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Information to support decisions on authorizing scientific surveys with bottom-contacting gears in NAFO closed areas

by

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Abstract

There are presently no existing frameworks or approaches in NAFO to assist in determining under what conditions scientific surveys employing bottom-contacting gear can be permitted in protected areas. Fisheries and Oceans Canada (DFO) has produced a Canadian National Framework to guide the evaluation of scientific surveys within protected areas inside the Canadian waters. The objective of this document is to apply to the scientific surveys that are carried out in the NRA the framework developed by the DFO for the collection of information that can help managers in the decision of whether the actual scientific surveys can sample or not in the closed areas to bottom fishing activities.

Results show that there are no major problems for the surveys indices of abundances of the main species and that their quality is very similar with and without the data of the hauls carried out in the closed areas for most stocks series. Only the indices for two stocks, Greenland halibut Subarea 2 and Division 3LMNO and roughhead grenadier Subarea 2 and 3, show a loss of quality when information on sets made within closed areas is omitted.

It can also be concluded that the benthic impact of the survey activities carried out in the NRA are likely to have time to recover to the levels that existed prior to the benthic impact of the sampling activity at least for the closed areas delimited based on high density of pennatulaceans. For the closed areas delimited based on concentrations of large gorgonians and sponges the conclusions are not so clear due to the lack of information about the longevity of some of the coral and sponges species. Reducing the trawling time in European surveys from 30 to 20 minutes for the hauls that are made within the closed areas would considerably reduce the benthic impact ensuring a sufficient recurrence time for closed areas based on pennatulaceans and extending the recurrence time to more than 1500 years for all closed areas based on high concentrations of large gorgonians and sponges.

Introduction

Within its Convention Area, NAFO has identified 26 bottom contact gears protected areas and closed these areas to bottom fishing. NAFO has also delineated existing bottom fishing areas (footprint) to regulate bottom fisheries that cause a significant adverse impact on vulnerable marine ecosystems.

The closed areas are divided into two main categories, the seamount closures and the VME (sponge, coral, and sea pen) closures. The coordinates for these areas are provided in Article 17 of the NAFO CEM (NAFO 2022) (Figure 1). The seamount closures are all outside the fishery footprint while the sponge, coral, and sea pen closures overlap all or part with the fishery footprint in the Divisions 3LMNO NAFO Regulatory Area (NRA) (Figure 2). A number of these sponge, coral, and sea pen closures protected area boundaries overlap also with the areas cover by the scientific surveys in the NRA.

The main annual scientific surveys carry out in the NRA use bottom trawl gears and have been conducted for several decades. At this moment, there are one annual multi-species bottom trawl research surveys that took place in the Division 3M carry out by the EU and three in the NRA Division 3LNO: one carries out by UE Spain and two by Canada. All these surveys use bottom trawl gear and have a stratified random design (Figure 3). The study area of these surveys (domain) overlaps with many of the bottom fishing closed areas (Figure 4). The information collected in these scientific surveys have become essential for the monitoring and assessment of the different exploited species as well as for the study and conservation of the ecosystems. These surveys provide indices of abundance for analytical assessments of stock status and they also provide information on a number of ecosystem aspects including species diversity and species distribution used in identifying conservation areas and developing ecosystem indicators.

The establishment of protected areas in the NRA in which survey bottom fishing activities are limited has created an urgent need for approaches to determine what surveys activities will be permitted within these areas in light of site-specific conservation objectives and monitoring requirements. Scientific surveys collected information that can support conservation-related management decision making within protected areas and in the broader ecosystem (e.g., advice for sustainable fisheries, species recovery, and ecosystem status). However, these same scientific activities can harm organisms, populations, assemblages and habitats within protected areas and therefore can hinder the achievement of conservation objectives. This is particularly true for areas with ecologically sensitive benthic taxa and features, which can be harmed by bottom-contacting sampling gear such as bottom-trawls used in multi-species surveys. On the other hand, excluding protected areas from established survey domains may preclude information gathering that could aid in managing the protected areas and that often forms the basis of advice for the management of populations and communities in the broader ecosystem.

There are presently no existing frameworks or approaches in NAFO to assist in determining under what conditions scientific surveys employing bottom-contacting gear can be permitted in protected areas. SC in 2017 (NAFO, 2017) recommends that scientific bottom trawl surveys in existing closed areas be avoided if possible and additional work be conducted as soon as possible to further evaluate the implications of excluding scientific surveys in closed areas on stock assessment metrics.

Before including or excluding the protected areas within the scientific survey protocols, an assessment of the impact of their activities should be required. This decision will be informed by an assessment of risks posed by the sampling equipment and strategy, and benefits to be derived from the information obