efforts exceeding 24 hours, often due to errors in recording the day, month or year of the start or end of the haul).
- b) **Errors in the position record**: These errors pertain to inaccuracies in recording the position of start and/or end of the fishing activity.
- c) **Errors in the gear record**: These errors, newly identified in this analysis, pertains to inaccuracies in recording the gear used for fishing.

Hauls with incorrect effort records in the logbook need to be removed before merging the datasets, as accurate start and/or end times are crucial for the merging process. However, hauls with errors in position records can be retained, as position data in subsequent analyses are derived from the VMS database, not from the logbook. It can be observed in table 3 the number of erroneous gear entries in the logbook, becoming evident that they are mainly due to human errors when entering the data. The gear is used to characterize the fishing effort by fishery, and only a further analysis considering position, season and catch composition, enabled the identification of the correct gear (OTB: otter trawls, LL: longlines).

#### Analysis of the coverage based on the Spanish Scientific Observers trawl hauls

The information collected by the Spanish scientific observers on board trawl vessels served to assess the coverage of both logbook and VMS, as well as the impact of missing information on the merged datasets.

With regards to the logbook coverage, it is clear that not all fishing trips and hauls documented by the Spanish scientific observers are recorded by the skippers in the logbook. Table 4 provides a summary of the number of trips and hauls recorded by the Spanish scientific observers, as well as the trips and hauls that are missing each year on the logbook. In 2016, all fishing trips with a Spanish scientific observer onboard were recorded in the



logbook, while in the rest of the years at least one complete fishing trip was missing, three in 2022. Concerning the total number of hauls, on average, around 300 hauls are missing every year, with the percentage of missing hauls ranging from 22.7% (2019) to 60.2% (2022).

The number of hauls where no pings were received, resulting in exclusion from subsequent analysis, is indicated in Table 5. From 2016 to 2018 this represented  $1-2\,\%$  of hauls. In 2019, this percentage increased to 6.1% with 42 missing hauls. In 2021 and 2022, the number of hauls without pings exceeded 100, representing more than 12% of the total hauls recorded by a Spanish scientific observer. Across all years, the total number of missing pings ranges from  $535-1\,366$ , which represents between 12.4 and 27.4%, depending on the year. Considering that the average duration of a single haul in the trawl fishery is around 5 hours, and VMS pings are recorded every hour, it is most likely that there are more hauls with some missing pings than hauls where all the pings are missing.

Finally, Table 6 illustrates the combined effect of errors when both datasets (VMS and logbook) are merged. The number of hauls that are excluded after datasets are merged increases slightly when compared to the excluded hauls described in Table 4. This is attributed to the fact that, in addition to those hauls that were not recorded in the logbook, hauls which were recorded but have no associated VMS pings are also removed.

When compared to Table 5 it is clear that merging the datasets resulted in a substantial increase in the number of pings excluded from further analysis. This is because pings for hauls that are not recorded in the logbook are not included in the merged dataset. As outlined Table 6, the percentage of missing pings ranges from 33.6-41.4% between 2016-2019 and 46.9-63.1% between 2021-2022.

#### Discussion

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

#### General analysis of VMS and logbook databases errors

Various issues have been identified in both the logbook and VMS data, and these errors may have an impact on the subsequent analyses conducted with the VMS, logbooks or the merged VMS and logbooks dataset.

In the logbook dataset, numerous errors have been detected, often stemming from mistakes made when records are being input into logbooks. These errors can have many different consequences. For instance, in hauls where the starting time is mistakenly recorded after the end time (logbook data), the information from the available pings (VMS data) for these erroneously entered hauls may be lost during the merging of both databases. Additionally, for logbook records where haul time is excessively long, the pings included in the merged (VMS and logbook) database may actually correspond with periods where the vessels are not fishing. In these instances, the number of pings erroneously assigned will depend on the duration error of the haul recorded in the logbook.

Although VMS pings are designed to be automatically sent by the vessel at a frequency of about an hour, technical issues in the transmission system can sometimes lead to deviations from this standard. While Thompson and Campanis (2007) found that such automatic transmission failures are uncommon in the NAFO regulatory area, the results presented in Table 1 indicate that every year around 30 to 50% of the received



pings occur at frequencies different from one hour. This suggests that VMS data problems, such as over and under transmission, may have an effect on the analyses that rely on this source of information to estimate fishing effort in the NRA, regardless of the methodology used.

#### Analysis of the coverage based on the Spanish Scientific Observers trawl hauls

Measuring the extent of errors in the VMS and logbook data is challenging due to inherent issues in both datasets. In order to assess the possible scope of these errors, an analysis of the merged VMS and logbook datasets procedure was conducted. This analysis relied on recreating the "ideal world" scenario using trawl data from Spanish scientific observers. In this analysis it was assumed that the actual effort exerted was precisely recorded and computed by these scientific observers.

Analysing the results, two primary sources of missing data were identified:

- a) Misreporting in the logbook: Not all the hauls and/or fishing trips are recorded in the logbook (Table 4). This discrepancy can be attributed to various reasons, including submission issues or inappropriate formats, as highlighted by the NAFO CESAG Working Group (NAFO, 2018b). Within recorded trips, diverse factors contribute to missing information. It has been observed that the last hauls of a fishing trip are sometimes missing. Additionally, some logbook entries appear to amalgamate data from multiple hauls, grouping catch information and effort data from different hauls.
- b) **Misreporting in the VMS system**: Each year around 12-27% of the pings that should be associated with hauls reported by the Spanish scientific observers are missing (Table 5). The cause of these errors should be further investigated to correct them and improve the quality of the VMS.

After merging the VMS and logbook datasets, it becomes evident that the effects of the misreporting are amplified when there is missing information in both sources of data. Missing hauls result in pings be discarded, while missing pings may lead to the exclusion of documented hauls from logbooks. Once the datasets are merged, just 40-70% of the original pings are retained, illustrating the magnitude of the potential impact that errors (due to missing pings or missing haul records) can have on subsequent and related analyses.

#### **Conclusions**

It is important to note that the conclusions drawn here would only be applicable to the overall NRA trawl data if the sample data used (the Spanish scientific observers' data) was representative of VMS and logbook data provided by all trawl fleets operating in the NRA. This sample represents around 9% of the total NAFO logbook data from 2016-2022. However, based on the data provided by the NAFO Secretariat for this analysis, even if the errors quantified for the Spanish fleet is not representative of all the trawl fleets operating in the NRA, the operational problems identified in the VMS and recording errors in the logbook datasets is likely to impact all fleets to some degree

Issues in VMS data transmission (i.e. including both over- and under- transmission), and in logbook data (i.e. missing trips and/or haul information) can significantly impact any analysis that relies on this information to estimate the fishing effort exerted by the fleet.

The merging of VMS and logbook data highlights that the effects of the misreporting are magnified when data coverage is less than 100%. When both datasets were merged, only around 40-70% of the expected pings, according to the "ideal world scenario", were considered. It is important to note that the impact of these problems (in logbook and VMS databases) on the estimation of fishing effort was not the primary objective of the current analysis. Further analyses should be conducted in order to determine them.



The quality of the information in both the VMS system and the logbooks should be of concern for NAFO. Improving the quality of these datasets is crucial for developing a more comprehensive understanding of effort distribution and directly impacts the accuracy of related analyses (i.e. SAI, fisheries footprint, fishing overlap with VME, assessments, etc).

The analyses conducted under the NEREIDA project are of great practical utility, as they contribute to meeting specific requests from the NAFO Commission, with particular relevance to the upcoming reassessment of NAFO bottom fisheries, scheduled for 2026.

In summary, addressing VMS and logbook data challenges, enhancing data coverage, and improving overall data quality are essential steps for advancing research on effort distribution and undertaking related tasks critical to effective fisheries management.



#### Acknowledgements

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#### References

Campanis, G., A. Thompson, J. Fischer and R. Federizon, 2008. The Geographical Distribution of the High-Seas Commercial Greenland Halibut Fishery in the Northwest Atlantic. NAFO SCR Doc. 08/01. Serial No. N5483.

Campbell, N. and R. Federizon, 2013. Estimating fishing effort in the NAFO regulatory area using vessel monitoring system data. NAFO SCR Doc. 13/001. Serial No. N6144.

Garrido, I., González-Costas, F., and González-Troncoso, D., 2020. Analysis of the NAFO VMS and logbook data. NAFO SCR Doc. 20/068REV. Serial No. 7144.

NAFO, 2009. Delineation of Existing Bottom Fishing Areas in the NAFO Regulatory Area. NAFO SCS Doc. 09/21. Serial No. N5676.

NAFO, 2016. Report of the Scientific Council Meeting. 03 -16 June 2016. Halifax, Nova Scotia. NAFO SCS Doc. 16-14 Rev. Serial No. N6587.

NAFO, 2017. Report of the 10<sup>th</sup> Meeting of the NAFO Scientific Council Working Group on Ecosystem Science and Assessment (WG-ESA). NAFO SCS Doc. 17/21. Serial No. N6774.

NAFO, 2018. Report of the 11<sup>th</sup> Meeting of the NAFO Scientific Council Working Group on Ecosystem Science and Assessment (WG-ESA). NAFO SCS Doc. 18/23. Serial No. N6900.

NAFO, 2018b. Report of the NAFO Joint Commission-Scientific Council Catch Estimation Strategy Advisory Group (CESAG) Meeting. NAFO COM-SC Doc. 18-01. Serial No. N6814.

NAFO, 2019. SC Working Group On Ecosystem Science And Assessment (WG-ESA) – November 2019. NAFO SCS Doc. 19/25. Serial No. N7027.

NAFO, 2023 (REV). NAFO Conservation and Enforcement Measures 2023 (Revised). NAFO/COM Doc. 23-01. Serial No. N7368.

NEREIDA data analysis in support of assessing VME habitat functions and SAI on VME in the NAFO Regulatory Area, 2020. Project Report for the European Commission under Grant Agreements SI2.770786 and SI2.793318, 109 pp.

R Core Team, 2023. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.



Thompson, A.B. and G.M. Campanis, 2007. Information on Fishing On and Around the Four Closed Seamount Areas in the NRA. NAFO SCR Doc. 07/06. Serial No. N5347.

WGDEC, 2008. Report of the ICES-NAFO Joint Working Group on Deep Water Ecology (WGDEC), 10–14 March 2008, Copenhagen, Denmark. ICES CM 2008/ACOM:45. 126 pp. http://www.ices.dk/reports/ACOM/2008/WGDEC/WGDEC\_2008.pdf



**Table 1.** VMS total pings and erroneous entries for the period 2016-2022.

	Total Pings	Duplicated	Incomplete	Short	Long	Wrong (Total)	Wrong (%)
2016	90 294	9 922	0	17 751	5 383	33 056	36.6
2017	64 151	7 933	0	8 352	4 498	20 783	32.4
2018	212 674	81 478	0	30 219	6 813	118 510	55.7
2019	143 031	26 149	0	36 901	5 841	68 891	48.2
2020	142 127	25 372	0	43 638	6 315	75 325	53
2021	127 297	23 050	0	27 734	6 895	57 679	45.3
2022	94 872	10 676	1	13 467	4 798	28 942	30.5

**Table 2.** Logbook hauls and erroneous recordings for the period 2016-2022.

	Total hauls	Misrecorded Effort			Misrecorded	Misrecorded	
	Total flauis	Negative	Zero	Big	Total	positions	gear
2016	7 697	101	12	151	264	9	1 346
2017	6 460	143	59	149	351	26	1 027
2018	8 194	146	7	171	324	11	564
2019	11 358	608	158	260	1 026	156	1 801
2020	12 007	155	139	119	413	2 610	417
2021	8 341	109	918	115	1 142	569	243
2022	8 700	58	1 138	186	1 382	9	256



**Table 3.** Logbook misrecorded gears and new gears assigned. Count represents the total for the period 2016-2022. OTB refers to otter trawl gears and LL to longline sets.

Gear type	Count	New gear
	237	LL
ОТВ	2	ОТВ
#N/A	69	
0TB	2	ОТВ
1	2	LL
2	7	LL
3	28	LL
4	1	LL
5	6	LL
6	1	LL
???	74	ОТВ
???-2	45	ОТВ
???1	13	ОТВ
???2	290	ОТВ
LLS	259	LL
OBT	1 915	ОТВ
ОТ	201	
OTB-2	190	ОТВ
OTB2	2 360	ОТВ
OTM	304	
OTW2	34	ОТВ
ТВ	67	ОТВ
TBS	1 254	
ТО	52	ОТВ



**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.

	Obs	ervers	Log	gbook	Difference (n)		Difference (%)	
	Trips (n)	Hauls (n)	Trips (n)	Hauls (n)	Trips	Hauls	Trips	Hauls
2016	7	927	7	691	0	236	0.0	25.5
2017	8	739	6	503	2	236	25.0	31.9
2018	7	685	5	399	2	286	28.6	41.8
2019	6	688	5	532	1	156	16.7	22.7
2020	-	-	-	-	-	-	-	-
2021	8	845	7	498	1	347	12.5	41.1
2022	8	796	5	317	3	479	37.5	60.2

**Table 5.** Number of VMS pings that should be received (i.e. "Ideal world" scenario) and number of pings actually received (i.e. "Real world" scenario) when filtering VMS pings by the trawl Spanish scientific 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	5 194	4 213	981	18.9	9	1.0
2017	4 597	3 557	1 040	22.6	15	2.0
2018	4 311	3 776	535	12.4	7	1.0
2019	4 026	2 924	1 102	27.4	42	6.1
2020	-	-	-	-	-	-
2021	5 445	4 229	1 216	22.3	115	13.6
2022	5 332	3 966	1 366	25.6	102	12.8



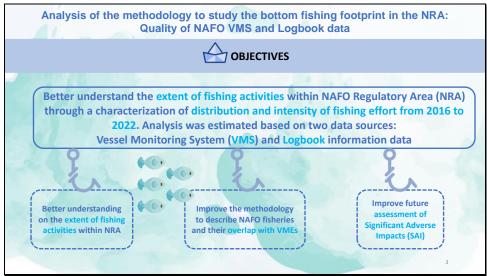
**Table 6.** Number of fishing trips and hauls recorded by the Spanish scientific observers on board trawlers, and ideal pings associated ("Ideal world" scenario). Also, the number of fishing trips, hauls and pings obtained after merging logbook and VMS and selecting the hauls where a Spanish scientific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

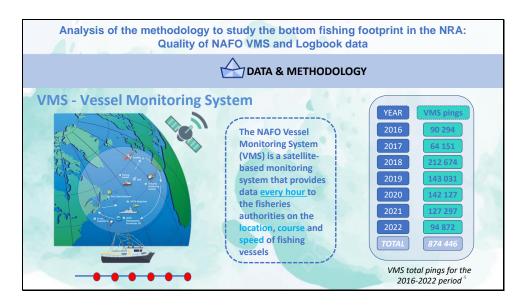
	Ideal (n)			Real (n)			Difference (%)		
	Trips Hauls Pings		Trips	Hauls	Pings	Trips	Hauls	Pings	
2016	7	927	5 194	7	682	3 113	0	26.4	40.1
2017	8	739	4 597	6	497	2 720	25	32.7	40.8
2018	7	685	4 311	5	396	2 528	28.6	42.2	41.4
2019	6	688	4 026	5	500	2 673	16.7	27.3	33.6
2020	-	-	-	-	-	-	-	-	-
2021	8	845	5 445	7	493	2 894	12.5	41.7	46.9
2022	8	796	5 332	5	316	1 968	37.5	60.3	63.1

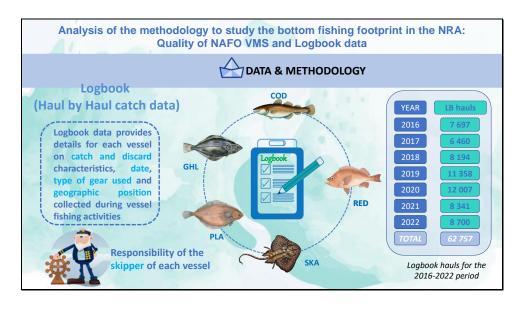


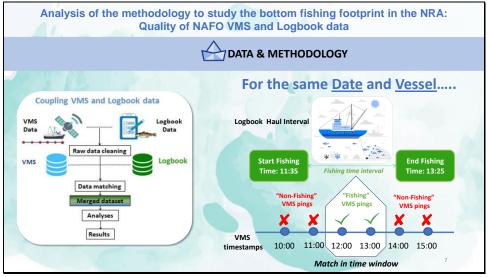
ANNEX 2. Task 1 Presentation. Scientific Council meeting, June 2024.

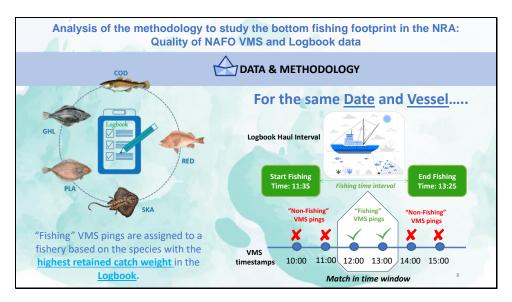


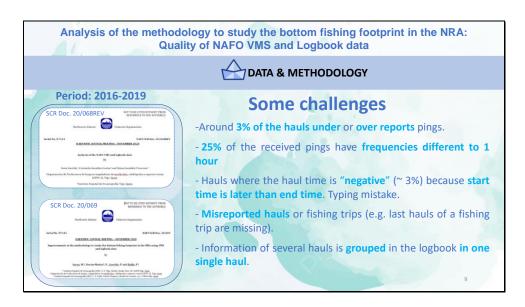


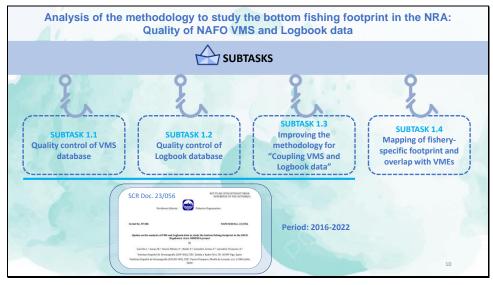


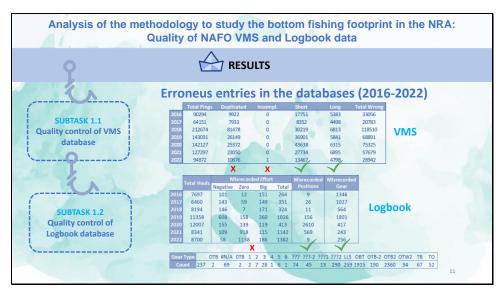


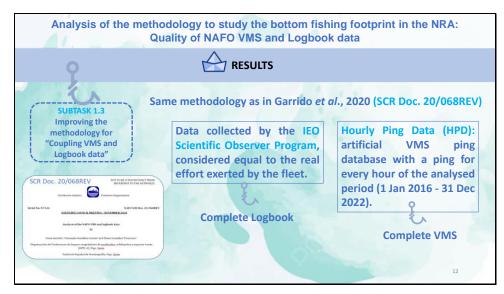


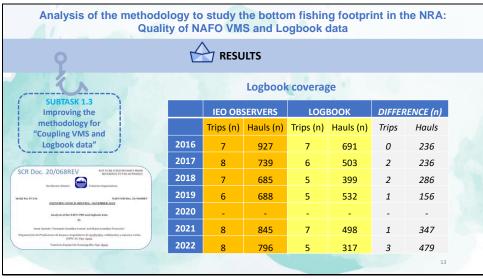


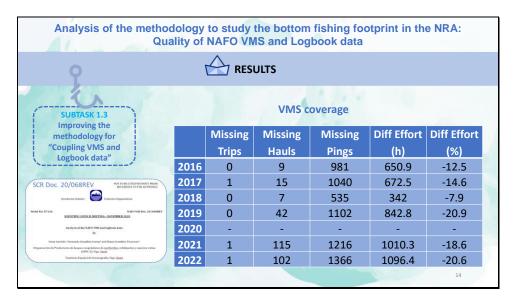


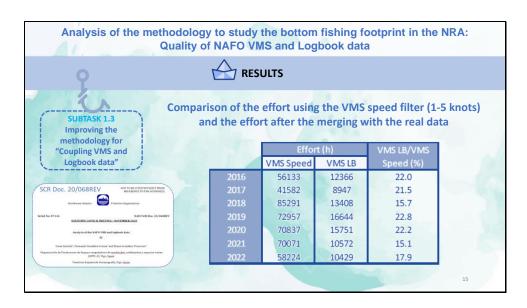


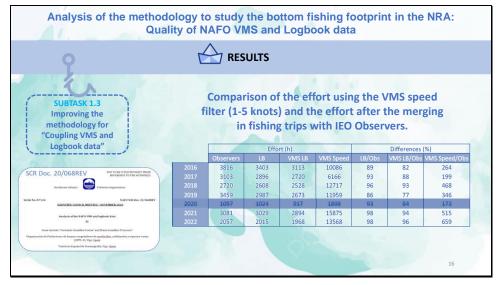


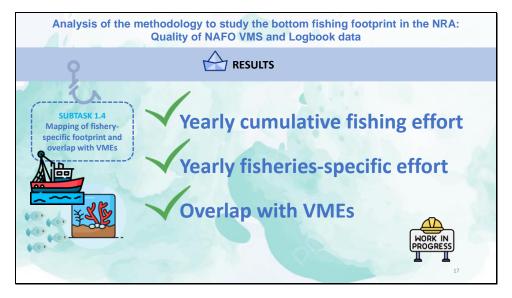


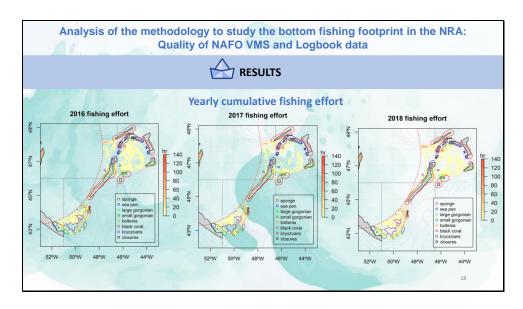


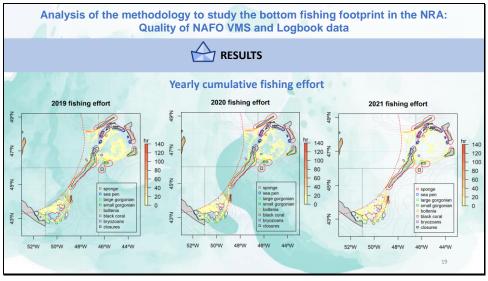


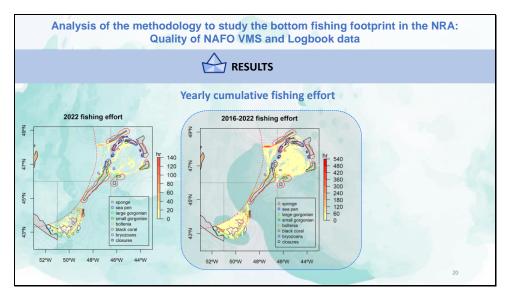


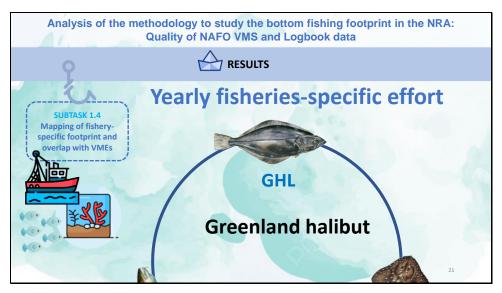


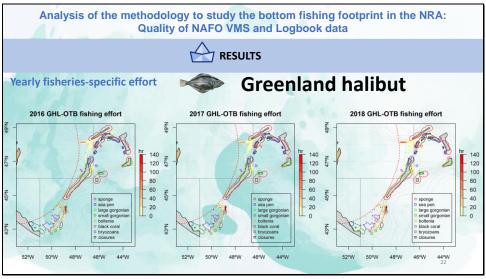


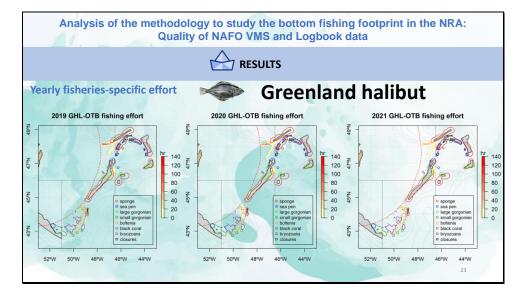


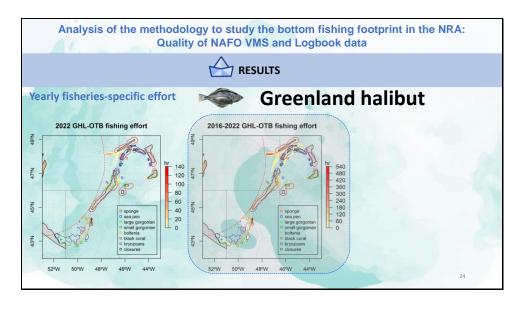


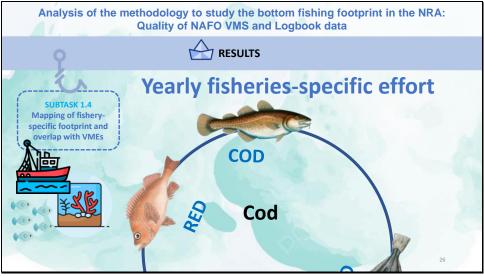


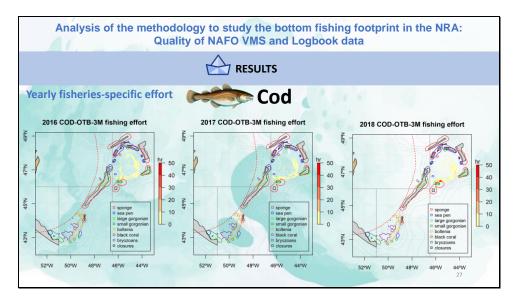


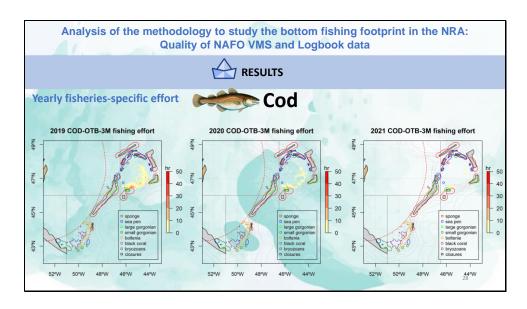


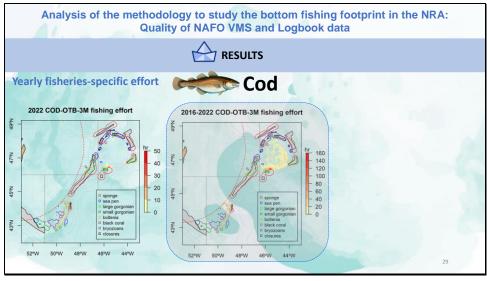


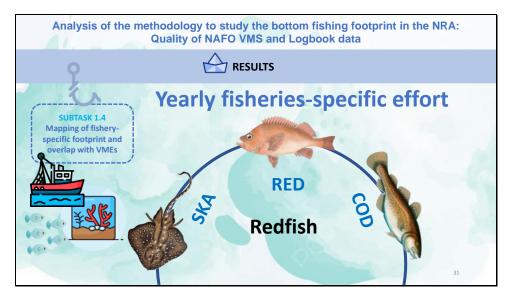


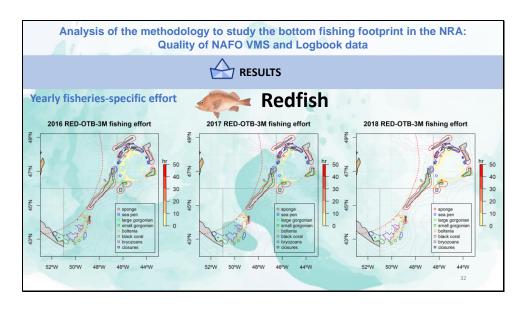


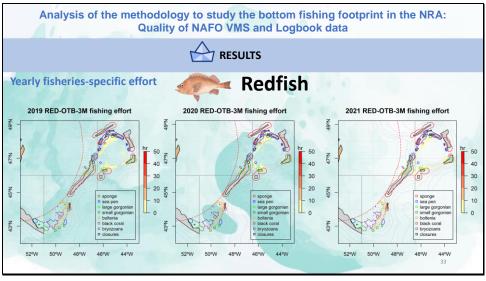


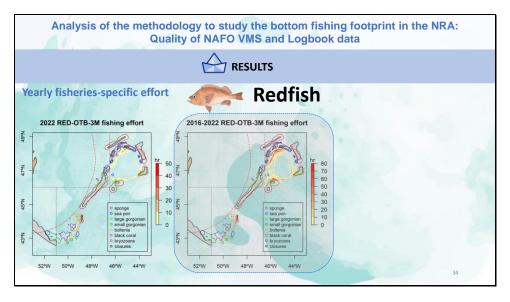


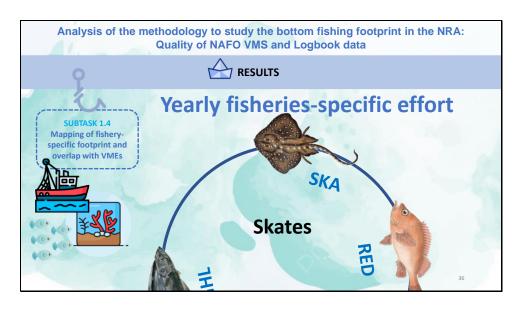


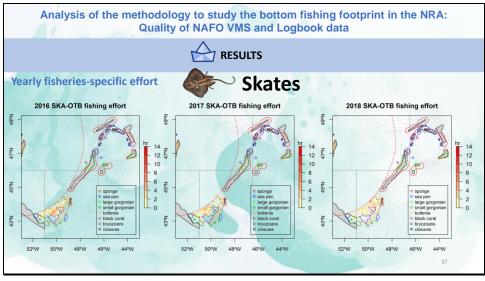


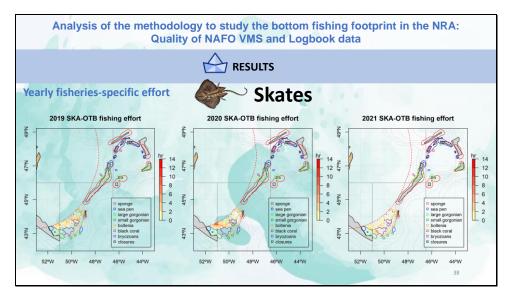


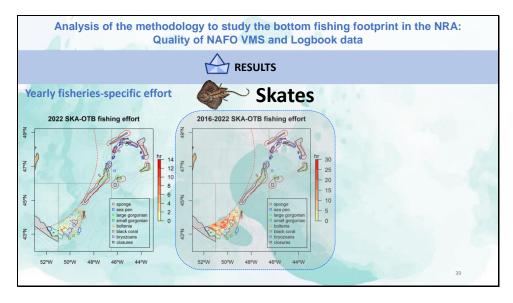


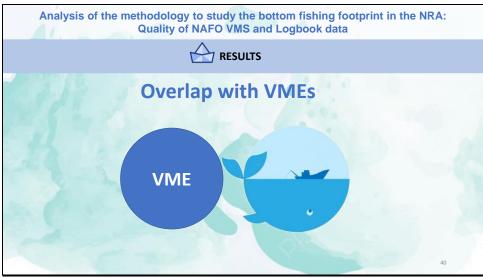


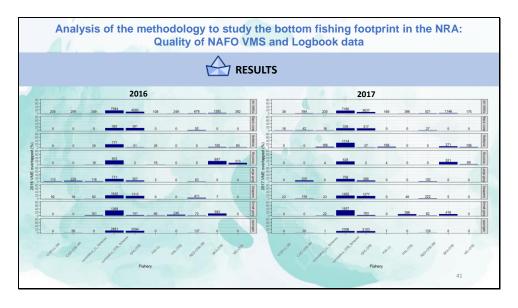


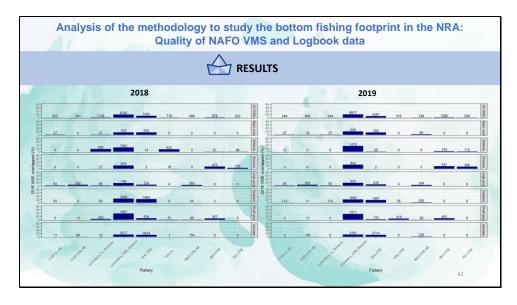


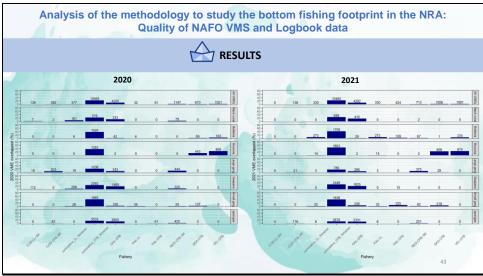


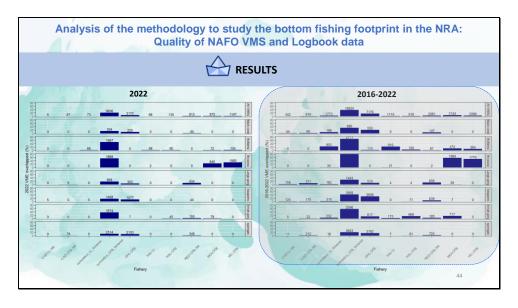














## Annexes Task 2

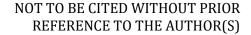
### ANNEX 3 - NAFO SCR Document

Abalo-Morla, S., Palas Otero, S., Román-Marcote, E., Durán Muñoz, P., Pérez, P., and Sacau, M. (2024) Preliminary results on seabed litter distribution on Flemish Cap (Div. 3M), Flemish Pass (Div. 3L) and Grand Banks of Newfoundland (Divs. 3NO). NAFO SCR Doc. 24/046. Serial No. N7553

### ANNEX 4 – Presentation at the NAFO Scientific Council meeting (June 2024)

Abalo-Morla, S., Palas Otero, S., Román-Marcote, E., Del Río, J.L., Pérez, P., Durán Muñoz, P., and Sacau, M. (2024). Seabed litter in NAFO Regulatory Area (Divs. 3LMNO): Protocol for data collection and preliminary results on Spatial distribution. NAFO Scientific Council Meeting June 2024. NEREIDA Task 2. Oral communication.

### **ANNEX 3. NAFO SCR Document**





Fisheries Organization

Serial No. N7553 NAFO SCR Doc. 24-046

### **SCIENTIFIC COUNCIL MEETING - JUNE 2024**

Preliminary results on seabed litter distribution on Flemish Cap (Div. 3M), Flemish Pass (Div. 3L) and Grand Banks of Newfoundland (Divs. 3NO).

Abalo-Morla, S.<sup>1</sup>, Palas Otero, S.<sup>1</sup>, Román-Marcote, E.<sup>1</sup>, Durán Muñoz, P.<sup>1</sup>, Pérez, P.<sup>1</sup>, Sacau, M.<sup>1</sup>

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2024-06-18

We analyzed seabed litter densities in the NAFO Regulatory Area (NRA; Divs. 3LMNO) using six years of demersal trawling data from the EU-Spain/Portugal groundfish surveys (period 2018–2023). This study provides a preliminary updated information and a baseline information on seabed litter for Div. 3L and Divs. 3MNO, respectively. A total of 1936 valid bottom trawl hauls were analysed (40-1481 m depth). Litter was found in 16.7% of the valid hauls, with mean densities of 6.7±18.5 items km-² and 7.7±121.5 kg km-². Fisheries was found to be the main source of seabed litter, and 41.8% of the hauls with litter presence showed litter included in the fisheries-related litter group category. Whereas in most cases the fisheries-related litter was composed of small fragments of rope, in other cases it was composed of entire fishing gears (e.g., pots from fisheries not managed by NAFO). Plastic, metal and other anthropogenic litter were the next most abundant group categories, accounting for 63.6%, 12.9% and 8.3% of the total seabed litter items recorded, respectively. The results from this study will provide information on the distribution of seabed litter in Divs. 3LMNO and will help to improve the current protocol for collecting seabed litter data and to implement best practices in groundfish surveys conducted in the region.

### 1. Introduction

The United Nations Environment Programme (UNEP) defines marine litter as "any persistent, manufactured or processed solid material discarded, disposed or abandoned in the marine and coastal environment". Nowadays, marine litter is a recognized worldwide problem that affects the marine environment in several ways such as economic loss, degradation of habitats and impact on biota (Pham et al., 2014). The large quantities of litter reaching the deep ocean floor is a major issue worldwide, yet little is known about its sources, patterns of distribution, abundance and, particularly, impacts on the habitats and associated fauna (UNEP, 2009). Benthic habitats and ecosystems, such

<sup>&</sup>lt;sup>1</sup> https://www.unep.org/topics/ocean-seas-and-coasts/regional-seas-programme/marine-litter

as the Vulnerable Marine Ecosystems (VMEs) (FAO, 2009), may be therefore affected or damaged by marine litter (Pham *et al.*, 2014, Canals *et al.*, 2021 and references therein), as the sea bottom is considered a long-term sink for marine litter (Woodall *et al.*, 2014; Egger *et al.*, 2020; Kaandorp *et al.*, 2020).

Most of the previous literature about seabed litter has studied areas close to the coast (see e.g. Neves et al., 2015; Moriarty et al., 2016; Lopez-Lopez et al., 2017; García-Rivera et al., 2018; Cau et al., 2022), and studies on deep bottoms and locations remote from land are relatively few (see e.g. Pham et al., 2014, Vieira et al., 2015; Woodall et al., 2015; García-Alegre et al., 2020; Parga Martínez et al., 2020; Ryan et al., 2020). Even remote areas of the sea floor have been found to accumulate litter, and previous studies suggested that seabed litter is ubiquitous on raised benthic features, such as seamounts (Woodall et al., 2015). The most common litter types found on the deep–sea floor in remote areas of the Atlantic Ocean are fishing gears, soft plastic (e.g. bags), hard plastic (e.g. bottles, containers), metal (e.g. tins, cans), and glass/ceramics (Ramirez-Llodra et al., 2011; Woodal et al., 2015; García-Alegre et al., 2020).

Marine litter is also a matter of concern for the NAFO Commission and Scientific Council (e.g. NAFO Commission Request #9²). To address the concerns about seabed litter in the NAFO Regulatory Area, the Spanish Institute of Oceanography (IEO) started to monitor in year 2006 the spatial and temporal distribution of seabed litter in the Flemish Pass (Division 3L) using data from the European groundfish surveys. A study was conducted in Division 3L (see García-Alegre *et al.*, 2020), in which an extensive seabed litter database was analyzed (Durán Muñoz *et al.*, 2020). Based on that study, NAFO WG-ESA³ recommended to Scientific Council that standardized protocols for marine litter data collection should be implemented by all Contracting Parties as part of their groundfish surveys conducted in the NAFO Regulatory Area (NRA), to facilitate the on-going monitoring and assessment of seabed litter (NAFO, 2019).

The present study aims to continue to provide updates on the spatial and temporal distribution of seabed litter in the NRA, based on relevant information collected by IEO between 2018 and 2023 from EU-Spain/Portugal groundfish surveys. This is in response to the NAFO Commission's request to continue monitoring and providing updates resulting from relevant research related to the potential impact of activities other than fishing (e.g. COM Request #9), existing strong arguments that justify the need to conduct new studies to better understand the non-fishing activities occurring in the NAFO context. Therefore, given the importance and value of the IEO database, the main objective of this study is to extend the analysis done in a previous study (García-Alegre *et al.*, 2020) temporarily in Flemish Pass (Div. 3L), and spatially to other areas sampled by EU-Spain/Portugal groundfish surveys: Flemish Cap (Div. 3M) and the Grand Banks (Divs. 3NO). The present analysis contributed to (i) characterizing marine litter on the seabed in these regions, and (ii) analyzing the spatial distribution of seabed litter in Divs. 3LMNO.

<sup>&</sup>lt;sup>3</sup> NAFO Working Group on Ecosystem Science and Assessment (WG-ESA).



<sup>&</sup>lt;sup>2</sup> **COM Request #9** (2024): "The Commission requests the SC to monitor and provide regular updates on relevant research related to the potential impacts of activities other than fishing in the Convention Area, subject to the capacity of the Scientific Council" (NAFO, 2024).

### 2. Materials and methods:

### 2.1 Study area

This study was conducted in the NW Atlantic Ocean within the Northwest Atlantic Fisheries Organization (NAFO) Regulatory Area, Divisions 3LMNO (Figure 1). The study area includes the Flemish Pass channel, the Flemish Cap offshore bank, and the Grand Banks of Newfoundland, including their slopes. The study area holds various types of valuable habitats and ecosystems, such as deep-water corals and deep-sea sponge grounds (see Murillo *et al.*, 2011, 2012).

### 2.2 Survey data

Seabed litter data used in this study were collected and gathered from 3 different European groundfish surveys<sup>4</sup>, conducted on board R/V *Vizconde de Eza* between late spring and summer during 2018 – 2023 (Table 1; Figure 1):

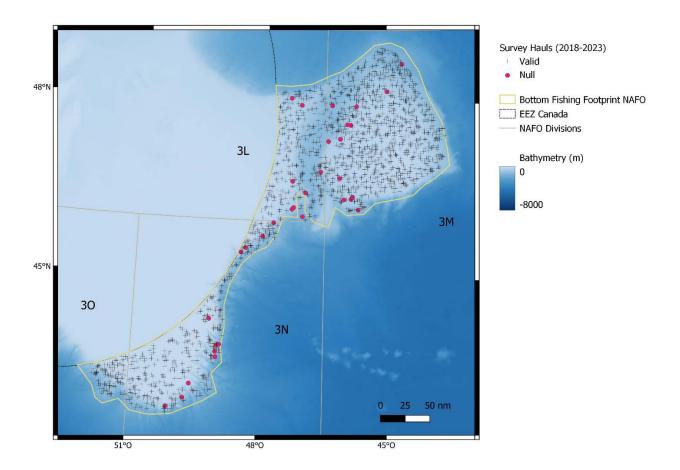
- 1. The EU-Spain 3L groundfish survey, conducted by the Instituto Español de Oceanografía (IEO, CSIC), sampled Div. 3L with a total of 298 tows (291 valid). The gear used in Division 3L was the Campelen 1800 otter trawl net (McCallum and Walsh 1994; Walsh *et al.*, 2001). Depth ranged between 116- 1491 meters. Due to the pandemic COVID-19, during 2020 and 2021 surveys were not conducted in Division 3L. During 2022 the survey was not conducted due to technical issues.
- 2. The EU-Spain and Portugal Flemish Cap groundfish survey, conducted by the Instituto Español de Oceanografía (IEO, CSIC), together with the Instituto de Investigaciones Marinas (IIM, CSIC), and Instituto Português do Mar e da Atmosfera (IPMA), sampled the Flemish Cap (NAFO Div. 3M), with a total of 1101 tows (1087 valid). In Division 3M the bottom trawl gear type used was the Lofoten (Vázquez *et al.*, 2014). Depth ranged between 128 1470 meters.
- 3. The EU-Spain 3NO groundfish survey, conducted by the Instituto Español de Oceanografía (IEO, CSIC), sampled the Grand Bank of Newfoundland (NAFO Divs. 3NO), with a total of 570 tows (558 valid). The bottom trawl gear used in Divisions 3NO was the same as that used in Div. 3L (Campelen 1800 gear type). Depth ranged between 40 1460 meters. Due to the pandemic COVID-19, survey during 2020 there was not conducted in Divisions 3NO.

<sup>&</sup>lt;sup>4</sup> These surveys are relevant to provide key data on the presence, distribution, and abundance of seabed litter. Although they are primarily intended for fisheries stock assessment, other ancillary ecosystem information is also collected, such as data on Vulnerable Marine Ecosystems indicator species, or seabed litter, which the earliest records dating back to as early as 2006.



**Table 1**. Summary of sampling: years with survey (✓); years without survey (×). Reasons for not conducting the survey were: COVID-19 pandemic (\*) technical issues (\*\*).

	2018	2019	2020	2021	2022	2023
Div. 3L	✓	✓	<b>*</b> *	<b>x</b> *	<b>*</b> **	✓
Div. 3M	✓	✓	✓	✓	✓	✓
Divs. 3NO	✓	✓	<b>*</b> *	✓	✓	✓



**Figure 1.** Valid (black crosses) and null tows (pink points) conducted during the European groundfish surveys from 2018 to 2023. The bathymetry (in blue scale), the boundaries of the bottom fishing footprint in the NAFO NRA (yellow line), the Canadian Economic Exclusive Zone (EEZ) (dashed black line) and the NAFO Divisions (grey line) are also shown.

### 2.3 Data collection

Based on the recommendation of the Scientific Council to the NAFO Commission that standardized protocols for the collection of seabed litter data should be implemented by all Contracting Parties as part of their groundfish surveys, the Spanish Institute of Oceanography (IEO) developed a protocol to be used in all the EU groundfish surveys in the NRA. The objective of implementing a protocol was to extend the seabed litter data collection started in year 2006 (García-Alegre *et al.*, 2020) in the Flemish Pass (Div. 3L) to the other areas sampled by the EU surveys: Flemish Cap (Div. 3M) and the



Grand Banks of Newfoundland (Divs. 3NO), using the same methodology. This protocol was first implemented in Divs. 3LNO (2018) and Div. 3M (2019) as a pilot experiment and its application continued until 2023 (included). An ongoing study is been conducted to review and improve the seabed litter data collection protocol.

According to the current protocol, after each haul, all seabed litter items collected and retained by the bottom trawl gear were examined, categorized, counted, weighed, sized, photographed (if possible), and recorded onboard the research vessel. Any evidence regarding the source of seabed litter was also recorded. For each haul, trawl gear characteristics, location, date, time and depth at start and end of trawl were also recorded.

Additionally, available spatial information about bottom fisheries effort (both regulated by NAFO and by the coastal State, Canada) was compiled. Cumulative fishing effort of groundfish fisheries operating in the NRA during 2016-2022 was obtained (Garrido et al., 2023). Spatial data on queensnow crab fisheries overlapping with NAFO NRA bottom fisheries footprint was obtained from Statistical Services, Fisheries and Oceans Canada (DFO) and consists of commercial landings data from 2012 to 2021. Data is available https://gisp.dfoat: mpo.gc.ca/arcgis/rest/services/FGP/Eastern\_Canadian\_Commercial\_Fishing/MapServer//2 4.

### 2.4 Data analysis

A comprehensive review, update and standardization of the list of seabed litter categories and codes was performed, with particular attention to the existing data recorded in the NAFO Regulatory Area (NRA), to obtain a standardized master file. That master file contains all the updated categories and specific codes of the records collected to date by the IEO in the NRA. A cross-check of the groundfish survey data collection form with the database was carried out to ensure that seabed litter database did not contain any typing errors, in which case they were removed or corrected. A cross-check of the seabed litter database with photographic records was also carried out to ensure that all items matched the records in the database. The criteria for counting seabed litter items was done as described in the ICES Manual for Seafloor Litter Data Collection (ICES, 2022). According to ICES, litter that arises from the survey itself, such as items released from the gear or the vessel during the trawl (e.g., codend strings, pieces of net, plastic floats from the trawl gear), were excluded from the analysis (ICES, 2022).

In order to simplify the analysis, seabed litter items were classified into seven litter group categories (Table 2), based on their material composition, degradability and original activity, namely: Plastics, Rubber, Metal, Fisheries related litter, Glass/Ceramics, Organic litter and Other anthropogenic litter (Modified from OSPAR, 2007 and ICES, 2022). The latter included processed wood, textiles, paper/cardboard, clothing, refractory material (with alumina), ropes made of natural fibers, and other anthropogenic litter not fitting into the other litter group categories. Fisheries derived items (i.e. pieces of longlines, nets, bobbins, floats, pots, hooks) were incorporated into a separated group category, as done in previous research (Pham *et al.*, 2014; Lopez-Lopez *et al.*, 2017; García-Alegre *et al.*, 2020). Additionally, it was determined whether synthetic ropes and/or entangled monofilaments could be associated with fisheries or not, and were accordingly assigned to the pertaining litter group category.



Haul data were then standardized as density per square km (both by number of seabed litter items and weight) and represented for each trawl and year and averaged for sampling strata, according to the NAFO stratification scheme (Doubleaday, 1981). These density values were calculated by the swept area, obtained by multiplying the distance trawled by the net and the estimated horizontal opening (Campelen 1800 swept area in Divs. 3LNO; see García-Alegre *et al.*, 2020) or by the haul path estimated by haul locations (Lofoten swept area in Div. 3M).

### 3. Results and discussion

### 3.1 Characterization of marine litter on the seabed

Litter debris was found on 16.7% of the total valid trawls analyzed. A total of 528 litter items were encountered throughout all sites surveyed. Plastic and fishing related litter items were the most frequently found in the study area, which is consistent with the pilot study conducted in 3L (García-Alegre *et al.*, 2020). Of the trawls with presence of litter, 41.8% has occurrence of fisheries related litter (Table 2). In most cases fishing-related litter consisted of small fragments of rope and entangled monofilaments, followed by fragments of fishing gear (e.g. hooks, lines, pieces of net, bobbins, floats) or entire fishing gears (e.g. pots, nets). Similar results were observed in García-Alegre *et al.*, (2020) for Division 3L.

Plastic accounted for 63.6% of litter items recorded, whilst metal accounted for 12.9% of the total. Remnants of fishing gear (7.8%), organic litter (4.4%), rubber (1.7%) and glass/ceramics (0.4%) were the least common. Items classified as "other anthropogenic litter" accounted for 8.3% of the litter items encountered in sites surveyed and included processed wood, paper/cardboard, clothing, alumina-based refractory material, ropes made using natural fibers, and other uncategorized anthropogenic litter (Table 3). Our results are in line with previous studies conducted in the remote areas of the North Atlantic Ocean, in which fishing related litter, plastics associated with food packaging and metals were the most predominant (Woodall *et al.*, 2015; García-Alegre *et al.*, 2020).



**Table 2**. Percentage of trawl tows with seabed litter occurrence per Division and for the entire study area. Percentage of hauls with seabed litter occurrence by litter group category is shown. Seven litter group categories were considered: plastic, rubber, metal, glass/ceramics, fishing-related litter, organic litter, and other anthropogenic litter.

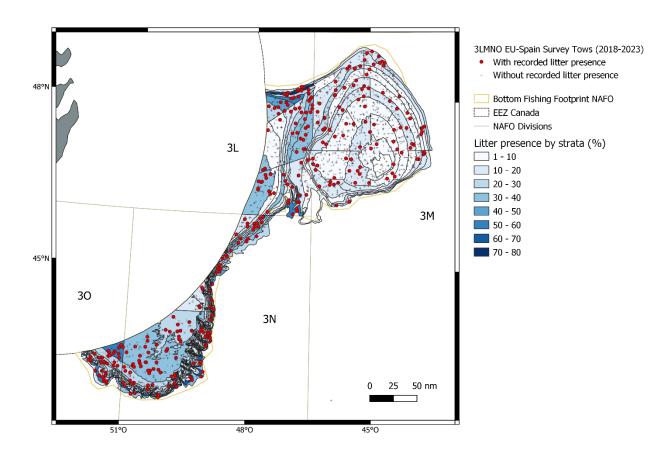
	Litter	. Hauls with litter occurrence by group categ						)
Division	occurrence (%)	Plastic	Rubber	Metal	Glass/ Ceramics	Fishing related	Organic	Other
3L	27.1	45.5	1.3	3.8	1.3	57.0	5.1	8.9
3M	9.5	36.5	5.2	20.8	0.0	36.5	0.0	17.7
3NO	28	63.5	2.0	12.8	0.7	37.2	2.7	13.5
3LMNO	16.7	51	2.8	13.0	0.6	41.8	2.5	13.6

**Table 3**. Frequency of seabed litter and mean densities over the study area regarding the number of items and weight recorded, for each group category.

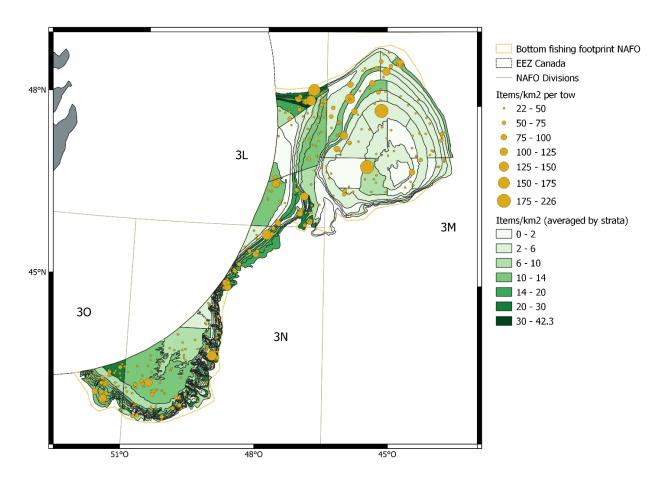
Group category	Frequency of items (%)	Mean density (item/km2)		-	Frequency of weight (%)	Mean density (kg/km2)		
Plastic	63.6	2.6	±	8.3	1.1	0.06	±	0.5
Rubber	1.7	0.1	±	1.7	3.8	0.3	±	10.2
Metal	12.9	8.0	±	7.9	26.8	2.0	±	87.4
Glass/Ceramics	0.4	0.02	±	0.3	0.2	0.01	±	0.5
Fishing related litter	7.8	2.1	±	8.4	56.4	4.4	±	79.9
Organic litter	4.4	0.3	±	5.7	4.1	0.3	±	9.3
Other anthropogenic litter	8.3	0.6	±	4.1	20.1	0.3	±	5.3

### 3.2 Spatial and temporal distribution

Strata with higher seabed litter occurrence were located on the northern and eastern slopes of the Flemish Pass and on the slopes of the Grand Banks of Newfoundland, but were evenly distributed along the slopes of the Flemish Cap (Figure 2). Similar results are shown by the higher densities of number of items (items/km²) by haul and by strata (Figure 3). In terms of litter occurrence and density of seabed litter items, the highest densities were found in Divisions 3LNO, mainly on the slopes of the Grand Banks of Newfoundland, and on the northern and southern slopes of Flemish Pass. The results obtained in Division 3L are in line with the previous study in the region, which highlighted that the highest presence and densities of seabed litter were found in the north and northeast of the Division 3L (García-Alegre *et al.*, 2020). Significant differences among Divisions were found regarding densities in kg/km² (Kruskal-Wallis = 105.44, df = 2, p-value = < 2.2e-16); and in items/km² (Kruskal-Wallis = 106.56, df = 2, p-value < 2.2e-16). Pairwise comparisons between Divisions showed that there were significant differences in seabed litter densities between Division 3M and Divisions 3LNO (Wilcoxon rank test; p-value < 0.0001).



**Figure 2.** Spatial distribution of hauls with seabed litter presence (red points) or absence (black crosses) recorded. In the background, the percentage of tows with litter presence by sampling strata (according to the NAFO scheme) is shown (in blue scale). The boundaries of the bottom fishing footprint in the NRA (yellow line), the Canadian Economic Exclusive Zone (EEZ) (dashed black line) and the NAFO Divisions (grey line) are also shown.

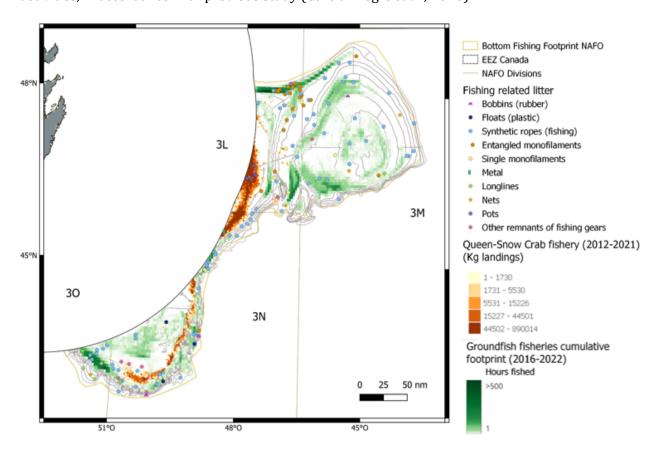


**Figure 3**. Seabed litter densities (number of items/km²) per tow (yellow points) and averaged by sampling strata (in green scale) recorded during the scientific bottom trawl surveys conducted in Divisions 3LMNO during 2018-2023.

The spatial distribution of fishing related litter showed that most records of fishing related items might be associated with areas of higher fishing effort, particularly on the northern slopes of the Flemish Pass and the south-western slopes of the Grand Banks of Newfoundland (Figure 4). An uneven distribution of fishing related items was recorded. Although synthetic ropes related with fishing activities were evenly distributed along the Flemish Cap, on the Flemish Pass and the Grand Banks of Newfoundland were mainly recorded on the slopes. Similar distribution was recorded to entangled monofilaments and single monofilaments, but these records were always recorded nearby or on the area covered by the cumulative fisheries effort of the groundfish fisheries. There are few records of bobbins and floats along the study area, both on slopes and plains, but always nearby the areas where groundfish fisheries operates. Few records of nets were located on the south and east of Flemish Cap and Flemish Pass, and in the slopes of the southwestern part of the Grand Banks (Division 30). Longlines were mainly recorded on the slope of the southwest part of the Grand Banks (Division 30), two of them close to the areas operating longline groundfish fisheries. Other remnants of fishing gears were mainly recorded on the southwestern part of the Grand Banks (Division 3N), close to the queen-snow crab fishery and the groundfish fisheries operating areas. Pots were found in the western part of the Flemish Pass, close to the Canadian EEZ, over the areas with the highest



landing recordings of the queen-snow crab fishery. Therefore, in Division 3L fishery-related litter items were identified as being associated with both NAFO managed and non-managed fishing activities, in accordance with previous study (García-Alegre *et al.*, 2020).



**Figure 4.** Spatial distribution of fishing related seabed litter by items. The cumulative fishing effort of groundfish fisheries operating in the NRA during 2016-2022 (green scale; Garrido *et al.*, 2023) and the landings (in kg) of the queen-snow crab fisheries (orange scale) are displayed. Data on queen-snow crab fisheries was obtained from Statistical Services, Fisheries and Oceans Canada (DFO) and consists of commercial landings data from 2012 to 2021. Each cell in a 2-minute hexagonal grid (approx.  $10 \text{km}^2$  cell) shows the total weight (kg) of landings summed over the ten-year period. The boundaries of the sampling strata (light grey lines), the boundaries of the bottom fishing footprint in the NAFO NRA (yellow line), the Canadian Economic Exclusive Zone (EEZ) (dashed black line) and the NAFO Divisions (grey line) are also shown.

### 3.3 Protocols for seabed litter data collection

Based on the recommendation of the Scientific Council to the NAFO Commission (NAFO, 2020) that standardized protocols for the collection of seabed litter data should be implemented by all Contracting Parties (CPs) as part of their groundfish surveys, the Spanish Institute of Oceanography (IEO) developed a protocol for seabed litter data collection, to be used in all the EU groundfish surveys in the NRA. The objective of implementing a protocol was to extend the seabed litter data collection started in year 2006 in the Flemish Pass (Div. 3L) (García-Alegre *et al.*, 2020) to the other areas sampled by the EU surveys: Flemish Cap (Div. 3M) and the Grand Banks of Newfoundland (Divs. 3NO), using a common methodology. This preliminary protocol was first implemented in Divs. 3LNO



(2018) and Div. 3M (2019) as a pilot experiment. Its application continued until 2023 (included), after which it will be reviewed and improved with the objective of providing a standardized sampling protocol for such surveys. This is part of the ongoing study referred to in this report.

### *Protocol* at a glance

According to the current sampling protocol, after each haul, all seabed litter items collected and retained by the bottom trawl gear are examined, categorized, counted, weighed, sized, photographed and recorded on board the research vessel (Diagram 1). Any evidence regarding the source of litter is also recorded. For each haul, the characteristics of the trawl gear, location, date, time and depth at the start and end of the trawl are also recorded, as well as other general information about the haul.



**Diagram 1.** Suggested sequence of steps for on-board collection and recording of seabed litter data.

In this context, it should be noted that have a common protocol agreed with other CPs for the collection of seabed litter in the NRA would facilitate the standardisation of monitoring practices. This would help to reduce differences in data collection and classification procedures, which would improve the comparability of the data and allow its assessment on a regional scale.

This fact encourages us to prepare and continue working on a new revised protocol, based on a previous review of protocols and manuals used in different areas by different groups (e.g. ICES, 2022). A comprehensive review, update and standardization of the list of marine litter categories and codes is also necessary, with particular attention to the existing data recorded in the NRA, in order to produce a standardized master file. Cross-checking the information collected on board with the seabed litter database and the photographic records has allowed us to identify typographical errors and guide the drafting of the improved protocol and best practices according to the needs and gaps identified. On this basis, for example, the criteria for counting litter items for further analysis, in the study referred to in this report, was carried out as described in the ICES Manual for Seafloor Litter Data Collection (ICES, 2022).

Recognising that seabed litter data are collected and recorded during groundfish surveys for stock assessment, which may be subject to time constraints and poor weather conditions, the procedures in the manual are intended to be simple and user-friendly, and will be presented accompanied by a photographic guide to facilitate a better categorisation of the different items.

### 4. Main outputs, challenges and future work

Preliminary results obtained showed that plastics and related fishing litter were the dominant types of litter found in the study area, similarly to other research (Buhl-Mortensen and Buhl-Mortensen, 2018; García-Alegre *et al.*, 2020). Previous studies highlighted that the distribution and effects of abandoned, lost and discarded fishing gears (ADLFG) had risen substantially over past decades with the rapid expansion of fishing effort and fishing grounds, and the transition to synthetic materials used for fishing gears (Derraik, 2002).

There are some limitations to the data collected from EU groundfish surveys, as the priority of these surveys is to assess fish stocks rather than litter accumulation and trends. Additionally, trawls only cover soft sediment trawlable areas, leading to sampling limitations in rocky areas. Small objects may not be sampled by fishing gears. Furthermore, how well the different gears types sample litter is not yet well understood (Barry *et al.*, 2022).

In summary, this study contributed to characterize marine litter on the seabed, and provides preliminary information about spatial distribution of seabed litter in Divs. 3LMNO. Outputs from this study will help in conducting ongoing research on seabed litter in the region, whose aim is to (i) update the knowledge about spatial distribution of seabed litter; (ii) determine the main litter sources; (iii) elucidate the potential drivers of seabed litter distribution; (iv) improve the current protocol and data forms for seabed litter data collection, and (v) provide recommendations and good practices. An update from this study is expected to be presented during next WG-ESA meeting, scheduled for November 2024.

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### References

- Barry, J., Russell, J., van Hal, R., van Loon, W.M.G.M., Norén, K., Kammann, U., Galgani, F., Gago, J., De Witte, B., Gerigny, O., Lopes, C., Pham, C. K., Garcia, S., Sousa, R., Rindorf, A. (2022). Composition and Spatial Distribution of Litter on the Seafloor. In: OSPAR, 2023: The 2023 Quality Status Report for the North-East Atlantic. OSPAR Commission, London. Available at: <a href="https://oap.ospar.org/en/ospar-assessments/quality-status-reports/qsr-2023/indicator-assessments/seafloor-litter/">https://oap.ospar.org/en/ospar-assessments/seafloor-litter/</a>
- Canals, M., Pham, C.K., Bergnamm, M., Gutow, L., Hanke, G., van Sebille, E., Angiolillo, M., Bulh-Mortensen, L., Cau, A., Ioakeimidis, C. (2021). The quest for seafloor macrolitter: a critical review of background knowledge, current methods and future prospects. Environ. Res. Lett. 16 023001. http://doi.org/10.1088/1748-9326/abc6d4
- Cau, A., Franceschini, S., Moccia, D., Gorule, P.A., Agus, B., Bellodi, A., Cannas, R., Carugati, L., Cuccu, D., Dessì, C., Marongiu, M.F., Melis, R., Mulas, A., Porceddu, R., Porcu, C., Russo, T., Follesa, M.C.



- (2022). Scattered accumulation hotspots of macro-litter on the seafloor: Insights for mitigation actions, Environmental Pollution, 292, Part A, 118338. https://doi.org/10.1016/j.envpol.2021.118338
- García-Alegre A., Román-Marcote E., Gago J., González-Nuevo G., Sacau M., Durán Muñoz P. (2020). Seabed litter distribution in the high seas of the Flemish Pass area (NW Atlantic). Scientia Marina 84(1). https://doi.org/10.3989/scimar.04945.27A
- García-Rivera, S., Lizaso, J.L.S., Millán, J.M.B. (2018). Spatial and temporal trends of marine litter in the Spanish Mediterranean seafloor. Mar. Pollut. Bull. 137: 252-261. https://doi.org/10.1016/j.marpolbul.2018.09.051
- Garrido, I., Sacau, M., Durán-Muñoz, P., Baldó, F., González-Costas, F., González-Troncoso, D. (2023). Update on the analysis of VMS and Logbook data to study the bottom fishing footprint in the NAFO Regulatory Area: NEREIDA project. NAFO SCR Doc. 23/056. Serial No. N7486. https://www.nafo.int/Portals/0/PDFs/sc/2023/scr23-056.pdf
- Derraik J (2002). The pollution of the marine environment by plastic debris: a review, Mar. Pollut. Bull. 44:842–852.
- Doubleday, W.G. (Ed.) (1981). Manual of Groundfish Surveys in the Northwest Atlantic. In: Northwest Atlantic Fisheries Organization. NAFO Scientific Council Studies, vol. 2, pp. 7–55.
- Durán Muñoz, P., Sacau, M., García-Alegre, A., and Román, E. (2020). Cold-water corals and deep-sea sponges by-catch mitigation: Dealing with groundfish survey data in the management of the northwest atlantic ocean high seas fisheries. *Marine Policy*, 116(103712). https://doi.org/10.1016/j.marpol.2019.103712
- Egger, M., Sulu-Gambari, F., Lebreton, L. First evidence of plastic fallout from the North Pacific Garbage Patch. Sci Rep 10, 7495 (2020). https://doi.org/10.1038/s41598-020-64465-8
- FAO (2009). Directrices Internacionales para la Ordenación de las Pesquerías de Aguas Profundas en Alta Mar. Roma, 73p. http://www.fao.org/3/i0816t/I0816T.pdf
- ICES (2022). ICES manual for seafloor litter data collection and reporting from demersal trawl samples. ICES Techniques in Marine Environmental Sciences Vol. 67. 16 pp. https://doi.org/10.17895/ices.pub.21435771
- Kaandorp, M., Dijkstra, H.A., van Sebille, E. (2020). Closing the Mediterranean marine floating plastic mass budget: inverse modelling of sources and sinks Environ. Sci. Technol. 54, 11980–9. https://doi.org/10.1021/acs.est.0c01984
- Lopez-Lopez, L., González-Irusta, J.M., Punzón, A., Serrano, A. (2017). Benthic litter distribution on circalittoral and deep-sea bottoms of the southern Bay of Biscay: Analysis of potential drivers. Cont. Shelf Res. 144: 112-119. https://doi.org/10.1016/j.csr.2017.07.003
- McCallum, B. R., Walsh, S.J. (1994). Survey Trawl Reference Manual: Campelen 1800. Dep. Fish. Oceans, Newfoundland, Canada.
- Moriarty, M., Pedreschi, D., Stokes, D., Dransfeld, L., Reid, D.G. (2016). Spatial and temporal analysis of litter in the Celtic Sea from Groundfish Survey data: Lessons for monitoring, Marine Pollution Bulletin, 103(1-2):195-205. https://doi.org/10.1016/j.marpolbul.2015.12.019



- Murillo, F.J., Durán Muñoz, P., Altuna, A., Serrano, A. (2011). Distribution of deep-water corals of the Flemish Cap, Flemish Pass, and the Grand Banks of Newfoundland (Northwest Atlantic Ocean): interaction with fishing activities. ICES J. Mar. Sci. 68: 319-332. https://doi.org/10.1093/icesjms/fsq071
- Murillo, F.J., Durán Muñoz, P., Cristobo, J., Ríos, P., González, C., Kenchington, E., Serrano, A. (2012). Deep-sea sponge grounds of the Flemish Cap, Flemish Pass and the Grand Banks of Newfoundland (Northwest Atlantic Ocean): distribution and species composition. Mar. Biol. Res. 8: 842-854. https://doi.org/10.1080/17451000.2012.682583
- NAFO (2024). The Commission's Request for Scientific Advice on Management in 2025 and Beyond of Certain Stocks in Subareas 2, 3 and 4 and Other Matters. NAFO Scientific Council. NAFO/SCS Doc. 24/01. No. N7491. https://www.nafo.int/Portals/0/PDFs/sc/2024/scs24-01.pdf
- NAFO (2021). Report of the 13th Meeting of the NAFO Scientific Council. Working Group on Ecosystem Science and Assessment (WG-ESA). NAFO/SCS Doc. 20/23. No. N7148. https://www.nafo.int/Portals/0/PDFs/sc/2020/scs20-23.pdf
- NAFO (2020). Report of the Scientific Council, 21 25 September 2020, via WebEx. NAFO SCS Doc. 20/19. https://www.nafo.int/Portals/0/PDFs/sc/2020/scs20-19.pdf
- NAFO (2019). Report of the 12th Meeting of the NAFO Scientific Council Working Group on Ecosystem Science and Assessment (WG-ESA). Northwest Atlantic Fisheries Organization. 19-28 November 2019, Dartmouth, Canada. Serial No. N7027 NAFO SCS Document 19/25. https://www.nafo.int/Portals/0/PDFs/sc/2019/scs19-25.pdf
- Neves, D., Sobral, P., Pereira, T. (2015). Marine litter in bottom trawls off the Portuguese coast. Mar. Pollut. Bull. 99: 301-304. https://doi.org/10.1016/j.marpolbul.2015.07.044
- OSPAR (2007). Monitoring of Marine litter in the OSPAR Region. Publication No. 306/2007. London, United Kingdom, 74 pp.
- Parga Martínez, K.B., Tekman, M.B., Bergmann, M. (2020). Temporal trends in marine litter at three stations of the HAUSGARTEN observatory in the Arctic deep-sea Front. Mar. Sci. 5 321. https://doi.org/10.3389/fmars.2020.00321
- Pelea, L. P. (2019). Outliers in data sets, how identify and handling them? Revista Del Jardín Botánico Nacional, 40, 99–107. https://www.jstor.org/stable/26937051
- Pham, C.K., Ramirez-Llodra, E., *et al.*, (2014). Marine litter distribution and density in European seas, from the shelves to deep basins. PLoS One 9: e95839. https://doi.org/10.1371/journal.pone.0095839
- Ramirez-Llodra, E., Tyler, P.A., Baker, M.C., Bergstad, O.A., Clark, M.R., et al. (2011). Man and the Last Great Wilderness: Human Impact on the Deep Sea. PLOS ONE 6(8): e22588. https://doi.org/10.1371/journal.pone.0022588
- Ryan, P.G., Weideman, E.A., Perold, V., Durholtz, D., Fairweather, T.P. (2020). A trawl survey of seafloor macrolitter on the South African continental shelf Mar. Pollut. Bull. 150 110741. https://doi.org/10.1016/j.marpolbul.2019.110741



- UNEP (2009). Marine Litter: A Global Challenge. Nairobi. 232 p. https://www.unep.org/resources/report/marine-litter-global-challenge
- Vázquez, A., Casas, J.M., Alpoim, R. (2014). Protocols of the EU bottom trawl survey of Flemish Cap. NAFO Scientific Council Studies, 46: 1–42. https://doi.org/10.2960/S.v46.m1
- Veiga, J.M., Fleet, D., Kinsey, S., Nilson, P., Vlachogianni, T., Werner, S., Galgani, F., Thompson, R.C., Dagevos, J., Gago, J., Sobral, P., Cronin, R. (2016). Identifying Sources of Marine Litter. MSFD GES TG Marine Litter Thematic Report; JRC Technical Report; EUR 28309. https://doi.org/10.2788/018068
- Vieira, R.P., Raposo, I.P., Sobral, P., et al. (2015). Lost fishing gear and litter at Gorringe Bank (NE Atlantic). J. Sea Res. 100: 91-98. https://doi.org/10.1016/j.seares.2014.10.005
- Walsh, S. J., Paz, X., Durán Muñoz, P. (2001). A preliminary investigation of the efficiency of Canadian and Spanish survey bottom trawls on the southern Grand Bank. NAFO SCR. Doc., No. 74. Serial No. N4453, 18 p. https://www.nafo.int/Portals/0/PDFs/sc/2001/scr01-074.pdf
- Woodall, L.C., Sanchez-Vidal, A., Canals, M., Paterson, G.L.J., Coppock, R., Sleight, V., Calafat, A., Rogers, A.D., Narayanaswamy, B.E., Thompson R.C. (2014). The deep sea is a major sink for microplastic debris. R. Soc. Open Sci.1140317. http://doi.org/10.1098/rsos.140317
- Woodall, L.C., Robinson, L.F., Rogers, A.D., Narayanaswamy, B.E., Paterson, G.L.J. (2015). Deep-sea litter: a comparison of seamounts, banks and a ridge in the Atlantic and Indian Oceans reveals both environmental and anthropogenic factors impact accumulation and composition. Front. Mar. Sci. 2:3. https://doi.org/10.3389/fmars.2015.00003



### ANNEX 4. Task 2 Presentation. Scientific Council meeting, June 2024

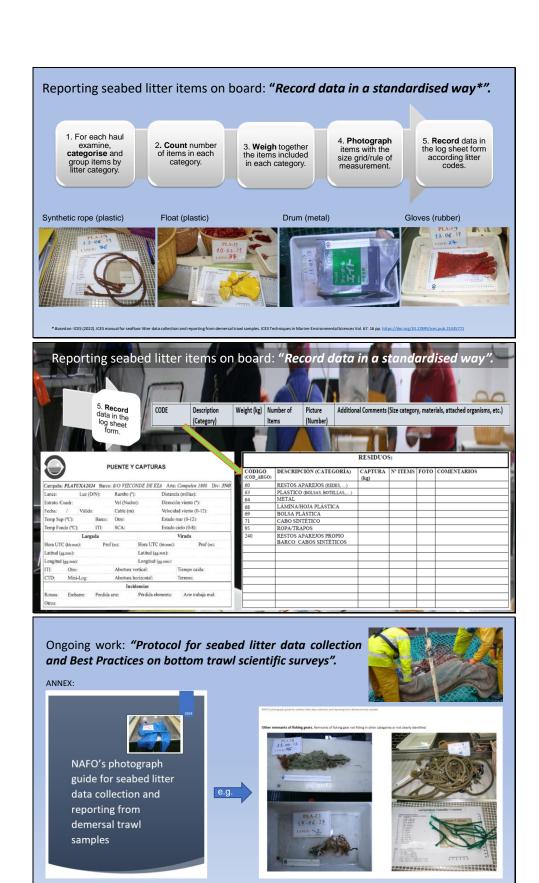


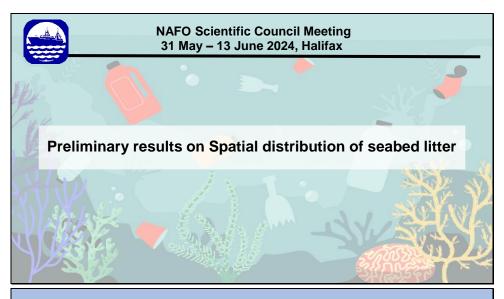
### SEABED LITTER DATA COLLECTION PROTOCOL: (FOR ANY ANTHROPOGENIC LITTER OR DEBRIS)

### Collection of seabed litter:

- Catch of each valid haul will be inspected to find and collect seabed litter items that will be categorised and recorded.





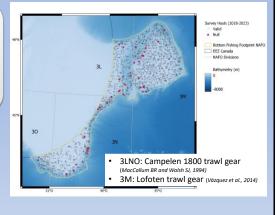


### **CHARACTERIZATION AND COMPOSITION OF SEABED LITTER**

### **Seabed litter collection:**

- EU bottom trawl groundfish surveys (2018-2023) in Divs. 3LMNO.
- 1936 valid hauls analyzed (40-1481 m depth).
- **± 528 litter items** found.
- **16.7%** of valid hauls recorded any litter.





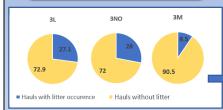
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MacCallum BR and Walsh SI (1994) Survey Trawl Reference Manual: Campelen 1800. Department of Fisheries and Oceans, Newfounland, Canada).

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### **CHARACTERIZATION AND COMPOSITION OF SEABED LITTER**

### Seabed litter collection:

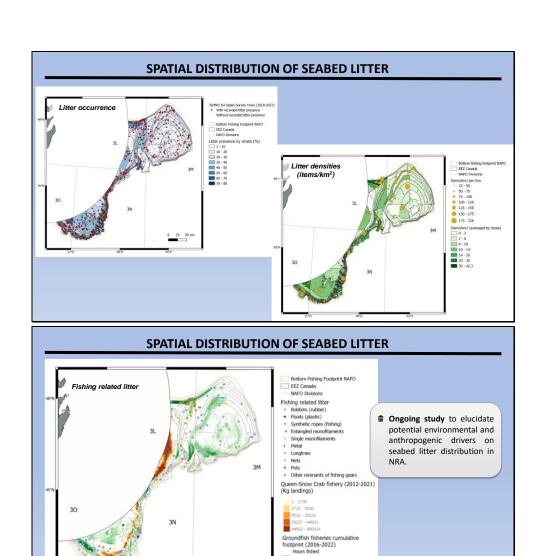
- EU bottom trawl groundfish surveys (2018-2023) in Divs. 3LMNO.
- **1936 valid hauls** analyzed (40-1481 m depth).
- 528 litter items found
- 16.7% of valid hauls recorded any litter.



### **Seabed litter composition and densities:**

Litter group category	Items/km <sup>2</sup>	kg/km²	
Plastic	2.6±8.3	0.06±0.5	
Fishing related litter	2.1±8.4	4.4±79.9	
Metal	0.8±7.9	2.0±87.4	
Other antropogenic litter	0.6±4.1	0.3±5.3	
Organic litter	0.3±5.7	0.3±9.3	
Rubber	0.1±1.7	0.3±10.2	
Glass/Ceramics	$0.02\pm0.3$	0.01±0.5	

Plastic (51%) and fishing related litter (41.8%) were the most commonly encountered litter items during trawling.
 Litter occurrence and densities were significantly higher in Divs. 3LNO compared to Div. 3M (Wilcoxon rank test; p-value < 0.0001).</li>





# Annexes Task 3

### ANNEX 5 - NAFO SCR Document

Durán Muñoz, P., Abalo-Morla, S., Palas Otero, S., and Sacau, M. (2024) Preliminary results from a desk-based study on activities other than fishing in the NRA: Interactions between oil and gas activities, deep-sea fisheries and VMEs - NEREIDA Task 3. NAFO SCR Doc. 24/047. Serial No. N7554.

### ANNEX 6 - Presentation at the NAFO Scientific Council meeting (June 2024)

Durán Muñoz, P., Abalo-Morla, S., Palas, S., and Sacau, M. (2024). A desk-based study on activities other than fishing in NAFO Regulatory Area. NEREIDA Task 3. NAFO Scientific Council Meeting June 2024. Oral communication.

### **ANNEX 5. NAFO SCR Document**

## NOT TO BE CITED WITHOUT PRIOR REFERENCE TO THE AUTHOR(S)



Northwest Atlantic

Fisheries Organization

Serial No. N7554 NAFO SCR Doc. 24/047

### SCIENTIFIC COUNCIL MEETING - JUNE 2024

Preliminary results from a desk-based study on activities other than fishing in the NRA: Interactions between oil and gas activities, deep-sea fisheries and VMEs - NEREIDA Task 3

by

Durán Muñoz, P., Abalo-Morla, S., Palas, S. and Sacau, M. Instituto Español de Oceanografía (COV-IEO), CSIC. Subida a Radio Faro, 50. 36390 Vigo. Spain

2024-06-21

### Abstract

This document compiles the preliminary results of a desk research on activities other than fishing taking place in the NAFO Regulatory Area, presented to the Scientific Council during the June 2024 meeting (NEREIDA Task 3). The main natural and socioeconomic ecosystem components were mapped. Spatial overlap (user-environment; user-user) and trends (period 2018-2024) were identified, focusing on offshore oil and gas, deep-sea fisheries and Vulnerable Marine Ecosystems (VMEs). In addition, the role of area-based management tools (i.e., NAFO closure No. 10) was emphasized, as well as the implications of multisectoral areas for the process of identifying, assessing and reporting other effective area-based conservation measures (OECMs). Finally, some key findings from the relevant scientific literature on the environmental impact of oil and gas activities, of interest in the context of NAFO, were summarized.

Keywords: Activities other than fishing, closures, deep-sea fisheries, impacts, NAFO Regulatory Area, protection, offshore oil and gas, other effective area-based conservation measures, Vulnerable Marine Ecosystems.

### 1. Introduction

1.1 Activities other than fishing: Oil and gas exploration, production and decommissioning

Oil and gas activities sequentially include the phases of (i) exploration, (ii) production and (iii) decommissioning. Not all phases are always completed, as this depends on multiple factors (e.g. characteristics and viability of discoveries, etc.). Nevertheless, seismic surveys and exploratory drilling are fundamental tools for oil and gas explorations, which can negatively affect the ecosystem (see section 3.3). In recent years, there has been exploration activity in the NAFO convention area. For example, on the Grand Banks of Newfoundland, starting in 1999, operators began exploring further afield, and the most recent decade has seen another wave of exploratory activity (Kaiser, 2020).

1.2 Activities other than fishing: A concern for the international community

<u>United Nations General Assembly.</u> United Nations General Assembly (UNGA) Resolution 71/123, adopted in 2016, reflects the international community' concern about the potential impacts of non-fishing activities. Specifically, paragraph 184 states that *Notes with concern that vulnerable marine ecosystems may also be impacted by human activities other than bottom fishing, and encourages in this regard States and competent international organisations to consider taking action to address such impacts.* Although Resolution 71/123, like the previous resolutions, focuses on sustainable fisheries, it also addresses the need to implement conservation measures for Vulnerable Marine Ecosystems (VMEs) in relation to human activities other than bottom fishing. This concern is reiterated in the

following resolutions (Table 1). In this context, it is noteworthy that, the participants of the last workshop<sup>1</sup> to review the implementation of UNGA resolutions (64/72, 66/68 and 71/123) on sustainable fisheries, held at UN headquarters in August 2022, acknowledged a concern that management actions taken by RFMO/As were unable to address potential impacts resulting from other activities taking place in the same area, thereby affecting the effectiveness of ecosystem-based approaches. In particular, NAFO's contribution<sup>2</sup> to the review workshop, pointed out that there are a number of non-fishing activities occurring in the Regulatory Area that have the potential to impact fisheries resources and the ecosystem. NAFO also expressed its concern about non-fishing activities (specifically mentioning oil and gas as an example) and confirmed that these remain on the agenda of the NAFO Commission during its annual meetings (e.g., 2023 Annual meeting: Commission Request #9)<sup>3</sup>.

**Table 1.** UNGA Resolutions on sustainable fisheries that included the issue of the impacts of non-fishing activities, indicating the date of adoption and the number of the *ad-hoc* paragraph about this issue.

UNGA Resolution	Date of adoption	ad-hoc paragraph about impacts of non-fishing activities
71/123	07 December 2016	184
72/72	05 December 2017	188
73/125	11 December 2018	197
74/18	10 December 2019	204
75/89	08 December 2020	203
76/71	09 December 2021	203
77/118	09 December 2022	217
78/68	05 December 2023	226

Convention on Biological Diversity. The Decision 14/8 adopted by the conference of the parties of the Convention on Biological Diversity (CBD), provides guidance about cross-sectoral coordination in relation to other effective area-based conservation measures (OECMs). In this context, mapping is essential to identify which areas are multi-sectoral, in order to further advance the process for nomination and recognizing OECMs (CBD, 2018; NAFO, 2023). According to the FAO handbook for fisheries OECMs, in the case of multi-sectoral areas (Figure 1), i.e. areas where many uses exist (e.g., Closed Area No.10), the optimal approach is to carry out cross-sectoral identification, assessment and reporting of OECMs (FAO, 2022). García *et al.*, (2020) suggest that a bilateral collaboration between two sectors may be enough to make an OECM operational and even to establish cross-sectoral OECM outcomes. They noted the need for international collaboration in the case of transboundary OECMs (areas where different jurisdictions overlap), suggesting that Regional Fisheries Management Organizations (RFMOs) could be used to promote effective OECMs. They also point out the importance of considering non-fishing impacts (cumulative impacts) and describing the potential contribution to connectivity.

BBNJ Agreement. The Agreement under the United Nations Convention on the Law of the Sea on the conservation and sustainable use of marine biological diversity of areas beyond national jurisdiction (BBNJ Agreement) was adopted in June 2023. It is organized around four areas: (i) marine genetic resources; (ii) establishment of a network of Area-Based Management Tools (ABMTs); (iii) Environmental Impact Assessments (EIA); and (iv) capacity-building. The Agreement shall be interpreted and applied in a manner that does not undermine relevant legal instruments, frameworks and sectoral bodies. Moreover, it applies to Areas Beyond National Jurisdiction (ABNJ). There are a number of challenges that could influence cross-sectoral aspects in the future, especially those related to the implementation of ABMTs and EIA. Most RFMOs have established area-based measures, such as bottom fishery closures to protect VMEs. Lothian (2024) suggests that these protected habitats are likely to be a priority area for the establishment of ABMTs under the BBNJ Agreement. In this complex scenario, some questions arise: (i) How will existing ABMTs, such as bottom fishing closures implemented by RFMOs, fit with potential ABMTs developed under the BBNJ Agreement, and (ii) Will the BBNJ Agreement interact with existing governance regimes without undermining them? Furthermore, in light of the NAFO case study, an additional question can be asked: How will the issue of multi-sectoral areas be addressed? With regard to EIA, Lothian (2024) also notes that, until the adoption of

<sup>&</sup>lt;sup>3</sup> NAFO Commission Request #9: Continue to monitor and provide updates resulting from relevant research related to the potential impact of activities other than fishing.



<sup>&</sup>lt;sup>1</sup> https://digitallibrary.un.org/record/3988731?ln=es

<sup>&</sup>lt;sup>2</sup> See pp.14 *In*: NAFO Input to the 2022 Workshop to discuss the implementation of UNGA resolutions (64/72, 66/68, 71/123). 16 March 2022. NAFO/22-096. 15 pp. https://www.un.org/depts/los/bfw/NAFO\_\_2022.pdf

the BBNJ Agreement, there was no mechanism in place to assess the cumulative impacts of all human activities on deep-sea VMEs. As some sectors already have sectoral impact assessment procedures in place, this raises the question of how the BBNJ Agreement's EIA provisions will interact with and sit alongside the EIA processes established under existing governance regimes, without undermining them. In light of this novel issue, the assessment of cumulative impacts from multiple sectors may become important within RFMOs.

### 1.3 Aim of this document

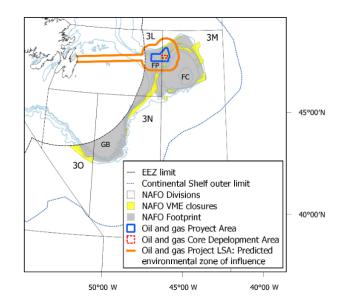
The objective of this document is to compile the information from the NEREIDA Task 3, presented to the Scientific Council in June 2024, in particular, that related to *NAFO Commission request #9*, focusing on the interactions between oil and gas activities, deep-sea fisheries and VMEs. It should be noted that this study is not intended to duplicate the work done by the relevant authorities in each sector (e.g., it is not intended to duplicate the work done through existing impact assessment processes). The ultimate goal of the NEREIDA tasks related to activities other than fishing is to understand some of these activities taking place in the NRA, in relation to their potential impact on the fishery resources, the ecosystem and the fishing activity regulated by NAFO. This work will help to develop approaches related to tackling impacts of non-fishing activities on the marine biological resources and fisheries in the NRA.

### 2. Material and Methods

### 2.1 Study area: NAFO Regulatory Area, Divs. 3LMNO

The study area (Figure 1) is located in international waters of the Northwest Atlantic Ocean, to the east of the Canadian coastline, in a depth range of about 45-1,500 m. This area corresponds to a part of the Grand Banks of Newfoundland and its slopes, the top and the slopes of the Flemish Cap, and the deep waters of the Flemish Pass. It covers the major international bottom fishing grounds (e.g., Greenland halibut, redfish, cod and skates) within the NRA (NAFO Divisions 3LMNO), i.e., the existing bottom fishing areas (NAFO fishing footprint), as well as important areas for other human activities (e.g., offshore oil and gas). In addition, the area of Flemish Cap hosts cold-water corals, sea pen fields and sponge grounds (Murillo, 2011; 2012) and most of the fishing closures implemented by NAFO to protect VMEs (NAFO, 2024). The NRA is located in the high seas (water column), and partly lies above the seabed within the extended continental shelf of the coastal state (Canada). This implies a complex situation derived from the intersection of the jurisdictional regimes affecting the water column beyond 200 miles (NAFO competence) and the continental shelf (coastal state competence).

**Figure 1.** Map of the southern part of the NAFO Regulatory Area showing the location of the study area. The footprint of deep-seafisheries (grey area) and the spatial limits of the oil and gas project in the Flemish Pass (outlined in blue, depth range of about 340-1,200 m) is showed. The predicted environmental zone of influence of this project (considering marine fish and fish habitat, including species at risk, marine mammals and sea turtles, and special areas) is outlined in orange (Equinor, 2020)<sup>4</sup>. NAFO VME closures are also indicated (yellow areas). (FC: Flemish Cap; FP: Flemish Pass; GB: Grand Banks of Newfoundland).



<sup>&</sup>lt;sup>4</sup> This zone also includes a smaller area of influence on seabirds.



### 2.2 Data collection and analysis

The present study is a desk-based research. Publicly available information on the ecosystem components (natural and socio-economic) of the study area was collated and integrated into a GIS. Spatial data were obtained from various sources (websites, reports, documents, etc.). When spatial data was available, the spatial location of each ecosystem component was mapped. In addition, relevant scientific literature on the environmental impact of offshore oil and gas activities was also reviewed, paying special attention to deep waters.

### 3. Results and discussion

### 3.1 Update of maps of main ecosystem components in NAFO Divs. 3LMNO

The baseline for this study was a previous study conducted in Divisions 3LM as part of the ATLAS project (Durán Muñoz *et al.*, 2020a). The main biophysical and natural ecosystem components identified within the study area include geomorphological features, fishery resources, marine species (i.e. marine mammals, seabirds and sea turtles), and VMEs, such as cold-water corals and deep-sea sponges (Kenchington *et al.*, 2019a), including its connectivity pathways (Gary *et al.*, 2020; Combes *et al.*, 2021) (Table 2; Figure 2). The main socio-economic components identified are related to fisheries, shipping, the offshore oil and gas industry, undersea cable routes, and marine research (Durán Muñoz *et al.*, 2012, 2020b) (Table 2; Figure 3). All this information was organized and integrated into a GIS using the open source software QGIS (v3.28).

Table 2. List of the main natural and socio-economic ecosystem components identified in the NRA (\*: Potential).

Biophysical/natural	Bathymetry and geomorphological features (e.g. seamounts, knolls).				
components	Substrate types (e.g. rock, gravel, sand, silt, clay).				
	Vulnerable Marine Ecosystems (VMEs).				
	Key species (i.e. marine mammals, sea birds and sea turtles).				
	Ecosystem connectivity (i.e. larval dispersal).				
	Epibenthic assemblages				
	Fisheries resources.				
Socio-economic	Deep sea fisheries (DSF) <sup>5</sup> and bottom fisheries regulated by coastal states (i.e. pots).				
components	Pelagic fisheries (seines, gillnets, trawls and longlines).				
	Shipping (passenger and items)				
	Offshore oil and gas industry				
	Offshore renewables* (windfarms, power cables)				
	Seabed mining*				
	Undersea telecommunication cables				
	Military activities				
	Pollution (marine litter and long-distance pollution; dumping)				
	Bioprospecting*6				
	Marine research (surveys)				
	Deep sea conservation and management (closed areas for VME protection; OECMs; EBSA areas,				
	etc.)				

<sup>&</sup>lt;sup>6</sup> Biodiversity prospecting or bioprospecting is the systematic search for biochemical and genetic information in nature in order to develop commercially-valuable products for pharmaceutical, agricultural, cosmetic and other applications (https://sdgfinance.undp.org/sdg-tools/bioprospecting)



<sup>&</sup>lt;sup>5</sup> Bottom fisheries operating in the NRA (bottom trawls and bottom longlines).

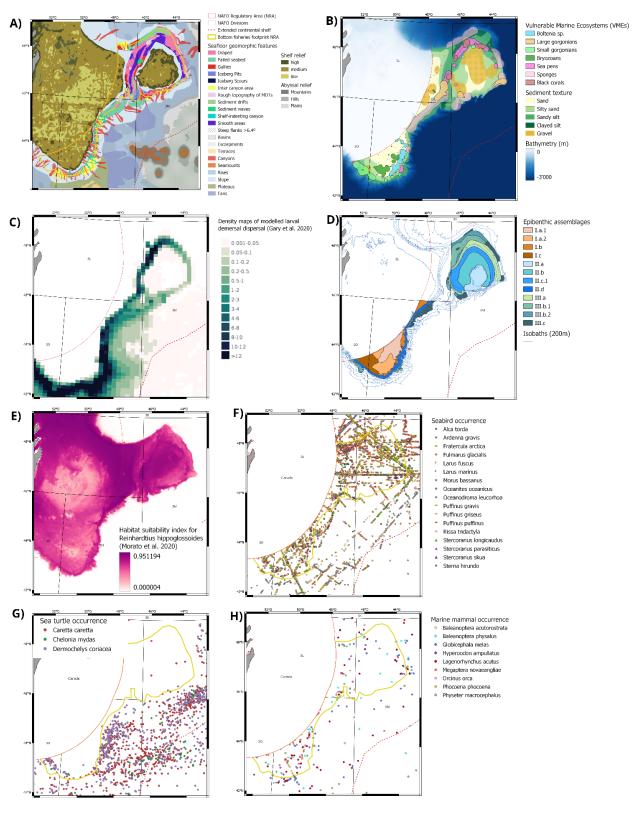


Figure 2.

Figure 2 (legend). Updated cartographic information on the main biophysical/natural components in the study area. A) Seafloor geomorphic features. Shelf and abyssal areas are classified upon its roughness (high, medium and low) (Harris *et al.*, 2014). Geomorphology on the slopes was obtained from the NEREIDA multibeam echosounder technology (Durán Muñoz *et al.*, 2012, 2020a); B) Bathymetry (blue scale; GEBCO Bathymetric Compilation Group 2023), sediment texture types according Shepard classification (yellow to green; and orange for gravel, Murillo *et al.*, 2016) and polygons of significant concentrations of VME indicator taxa (Kenchington *et al.*, 2019a); C) Density maps (particles per square km) of modelled particles of larvae released from Flemish Cap (Gary *et al.*, 2020); D) Epibenthic megafaunal assemblages in Divisions 3MNO. Assemblages were grouped into three major groups: (i) Continental shelf of the Tail of Grand Bank; (ii) Shallow waters of Flemish Cap and upper slope of the Tail of Grand Bank; and (iii) Lower slope of Flemish Cap and Tail of Grand Bank (see Murillo *et al.*, 2016); E) Fisheries resources: e.g., Habitat suitability index for *R. hippoglossoides* (Morato *et al.*, 2020); F) Spatial distribution of seabirds; G) Spatial distribution of sea turtles; H) Spatial distribution of marine mammals. Limits of the NAFO Regulatory Area (red lines), NAFO Divisions (black lines) and extended continental shelf (dashed red line) are shown in all maps. Occurrence data for seabirds, sea turtles and marine mammals were obtained from OBIS (https://obis.org/).



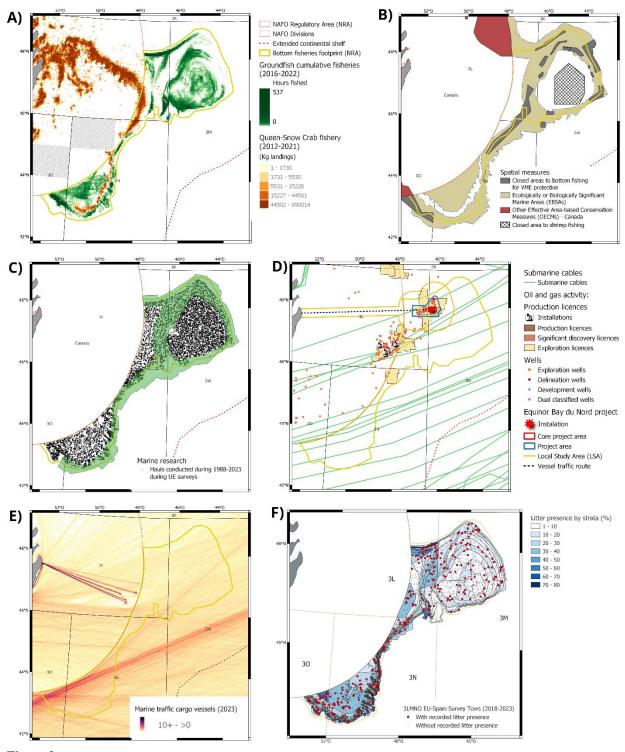


Figure 3.

Figure 3 (legend). Updated cartographic information on the main socio-economic components identified in the study area. A) Bottom fisheries: NAFO cumulative bottom fisheries in 2016-2022 (hours fished: green scale) (Task 1 NEREIDA contract) and queen-snow crab fishery during 2016-2021 (kg landings; orange scale). Snow crab data obtained from Fisheries and Oceans Canada (DFO) available at: https://open.canada.ca/data/en/dataset/502da2ef-bffa-4d9b-9e9c-a7425ff3c594; B) Areas closed for VME protection (grey polygons; NAFO, 2024), areas closed for shrimp fishing during 1 June to 31 September in Division 3M (NAFO, 2024), Ecologically and Biologically Significant Marine Areas (EBSA): Slopes of the Flemish Pass and Grand Bank and Southeast shoal and adjacent areas on the Tail of the Grand Bank (beige polygons) (https://www.cbd.int/ebsa/), and Other-Effective Area-based Conservation Measures (OECMs) established in Canadian waters (red polygons) (UNEP-WCMC and IUCN, 2024); C) Marine research: Hauls conducted during the EU surveys during 1988 to 2023 in the NRA (black crosses; González-Costas et al., 2023; Abalo-Morla et al., 2023) and the study area of NEREIDA cruises: 2009-2010 (in green) (Durán Muñoz et al., 2012); D) Oil and gas activities: installation locations, licences (production licences (PL), significant discovery licences (SDL), exploration licences (EL)), wells (delineation wells, development wells, dual classified wells) and available information about the Equinor Bay du Nord project (installation location, project area, core project area, local study area and vessel traffic route). Data available in May 2024 at https://www.cnlopb.ca/. Submarine cables (green lines) obtained from https://www.submarinecablemap.com/; E) Marine traffic: Cargo vessel density map during 2023 (Fisheries Oceans Canada; https://open.canada.ca/data/en/dataset/5b86e2d2-cec1-4956-a9d5-12d487aca11b); F) Spatial distribution of seabed litter in the NRA (Abalo-Morla et al., 2024) Limits of the NAFO Regulatory Area (red lines), NAFO Divisions (black lines) and extended continental shelf (dashed red line) are shown in all maps.

### 3.2. Update of spatial overlap maps

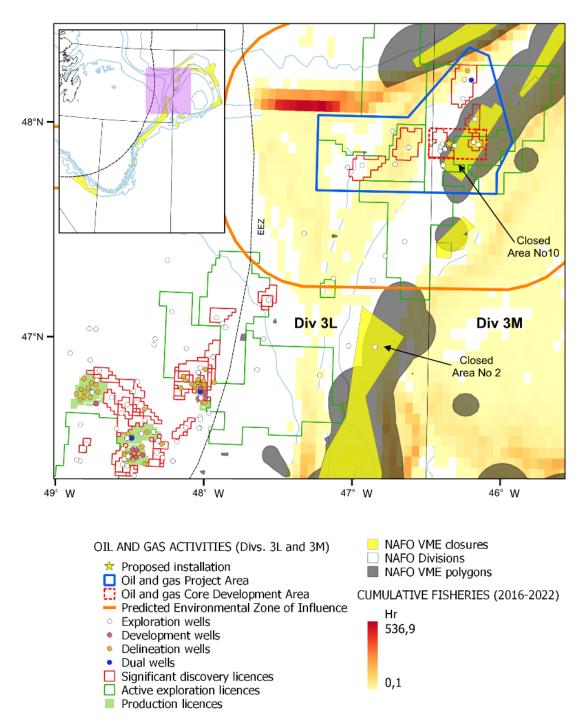
Knowing the spatial and bathymetric location of areas where other human activities overlap with VMEs, VME closures and fisheries, is the starting point to better understand potential interactions and conflicts. This includes: (i) environmental impacts from accidental events or routine activities, (ii) conflicts of use of marine space (loss of fishing opportunities), and (iii) interactions between measures in multiple sectors and the transboundary implications of these measures (Molenaar, 2021). This knowledge help to understand whether non-fishing activities may affect the effectiveness of the conservation and management measures adopted by NAFO (e.g., closed areas). Such information is essential to fill the NAFO Ecosystem Summary Sheets (ESS), particularly the sections on (i) *human activities other than fisheries* and (ii) *pollution*.

Extent of oil and gas activities (licences and wells) and overlap with deep-sea fisheries, VMEs and closed areas

The spatial extent of oil and gas activities (licences and wells) was mapped based on the available information, collected on February 2024, from the Canada-Newfoundland and Labrador Offshore Petroleum Board (C-NLOPB) website. Data on cumulative bottom fisheries (2016-2022 period) was obtained from NEREIDA Project. The map of the Figure 4 reveals that some licences<sup>7</sup> and wells<sup>8</sup> overlap with NAFO-regulated fisheries (fishing grounds), VMEs and areas closed to protect such ecosystems. In summary, the map shows the overlaps between the different users of the marine space, as well as between users and the marine environment. Such overlaps could lead to future conflicts.

<sup>&</sup>lt;sup>7</sup> A **licence** is the mechanism under the Accord Act by which certain rights are granted in lands in the Canada Newfoundland and Labrador offshore area. According to AMEC (2014), normally, an owner of an **exploration licence** will explore that licence and, upon finding a significant discovery (i.e. accumulation of oil that has potential for sustained production), be issued a **significant discovery licence** to further delineate the discovery in anticipation of finding commercial resources (i.e. discovery that justify the investment and effort to bring the discovery to production) which may lead to the issuance of a **production licence** (for oil production).

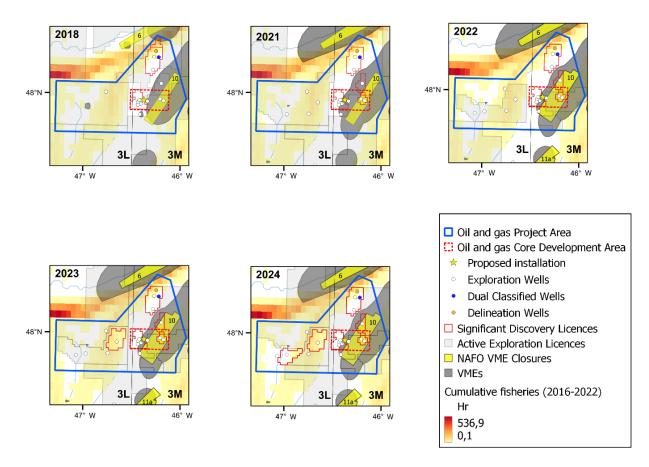
<sup>&</sup>lt;sup>8</sup> According to Kaiser (2021), **exploration** and **development** wells are used to find commercial accumulations of hydrocarbons and develop them. Exploration wells are drilled outside known reservoirs, and therefore, exploratory drilling almost always takes place from a mobile offshore drilling unit. Development drilling is different from exploration drilling, since the objective is to produce, while in exploration the objective is to find hydrocarbons, and in appraisal, to delineate the reservoir and gather the necessary data for planning the development. **Delineation** wells are used to determine the areal and vertical extent of reservoirs and have many similarities to exploration wells. **Dual wells** have dual nature.



**Figure 4.** Updated map showing the geographical location of oil and gas activities (licences and wells) in NAFO Divs. 3L and 3M. Data collected in February 2024 (source: C-NLOPB). The yellow star indicates the location of the proposed production installation within the *Bay du Nord Development Project* in the Flemish Pass (outlined in blue). Bottom fishing activity (cumulative fishery 2016-2022) is expressed in hours fished in each cell (from yellow to red). Dark color indicates higher value (source: NEREIDA).

Trends of oil and gas activities (licences and wells) in Divisions 3L and 3M (2018 - 2024 period)

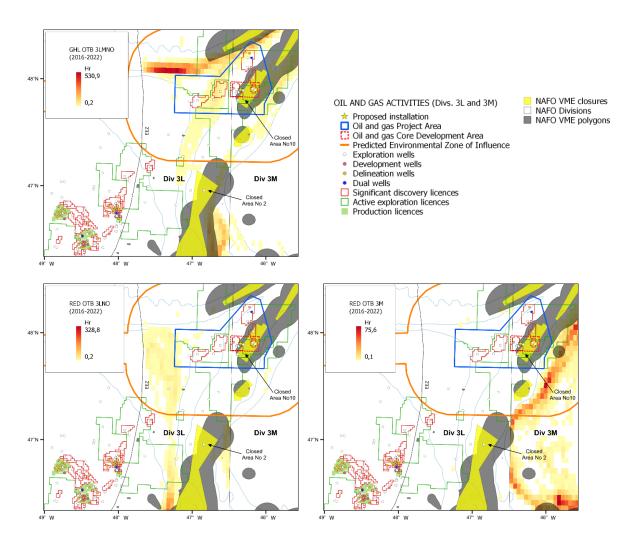
Figure 5 shows the evolution over time of the overlap between oil and gas activities (licences and wells), NAFO-regulated fisheries, VMEs and VME Area Closure No. 10, along the period 2018 - 2024. There has been an increase in overlap due to both the increase in the number of Significant Discovery Licences, the expansion of Area closure No. 10 and the redefinition of NAFO VME polygons occurred in 2019. In addition, the number of Exploration Wells within the project area has also increased during the period analyzed. In this scenario, the potential tension between commitments to protect VMEs and biodiversity, the maintenance of fisheries and the expansion of oil and gas activities is likely to intensify in the near future.



**Figure 5**. Updated map showing the evolution over time of the degree of overlap between oil and gas activities, VMEs and VME Area closure No. 10 (2018 - 2024 period). Source C-NLOPB. Bottom fishing activity (cumulative fishery 2016-2022) is expressed in hours fished in each cell (from yellow to red). Dark color indicates higher value (source: NEREIDA).

### Spatial overlap with the Greenland halibut and redfish bottom fisheries

The international bottom fisheries regulated by NAFO most affected by the overlap with oil and gas activities (wells and licences) is, by far, the Greenland halibut trawl fishery (GHL OTB 3LMNO) and, to a lesser extent, the redfish bottom trawl fisheries (RED OTB 3LNO; RED OTB 3M). Figure 6 shows the overlap of such activities with the mentioned fisheries (2016-2022 period), based on new data from NEREIDA project. The historical footprint of the Greenland halibut trawl fishery is located in the same area where the main oil and gas activities are currently taking place, namely the Flemish Pass area.



**Figure 6**. Map showing the spatial overlap between oil and gas activities (wells and licences) and the demersal fisheries for Greenland halibut and redfish (2019). Bottom fishing activity (cumulative fishery 2016-2022) is expressed in hours fished in each cell (from yellow to red). Dark color indicates higher value (source: NEREIDA).



Spatial overlap with VMEs and VME closures: Role in connectivity

Oil and gas activities (wells and licences) in the Flemish Pass, overlap significantly with several patches of VMEs described in Wang *et al.* (2024), specifically those of sponges (S7), sea pens (SP1) and black corals (BC4). VME patches are partially protected from the impact of bottom fishing through fishing closed areas (Table 3; Figures 7 to 9). Based on the available information, the patches of VME are open to oil and gas activities (e.g., drilling, anchoring). It is important to highlight that the fisheries closure No.10, provides protection to three different VMEs (S7, SP1 and BC4). The closed areas 2, 7 to 12 and 14 show physical connectivity and appear to form a network<sup>9</sup> over Flemish Cap (Kenchington *et al.*, 2019b). In addition, the Closed Areas put in place to protect VMEs also contribute to the protection of 3 of the 12 benthic assemblages (NAFO, 2019) identified in the area by Murillo *et al.* (2016).

**Table 3**. VME patches of sponges, sea pens and black corals, partially protected by NAFO VME Area Closures. Closure Area No. 10 is highlighted in blue.

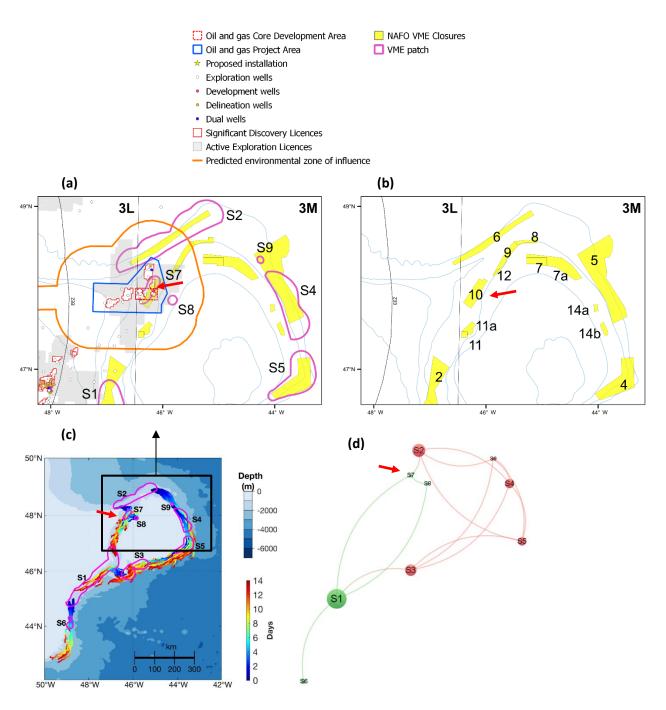
NAFO VME Closures	VME patches (Wang et al., 2024)					
(NAFO, 2024)	Sponge (S)	Sea pen (SP)	Black coral (BC)			
1	<b>S</b> 6					
2	S1	SP10	BC3			
3	S3					
4	S5					
5	S4, S9					
6	S2					
7		SP1	BC2			
8		SP1				
9		SP1	BC1			
10	S7	SP1	BC4			
11		SP6				
12		SP1	BC1			
13	<b>S</b> 3					
14		SP5, SP8	BC7			

Wang *et al.* (2024) and the literature cited in that paper, suggest that persistence of the sessile benthos over the long term depends on larval supply, and hence on inter-patch connections. Habitat fragmentation has the potential to alter connectivity, affecting population dynamics and ecosystem functioning, and may lead to a loss of biodiversity. According to Wang *et al.* (2024), in the NRA, sea pens had the highest degree of connectivity, while black corals had the least connected network (e.g., BC4 has connections only with 2 black coral patches). Patches serving as source populations to multiple other patches were prevalent in the sea pen network, in which every patch was a source to at least one other, and SP1 had downstream connections to all other patches. In general, the existing networks, including the extant networks of sponge VME, are generally well connected (e.g., S7 has connections with three sponge patches) and, by inference, those connections are likely important to the persistence of VME within the study area. These authors concluded that patches of VMEs within the NRA comprise inter-connected networks, such that maintenance of connectivity should be assumed essential to the persistence of the patches and hence of the VMEs. They also observed that the existing patches in each network differ in their relative importance for connectivity (Figures 7 to 9). On the other hand, connectivity can exacerbate harmful effects caused by anthropogenic activities, such as the spread of pollutants trough a food web or ecosystem (DOSI, 2020; Popova, 2019).

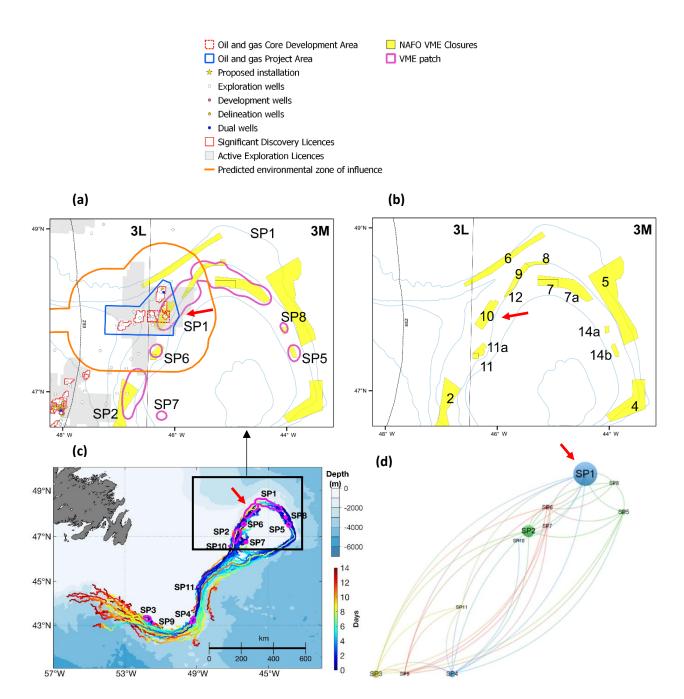
VMEs in closure No. 10 (i.e., sea pens, sponges and black corals) are part of an inter-connected network, and hence, impacts on one VME could have cascading effects on other VME areas. In this regard, the effects of non-fishing activities should be further studied in the context of protecting connected VME network, as the development of potentially damaging activities (e.g., oil and gas) may compromises the network (e.g., habitat fragmentation).

<sup>&</sup>lt;sup>9</sup> The incremental establishment of the closed areas meant that there was no collective "design" to their placement; however, they could qualify after the fact as a "network" of protected areas (Kenchington *et al.*, 2019b).

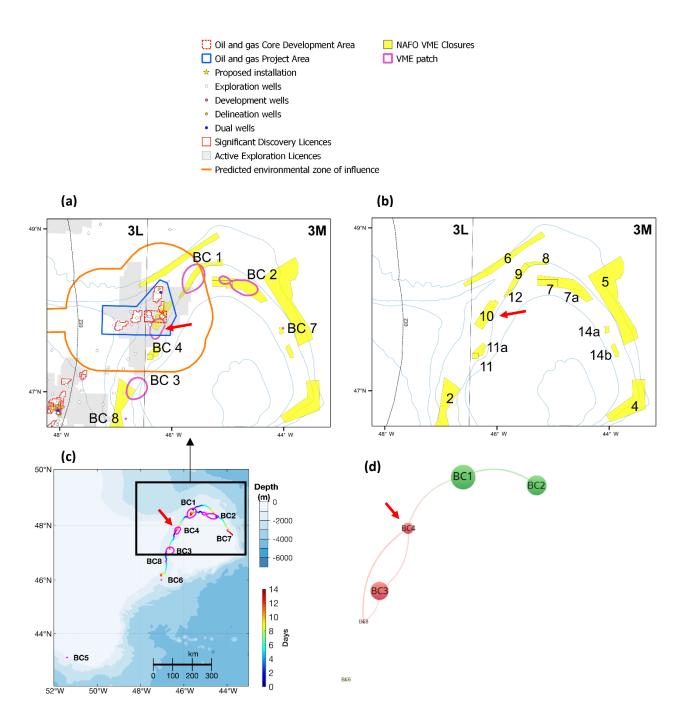




**Figure 7**. Maps of the NAFO Regulatory area showing the spatial interactions between oil and gas activities (licences and wells), sponge VME and fishing closures, as well as the diagrams of connectivity according to Wang *et al.* 2024. Pannel (a): Spatial overlap between oil and gas activities (licences and wells), sponge VME patches (S) and fishing closures in the Flemish Pass area, in the context of the NAFO network of VME closures shown in Pannel (b). The patches of VME are labeled according to Wang *et al.* 2024. Pannel (c): Minimum particle trajectories connecting the patches of sponges (S). Source: Wang *et al.*, 2024. Pannel (d): Stylized network map created in VOSviewer, using default settings. Nodes are labelled by patch code and their size is proportional to patch area, within the taxon. Node position represents the patch centroid in geographic space. Source: Wang *et al.*, 2024. Oil and gas activities in the Flemish Pass overlap significantly with a sponge patch (S7). The red arrows indicate the location of such patches in all maps.



**Figure 8**. Maps of the NAFO Regulatory area showing the spatial interactions between oil and gas activities (licences and wells), sea pen VME and fishing closures, as well as the diagrams of connectivity according to Wang *et al.* 2024. Pannel (a): Spatial overlap between oil and gas activities (licences and wells), sea pen VME patches (SP) and fishing closures in the Flemish Pass area, in the context of the NAFO network of VME closures shown in Pannel (b). The patches of VME are labeled according to Wang *et al.* 2024. Pannel (c): Minimum particle trajectories connecting the patches of sea pens (SP). Source: Wang *et al.*, 2024. Pannel (d): Stylized network map created in VOSviewer, using default settings. Nodes are labelled by patch code and their size is proportional to patch area, within the taxon. Node position represents the patch centroid in geographic space. Source: Wang *et al.*, 2024. Oil and gas activities in the Flemish Pass overlap significantly with a sea pen patch (SP1). The red arrows indicate the location of such patches in all maps.



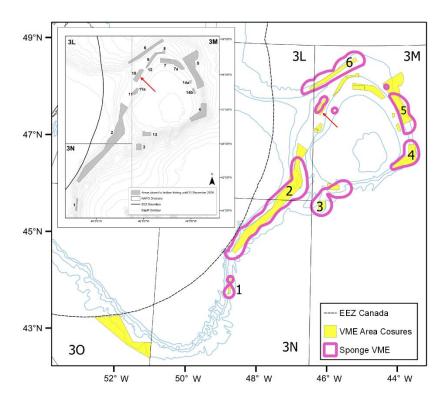
**Figure 9**. Maps of the NAFO Regulatory area showing the spatial interactions between oil and gas activities (licences and wells black coral VME and fishing closures, as well as the diagrams of connectivity according to Wang *et al.* 2024. Pannel (a): Spatial overlap between oil and gas activities (licences and wells), black coral VME patches (BC) and fishing closures in the Flemish Pass area, in the context of the NAFO network of VME closures shown in Pannel (b). The patches of VME are labeled according to Wang *et al.* 2024. Pannel (c): Minimum particle trajectories connecting the patches of sea pens (SP). Source: Wang *et al.*, 2024. Pannel (d): Stylized network map created in VOSviewer, using default settings. Nodes are labelled by patch code and their size is proportional to patch area, within the taxon. Node position represents the patch centroid in geographic space. Source: Wang *et al.*, 2024. Oil and gas activities in the Flemish Pass overlap significantly with a black coral patch (BC4). The red arrows indicate the location of such patches in all maps.



# Implications for the process for nomination and recognizing OECMs

To achieve sustained, long-term biodiversity outcomes, a multi-sectoral, integrated and collaborative process for the identification, assessment and reporting of OECMs is considered best practice in areas with multiple uses and pressures (García *et al.*, 2020; FAO, 2022). In the NAFO context, in absence of such approach, the current process for nomination and recognizing potential OECMs has focused on areas that only support fishing activities. Consequently, Closed Area No.10 was excluded from the process for nomination of the Sponge VME OECM (Figure 10). Sponge VME within closure No. 10 are part of an interconnected network, and they are partially protected from the impacts of bottom fishing. But impacts from activities other than fishing on such a VME could have cascading effects on other areas of VMEs.

Currently, the existence of oil and gas activities within an area closed to bottom fishing to protect VMEs (i.e., Closure Area No.10), hinders its inclusion in the global OECM database. Consideration of Area 10 would bring greater coherence to the OECM proposal (i.e., integrity of the network of closed areas), but this would require a multi-sectoral approach and international collaboration, as recommended by FAO (2022).



**Figure 10**. Map showing the six closed areas (1 to 6) comprised in the potential Sponge VME OECM. The box shows the complete NAFO (2024) network of closed areas. The red arrows indicate the location of Closed Area No.10, excluded from the nomination due to risks from oil and gas activities.



## 3.3. Literature on the impacts of oil and gas: Some key findings

A literature review on relevant research on the impact of offshore oil and gas activities was conducted under the NEREIDA project. A brief selection of key findings, relevant in the NAFO context, are summarized below:

- According to the review from Cordes et al. (2016), besides accidental events (e.g. oil spills), routine oil and gas activities can have detrimental environmental effects during each of the main phases of exploration, production, and decommissioning. Environmental impacts can occur throughout the lifecycle of these activities, as OSPAR recognized (Marappan et al., 2022). Moreover, non-fishing activities, including oil and gas, may adversely affect essential fish habitats (Limpisel et al., 2023).
- A study in the Gulf of Mexico revealed that incidents, such as blowouts, injuries, and oil spills, are positively correlated with deeper water (Muehlenbachs *et al.*, 2013). In addition, climate change may affect oil and gas facilities and operations (e.g., damage to pipelines and platforms) both in coastal areas and in the outer continental shelf, due to more intense storms and higher winds and waves (Burkett, 2011). The coexistence of fisheries and oil and gas activities can create competition and conflicts (e.g., limited access to valuable areas, damage of gear and installations, navigational hazards due to installations and increased traffic, operational harms, ecosystem impacts, etc.) as Arbo and Thuy (2016) suggest. The authors concluded that resolving use conflicts is a central issue in the context of ecosystem-based management and is beneficial for the sectors involved and for ecosystem health.
- Marine seismic surveys are a fundamental tool for oil and gas explorations. Noise from seismic surveys may affect a range of species, such as marine mammals (Affati and Camerlenghi, 2023 and references herein) and fish. Van der Knaap *et al.* (2021) observed changes in cod behavior. Cod exhibited disruptions of diurnal feeding activities, unraveling an issue that could potentially lead to consequences at the population level. In addition, McCauley *et al.* (2017) presented evidences suggesting that sound from air gun surveys causes significant mortality to zooplankton populations. This may have implications for ocean health in general (e.g. modifications in plankton community structure).
- According to Ronconi *et al.* (2015), the effects of platforms on birds include both direct and indirect lethal and sub-lethal effects. For seabirds and landbirds (particularly, migrating species), the most frequently observed effect is attraction and sometimes collisions and incinerations associated with lights and flares. Other effects include provision of foraging and roosting opportunities, increased exposure to oil and hazardous environments, increased exposure to predators, or repulsion from feeding sites.
- Environmental effects of oil and gas activities include impacts from routine operational activities such as drilling waste and produced water discharges (Neff *et al.*, 2011; Neff *et al.*, 2014), accidental discharges and spills (Cordes *et al.*, 2016), long-term impacts on deep-sea corals (Fisher *et al.*, 2014; Girard and Fisher, 2018) and deep-sea sponges and the habitats they form (Vad *et al.*, 2018). Studies on the effects of the Deepwater Horizon oil spill, indicate that many years are required for moderately to heavily impacted corals to recover, and that some coral colonies may never recover.
- Operational discharges from offshore oil and gas platforms are a continuous source of contaminants to continental shelf ecosystems (Bakke *et al.*, 2013). Drill cuttings (Tornero and Hanke, 2016) and produced water (Beyer *et al.*, 2020; Hansen, 2019; OSPAR, 2021) are the largest operational source of pollution from the offshore petroleum industry. Effects are generally local (Bakke *et al.*, 2013; OSPAR, 2021) but persistent (Gates *et al.*, 2017). Exposure to produced water can be detected in fish and mussels in laboratory and in field studies, indicating modest impacts (OSPAR, 2021). Haddock and cod larvae subjected to embryonic exposure to produced water extracts were smaller, and displayed signs of cardiotoxicity and body deformations, with more larvae displaying higher severity in haddock compared to cod (Hansen, 2019). Drill cuttings affect *Lophelia* larvae, but there is an age-dependent difference in sensitivity (Järnegren *et al.*, 2017). They also produce local decline of echinoids (Hughes *et al.*, 2010) and meiofauna (Netto *et al.*, 2009). Connectivity can also spread of pollutants trough a food web or ecosystem (DOSI, 2020; Popova, 2019).



- There is evidence for the toxicity of both oil and dispersant on deep-water corals (De Leo, *et al.*, 2016 and references herein) and sponges. Global ocean change can affect the resilience of corals to environmental stressors, and the exposure to dispersants may pose a greater threat than oil itself (Weinnig, 2020). Larvae of sponge survived exposure to high concentrations of petroleum hydrocarbons; however, their ability to settle and metamorphose was adversely affected at environmentally relevant concentrations, and these effects were paralleled by marked changes in sponge gene expression and preceded by disruption of the symbiotic microbiome (Luter *et al.*, 2019). The use of dispersants increases the risk posed by hydrocarbon contamination to sponges and should therefore be limited within areas rich in sponges (Vad *et al.*, 2020) or that contain sponge grounds (Vad *et al.*, 2022).
- Oil and gas exploitation introduce toxic contaminants to the surrounding sediment, resulting in deleterious impacts on marine benthic communities. In the North Sea, contamination from oil and gas platforms caused declines in benthic food web complexity, community abundance, and biodiversity at local level (Chen *et al.*, 2024).
- Effects-oriented studies related to the Deepwater Horizon oil spill (Beyer *et al.*, 2016) demonstrated that the oil was toxic to a wide range of organisms (plankton, invertebrates, fish, birds, and sea mammals), causing a wide array of adverse effects (reduced growth, disease, impaired reproduction, impaired physiological health, and mortality). Both oil exposure and spill response actions caused injuries to a wide range of habitats, species and ecological functions over a vast area.

# 4. Main outputs and challenges

- Activities other than fishing are a matter of concern for the international community and stakeholders.
- Main natural components and human activities were mapped, based on updated available spatial data.
- Oil and gas licences and wells overlap with NAFO fisheries, VMEs and closed areas, particularly in Divs.
   3LM.
- In recent years, an increase in the number of significant discovery licenses has been observed in Divs. 3LM, as well as an increase in overlap with fisheries, VMEs and closed areas.
- VMEs within closure No. 10 (e.g., sea pens, sponges and black corals) are part of an inter-connected network, and hence, impacts on one VME could have cascading effects on other VME areas. They are important for achieving the overall conservation goals.
- Consideration of Area 10 would bring greater coherence to the OECM proposal. This would require a multisectoral approach and international collaboration, as recommended by FAO.
- Scientific literature indicates that oil and gas activities can produce impacts during the exploration, production and decommissioning phases. They may also result in conflicts with other users of the marine space.

# 5. Acknowledgements

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# 6. References

- Abalo-Morla, S., Palas Otero, S., Román-Marcote, E., Durán Muñoz, P., Pérez, P., and Sacau, M. (2024) Seabed litter distribution on Flemish Cap (Div. 3M), Flemish Pass (Div. 3L) and Grand Banks of Newfoundland (Divs. 3NO). NAFO SCR Doc. 24/046. Serial No. N7553.
- Abalo-Morla S., Neves, B.M., Hayes V., Sacau, M., Command, R.J., and Durán Muñoz, P. (2023) New preliminary data on VME encounters in NAFO Regulatory Area (Divs. 3LMNO) from EU; EU-Spain and Portugal Groundfish Surveys (2023) and Canadian surveys (Fall 2022 & Spring 2023). NAFO SCR Doc. 23/055. Serial No. N7485. https://www.nafo.int/Portals/0/PDFs/sc/2023/scr23-055.pdf
- Affatati, A. and Camerlenghi, A. (2023) Effects of marine seismic surveys on free-ranging fauna: a systematic literature review. Front. Mar. Sci. 10:1222523. https://doi.org/10.3389/fmars.2023.1222523
- AMEC (2014) Eastern Newfoundland Strategic Environmental Assessment. Final Report for Canada-Newfoundland and Labrador Offshore Petroleum Board.
- Arbo, P. and Thuy P.T.T. (2016). Use conflicts in marine ecosystem-based management The case of oil versus fisheries. Ocean & Coastal Management. 122. 77-86. https://doi.org/10.1016/j.ocecoaman.2016.01.008.
- Bakke, T., Klungsøyr, J., and Sanni, S. (2013) Environmental impacts of produced water and drilling waste discharges from the Norwegian offshore petroleum industry. *Marine environmental research*, 92, 154-169.
- Beyer, J., Goksøyr, A., Hjermann, D. Ø., and Klungsøyr, J. (2020) Environmental effects of offshore produced water discharges: A review focused on the Norwegian continental shelf. *Marine environmental research*, 162, 105155
- Beyer, J., Trannum, H. C., Bakke, T., Hodson, P. V., and Collier, T. K. (2016). Environmental effects of the Deepwater Horizon oil spill: a review. *Marine pollution bulletin*, 110(1), 28-51.
- Burkett, V. (2011) Global climate change implications for coastal and offshore oil and gas development. *Energy policy*, 39(12), 7719-7725.
- CBD (2018) Decision 14/8 Protected areas and Other Effective Area-based Conservation Measures. 14th Meeting of the Conference of the Parties to the Convention on Biological Diversity, 17-29 November, Sharm El-Sheikh, Egypt. CBD/COP/DEC/14/8: 19 pp. https://www.cbd.int/doc/decisions/cop-14/cop-14-dec-08-en.pdf.
- Chen, Z., Cameron, T. C., Couce, E., Garcia, C., Hicks, N., Thomas, G. E., ... & O'Gorman, E. J. (2024). Oil and gas platforms degrade benthic invertebrate diversity and food web structure. *Science of the Total Environment*, 929, 172536.
- Combes, M., Vaz S., Grehan, A., Morato, T., Arnaud-Haond, S., Dominguez-Carrió, C., Fox, A., González-Irusta, J.M., Johnson, D., Callery, O., Davies, A., Fauconnet, L., Kenchington, E., Orejas, C., Roberts, J.M., Taranto, G., Meno,t L. (2021) Systematic Conservation Planning at an Ocean Basin Scale: Identifying a Viable Network of Deep-Sea Protected Areas in the North Atlantic and the Mediterranean, Frontiers in Marine Science, 8. https://doi.org/10.3389/fmars.2021.611358
- Cordes, E.E., Jones, D.O.B., Schlacher, T.A., Amon, D.J., Bernardino, A.F., Brooke, S., Carney, R., DeLeo, D.M., Dunlop, K.M., Escobar-Briones, E.G., Gates, A.R., Génio, L., Gobin, J., Henry, L.-A., Herrera, S., Hoyt, S., Joye, M., Kark, S., Mestre, N.C., Metaxas, A., Pfeifer, S., Sink, K., Sweetman, A.K., Witte, U. (2016) Environmental impacts of the deep-water oil and gas industry: a review to guide management strategies. Frontiers in Environmental Science 4. https://doi.org/10.3389/fenvs.2016.00058.
- DeLeo, D. M., Ruiz-Ramos, D. V., Baums, I. B., and Cordes, E. E. (2016) Response of deep-water corals to oil and chemical dispersant exposure. *Deep Sea Research Part II: Topical Studies in Oceanography*, 129, 137-147.
- DOSI (2020) Ecological Connectivity: Implications for Ocean Governance. DOSI policy brief position paper. Available online at: https://www.dosi-project.org/wp-content/uploads/DOSI-Connectivity\_brief\_Feb2020.pdf
- Durán Muñoz, P., Sacau, M., Román-Marcote, E. and García-Alegre, A. (2020a) A theoretical exercise of Marine Spatial Planning in the Flemish Cap and Flemish Pass (NAFO Divs. 3LM): implications for fisheries management in the high seas. NAFO SCR Doc. 20/022. pp 25.



- Durán Muñoz, P., Sacau, M., García-Alegre, A., and Román, E. (2020b). Cold-water corals and deep-sea sponges by-catch mitigation: Dealing with groundfish survey data in the management of the northwest atlantic ocean high seas fisheries. Marine Policy, 116(103712). https://doi.org/10.1016/j.marpol.2019.103712
- Durán Muñoz, P., Sayago-Gil, M, Murillo, FJ, Del Rio, JL, López-Abellán, LJ, Sacau, M and Sarralde, R (2012) Actions taken by fishing Nations towards identification and protection of vulnerable marine ecosystems in the high seas: the Spanish case (Atlantic Ocean). Marine Policy 36, 536-543.
- Equinor Canada Ltd. (2020). Bay du Nord Development Project Environmental Impact Statement. Prepared by Wood Environment & Infrastructure Solutions and Stantec Consulting. St. John's, NL Canada. July 2020.
- FAO (2022) A handbook for identifying, evaluating and reporting other effective area-based conservation measures in marine fisheries. Rome. https://doi.org/10.4060/cc3307en
- Fisher, C.R., Hsing, P.Y., Kaiser, C.L., Yoerger, D.R., Roberts, H.H., Shedd, W.W., Cordes, E.E., Shank, T.M., Berlet, S.P., Saunders, M.G., Larcom, E.A., Brooks, J.M. (2014) Footprint of Deepwater Horizon blowout impact to deep-water coral communities. Proc Natl Acad Sci U S A. 2014 Aug 12;111(32):11744-9. https://doi.org/10.1073/pnas.1403492111.
- García, S., Rice, J., Charles, A., and Diz, D. (2020) OECMs in Marine Capture Fisheries: Systematic approach to identification, use and performance assessment in marine capture fisheries. Fisheries Expert Group of the IUCN Commission on Ecosystem Management, Gland, Switzerland. European Bureau of Conservation and Development, Brussels, Belgium: 87 p. Available at www.ebcd.org/feg.
- Gary, S.F., Fox, A.D., Biastoch, A., Roberts, J.M., and Cunningham, S.A. (2020) Larval behaviour, dispersal and population connectivity in the deep sea. Sci. Rep. 10:10675. https://doi.org/10.1038/s41598-020-67503-7
- Gates, A. R., Benfield, M. C., Booth, D. J., Fowler, A. M., Skropeta, D., and Jones, D. O (2017). Deep-sea observations at hydrocarbon drilling locations: Contributions from the SERPENT Project after 120 field visits. *Deep Sea Research Part II: Topical Studies in Oceanography*, 137, 463-479.
- GEBCO Bathymetric Compilation Group 2023 (2023). The GEBCO\_2023 Grid a continuous terrain model of the global oceans and land. NERC EDS British Oceanographic Data Centre NOC. https://doi.org/10.5285/f98b053b-0cbc-6c23-e053-6c86abc0af7b
- Girard, F. and Fisher, C. (2018) Long-term impact of the Deepwater Horizon oil spill on deep-sea corals detected after seven years of monitoring. Biological Conservation 225, 117-127. https://doi.org/10.1016/j.biocon.2018.06.028.
- González-Costas, F., Ramilo, G., Román, E., Lorenzo, J., González-Troncoso, D., Sacau, M., Duran, P., Del Rio, J.L., and Blanco, R. (2023). Spanish Research Report for 2022. Serial No N7380. NAFO SCS Doc. 23-06
- Hansen, B. H., Sørensen, L., Størseth, T. R., Nepstad, R., Altin, D., Krause, D., *et al.* (2019). Embryonic exposure to produced water can cause cardiac toxicity and deformations in Atlantic cod (Gadus morhua) and haddock (Melanogrammus aeglefinus) larvae. *Marine environmental research*, 148, 81-86.
- Harris P.T., Macmillan-Lawler M, Rupp J, Baker EK (2014) Geomorphology of the oceans. Marine Geology, 352: 4-24. https://doi.org/10.1016/j.margeo.2014.01.011
- Hughes, S. J. M., Jones, D. O. B., Hauton, C., Gates, A. R., & Hawkins, L. E. (2010) An assessment of drilling disturbance on Echinus acutus var. norvegicus based on in-situ observations and experiments using a remotely operated vehicle (ROV). *Journal of Experimental Marine Biology and Ecology*, 395(1-2), 37-47.
- Järnegren, J., Brooke, S., and Jensen, H. (2017) Effects of drill cuttings on larvae of the cold-water coral Lophelia pertusa. *Deep Sea Research Part II: Topical Studies in Oceanography*, 137, 454-462.
- Kaiser, M.J. (2021) A Review of Exploration, Development, and Production Cost Offshore Newfoundland. Natural Resources Research, 30: 1253–1290. https://doi.org/10.1007/s11053-020-09784-3
- Kenchington, E., Lirette C., Murillo, .FJ., Beazley, L., and Downie, A.-L. (2019a) Vulnerable Marine Ecosystems in the NAFO Regulatory Area: Updated Kernel Density Analyses of Vulnerable Marine Ecosystem Indicators. NAFO SCR Doc. 19/058. Serial No. N7030. https://www.nafo.int/Portals/0/PDFs/sc/2019/scr19-058.pdf



- Kenchington, E., Wang, Z., Lirette, C., Murillo, F. J., Guijarro, J., Yashayaev, I., *et al.* (2019b) Connectivity modelling of areas closed to protect vulnerable marine ecosystems in the northwest Atlantic. Deep Sea Research Part I: Oceanographic Research Papers, 143: 85 103. https://doi.org/10.1016/j.dsr.2018.11.007.
- Limpinsel, D., McDermott, S., Felkley, C., Ammann, E., Coxe, S., Harrington, G.A., Kelly, S., Pirtle, J.L., Shaw, L., and Zaleski, M. (2023). Impacts to Essential Fish Habitat from Non-Fishing Activities in Alaska: EFH 5-year review from 2018-2023. National Marine Fisheries Service, Alaska Region, Juneau, Alaska. U.S. Dep. Commerce, NOAA Tech. Memo. NMFS-F/AKR-30. https://doi.org/10.25923/9z4h-n860
- Lothian, S. (2024) The BBNJ Agreement: Through the Prism of Deep-Sea Vulnerable Marine Ecosystems, Ocean Development & International Law, https://doi.org/10.1080/00908320.2023.2296400
- Luter, H. M., Whalan, S., Andreakis, N., Abdul Wahab, M., Botté, E. S., Negri, A. P., & Webster, N. S. (2019) The effects of crude oil and dispersant on the larval sponge holobiont. *Msystems*, 4(6), 10-1128.
- Marappan, S., Stokke, R., Malinovsky, M.P. and Taylor, A. (2022) Assessment of impacts of the offshore oil and gas industry on the marine environment. In: OSPAR, 2023: The 2023 Quality Status Report for the North-East Atlantic. OSPAR Commission, London.
- McCauley, R. D., Day, R. D., Swadling, K. M., Fitzgibbon, Q. P., Watson, R. A., and Semmens, J. M. (2017) Widely used marine seismic survey air gun operations negatively impact zooplankton. *Nature ecology & evolution*, 1(7), 0195.
- Molenaar, E. (2021) Multilateral Creeping Coastal State Jurisdiction and the BBNJ Negotiations. The International Journal of Marine and Coastal Law 36: 5–58.
- Morato, T., González-Irusta, J.-M., Dominguez-Carrió, C., *et al.* (2020) Climate-induced changes in the suitable habitat of cold-water corals and commercially important deep-sea fishes in the North Atlantic. Glob Change Biol. 26:2181–2202. https://doi.org/10.1111/gcb.14996
- Muehlenbachs, L., Cohen, M.A., and Gerarden, T. (2013) The impact of water depth on safety and environmental performance in offshore oil and gas production. Energy Policy 55:699–705. https://doi.org/10.1016/j.enpol.2012.12.074
- Murillo, F.J., Serrano, A., Kenchington, E., and Mora, J. (2016). Epibenthic assemblages of the Tail of the Grand Bank and Flemish Cap (northwest Atlantic) in relation to environmental parameters and trawling intensity. Deep-Sea Res. I, 109: 99–122.
- Murillo, F.J., Durán Muñoz, P., Altuna, A. and Serrano, A. (2011) Distribution of deep-water corals of the Flemish Cap, Flemish Pass and the Grand Banks of Newfoundland (Northwest Atlantic Ocean): interaction with fishing activities. ICES Journal of Marine Science 68, 319–332.
- Murillo, F.J., Durán Muñoz, P., Cristobo, F.J. Ríos, P. González, C. Kenchington, E. and Serrano A. (2012) Deep-sea Sponge Grounds of the Flemish Cap, Flemish Pass and the Grand Banks of Newfoundland (Northwest Atlantic Ocean): distribution and species composition. Marine Biology Research 8, 842-854.
- NAFO (2024) Northwest Atlantic Fisheries Organization Conservation and Enforcement Measures 2024. NAFO/COM Doc. 24/01: 195pp.
- NAFO (2023) 2023 informal group of WG-EAFFM on OECMs. 20th March 2023. COM-SC WP 23-02. 5 pp
- NAFO (2019) Report of the Scientific Council Working Group on Ecosystem Science and Assessment, 18 29 November 2019, Dartmouth, Nova Scotia, Canada. NAFO SCS Doc. 19/25
- Neff, J., K. Lee, E.M. DeBlois and G.G. Janes (2014) Environmental Effects of offshore drilling in a cold ocean ecosystem: A 10-year monitoring study at the Terra Nova offshore oil development off the Canadian east coast. Deep Sea Research II: Topical Studies in Oceanography 110: 1-3. https://doi.org/10.1016/j.dsr2.2014.10.018.
- Neff, J.M., K. Lee and E.M. DeBlois (2011) Produced water: overview of composition, fates and effects. In: Produced Water: Environmental Risks and Advances in Mitigation Technologies. K. Lee and J.M. Neff (eds.), Springer Press, NY. pp. 3-54.
- Netto, S. A., Gallucci, F., and Fonseca, G. (2009) Deep-sea meiofauna response to synthetic-based drilling mud discharge off SE Brazil. *Deep Sea Research Part II: Topical Studies in Oceanography*, 56(1-2), 41-49.



- OSPAR (2021) Report on impacts of discharges of oil and chemicals in produced water on the marine environment. Offshore Oil & Gas Industry Series, Publication Number:804/2021, OSPAR Commission.
- Popova, E., Vousden, D., Sauer, W.H.H., Mohammed, E. Y., Allain, V., Downey-Breedt, N., Fletcher, R., Gjerde, K.M., Halpin, P.N., Kelly, S., Obura, D., Pecl, G., Roberts, M., Raitsos, D.E., Rogers, A., Samoilys, M., Sumaila, U.S., Tracey, S., and Yool, A. (2019) Ecological connectivity between the areas beyond national jurisdiction and coastal waters: Safeguarding interests of coastal communities in developing countries, Marine Policy 104: 90-102.
- Ronconi, R. A., Allard, K. A., and Taylor, P. D. (2015) Bird interactions with offshore oil and gas platforms: Review of impacts and monitoring techniques. *Journal of Environmental Management*, 147, 34-45.
- Tornero, V., & Hanke, G. (2016) Chemical contaminants entering the marine environment from sea-based sources: A review with a focus on European seas. *Marine Pollution Bulletin*, 112 (1-2), 17-38.
- UNEP-WCMC and IUCN (2024). Protected Planet: The World Database on Other Effective Area-based Conservation Measures (WD-OECM) [Online], May 2024, Cambridge, UK: UNEP-WCMC and IUCN. Available at: www.protectedplanet.net.
- Vad, J., Duran Suja, L., Summers, S., Henry, T. B., and Roberts, J. M. (2022) Marine sponges in a snowstorm–extreme sensitivity of a sponge Holobiont to marine oil snow and chemically dispersed oil pollution. Frontiers in Microbiology, 13, 909853.
- Vad, J., Dunnett, F., Liu, F., Montagner, C. C., Roberts, J. M., and Henry, T. B. (2020) Soaking up the oil: Biological impacts of dispersants and crude oil on the sponge Halichondria panicea. *Chemosphere*, 257, 127109.
- Vad, J., Kazanidis, G., Henry, L.A., Jones, D.O.B., Tendal, O.S., Christiansen, S., Henry, T.B. and Roberts, JM (2018) Potential Impacts of Offshore Oil and Gas Activities on Deep-Sea Sponges and the Habitats They Form. In Advances in Marine Biology 79, Elsevier, pp. 33-60. https://doi.org/10.1016/bs.amb.2018.01.001.
- van der Knaap, I., Reubens, J., Thomas, L., Ainslie, M. A., Winter, H. V., Hubert, J., Martin, and Slabbekoorn, H. (2021) Effects of a seismic survey on movement of free-ranging Atlantic cod. *Current Biology*, 31(7), 1555-1562.
- Wang, S., Kenchington, E., Murillo, F. J., Lirette, C., Wang, Z., Koen-Alonso, M., Kenny, A. Sacau, M. and Pepin, P. (2024) Quantifying the effects of fragmentation of connectivity networks of deep-sea vulnerable marine ecosystems. Diversity and Distributions, e13824.
- Weinnig, A.M., Gómez, C.E., Hallaj, A., and Cordes, E.E. (2020) Cold-water coral (*Lophelia pertusa*) response to multiple stressors: High temperature affects recovery from short-term pollution exposure. Scientific Reports, 10(1), 1768.













**NAFO Scientific Council Meeting** 31 May - 13 June 2024, Halifax

# A desk based study on activities other than fishing in NAFO Regulatory Area

#### **NEREIDA Task 3**

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#### Aim of NEREIDA Task 3

- To better understand some of the non-fishing activities that take place in the NRA (e.g., oil and gas), in relation to their potential impact on the fishery resources, the ecosystem and the fishing activity regulated by NAFO.
- To conduct a literature review focused on oil and gas.
- To help developing approaches related to tackling impacts of non-fishing activities on the marine biological resources in the NRA.

This knowledge is necessary to feed the ESSs and will help to understand whether non-fishing activities may affect the effectiveness of conservation measures adopted by NAFO.(e.g. closed areas).

It should be noted that this study is not intended to duplicate work done by the relevant authorities (e.g., it is not intended to duplicate work done through existing impact assessment processes).

# Activities other than fishing: A concern for the international community...



[\*] "Notes with concern that vulnerable marine ecosystems may also be impacted by human activities other than bottom fishing, and encourages in this regard States and competent international organisations to consider taking action to address such impacting.







# OECMs defined by COP-CBD in 2018

- Aichi Biodiversity Target 11 refers to effectively and equitably managed, ecologically representative and well-connected systems of protected areas and **OECMs**.
- **FAO (2022)** Handbook for identifying, evaluating and reporting **OECMs** in marine fisheries.

A <u>multi-sectoral</u>, integrated and collaborative process is considered **best practice** in areas with **multiple uses/pressures**, to achieve sustained, long-term biodiversity outcomes.

# BBNJ Agreement adopted in 2023



- Applies in ABNJ, without "undermining" existing governance regimes. Organized around 4 key topics:
  - 2. Network of Area-Based Management Tools (ABMTs)
  - 3. Environmental Impact Assessments (EIAs)

Cumulative impacts?

# ... and also a concern for NAFO



NAFO Input to the 2022 Workshop to discuss the implementation of UNGA resolutions (64/72, 66/68, 71/123)

United Nations Headquarters New York (2-3 August 2022)

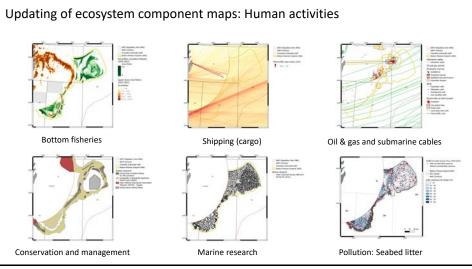
"....NAFO has noted that there are a number of non-fishing activities occurring in the Regulatory Area that have the potential to impact fisheries resources and the ecosystem. In this context, non-fishing activities, e.g. oil and gas activities, continue to be in the NAFO Commission agenda during its Annual Meetings...."

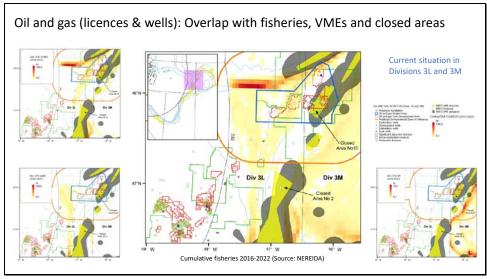
### 2023 Annual Meeting

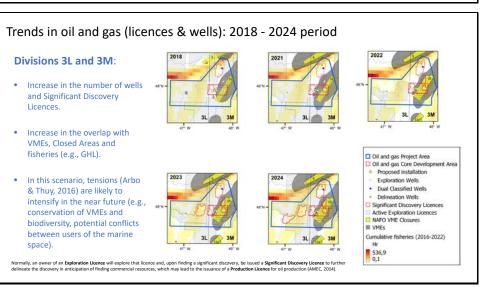
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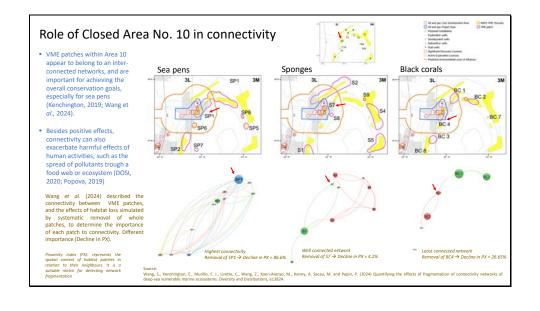
"The Commission request the SC to monitor and provide regular updates on relevant research related to the potential impacts of activities other than fishing in the Convention Area, subject to the capacity of the Scientific Council".

# Updating of ecosystem component maps: Natural components \*\*The component service of the compone



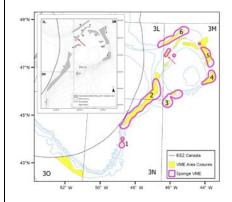






# Implications for the process for nomination and recognizing OECMs

Consideration of Area 10 would bring greater coherence to the OECM proposal (e.g., integrity of the NAFO network of closures)



- In the case of multi-sectoral areas, the optimal approach is to carry out cross-sectoral identification, assessment and reporting of OECMs (FAO 2022. Handbook for fisheries OECMs).
- A bilateral collaboration between sectors may be enough to make an OECM operational and even to establish crosssectoral OECM outcomes; There is a need for international collaboration in the case of transboundary OECMs, and RFMOs could be used to promote effective OECMs (García et al., 2020).
- Importance of considering non-fishing impacts (cumulative impacts) and describing the potential contribution of OECM to connectivity (García et al., 2020).

# Literature on the impacts of oil and gas, at a glance

Review of impacts (description, assessments, etc.)

Deepwater Horizon oil spill

Terranova offshore drilling

SERPENT (ROV) drilling sites

Reports by FAO,
OSPAR, EU (NE Atlantic),
NOAA, BOEM, DFO (N Atlantic, Pacific)

Governance

Conflicts with fisheries, fishers, coastal communities, social aspects (-/+) Produced water

Drilling fluids, cutting piles, wastes

Chemicals, dispersants

GHG Emissions

Oil spills Light

Noise

Installations, decommissioning (-/+), effects of climate change

Benthic Invertebrates (larvae and adults): Cold water corals, deep-water sponges, crustaceans, etc.

> Essential Fish Habitats

Zooplankton & food web

Fish

Seabirds

Sea turtles

Marine mammals

# Some key findings

- Routine oil and gas activities can have detrimental environmental effects during each of the main phases of exploration, production, and decommissioning (Cordes et al., 2016).
- Incidents, such as blowouts, injuries, and oil spills, are positively correlated with deeper water (Muehlenbachs et al., 2013). Climate change may affect oil and gas facilities and operations due to more intense storms and stronger winds and waves (Burkett, 2011).
- Noise from seismic surveys may affect a range of species, such as marine mammals (Affati and Camerlenghi, 2023) and fish (van der Knaap et al., 2021), and causes significant mortality to zooplankton populations (McCauley et al., 2017).
- For seabirds and landbirds, the most frequently observed effect is attraction and sometimes collisions associated with lights and flares (Ronconi et al., 2015).
- Environmental effects include impacts from routine operational activities such as drilling waste and produced water discharges (Neff et al., 2011; Neff et al., 2014), accidental discharges and spills (Cordes et al., 2016), long-term impacts on deep-sea corals (Fisher et al., 2014; Girard and Fisher, 2018) and deep-sea sponges and habitats (Vad et al., 2016).
- There is evidence for the toxicity of both oil and dispersant on deep-water corals (De Leo, et al., 2016) and sponges (Luter et al., 2019; Vad et al., 2020; Vad et al., 2022).
- Operational discharges from offshore oil and gas platforms are a continuous source of contaminants to continental shelf ecosystems (Bakke et al., 2013). Drill cuttings (Tomero and Hanke, 2016) and produced water (Beyer, 2020; Hansen, 2020; OSPAR, 2021) are the largest operational source of all pollution from the offshore petroleum industry. Effects are generally local but persistent (Gates et al., 2012). For example, coal favore subjected to embryonic exposure to produced water extracts were smaller, and displayed signs of cardiotoxicity and body deformations (Hansen, 2020). Drill cuttings affect Lophelia larvae (Jarnegren et al., 2017), e-chinoids (Hughes et al., 2010) and meiofauna (Netto et al., 2009).
- Oil and gas exploitation introduces toxic contaminants to the surrounding sediment, resulting in deleterious impacts on marine benthic communities. Contamination from oil and
  gas platforms caused declines in benthic food web complexity, community abundance, and biodiversity (Chen et al., 2024).
- Effects-oriented studies (Beyer et al., 2016) demonstrated that the oil was toxic to a wide range of organisms (plankton, invertebrates, fish, birds, and sea mammals), causing a wide array of adverse effects (reduced growth, disease, impaired reproduction, impaired physiological health, and mortality).

# Conclusions

- Activities other than fishing are a matter of concern for the international community and stakeholders.
- Main natural components and human activities were mapped, based on available spatial data.
- Oil and gas licences and wells overlap with NAFO fisheries, VMEs and closed areas, particularly in Divs. 3L and 3M.
- In recent years, an increase in the number of wells and Significant Discovery Licenses has been observed, as well as an increase in overlap with fisheries, VMEs and closed areas.
- VME patches within Closed Area 10 appear to belong to an inter-connected networks, and are important for achieving the overall conservation goals.
- · Consideration of Area 10 would bring greater coherence to the OECM proposal. This would require a multi-sectoral approach and international collaboration, as recommended by FAO.
- Scientific literature indicates that oil and gas activities can produce impacts during the exploration, exploitation and decommissioning phases. They may also result in conflicts with other users of the marine space.











# Thank you!

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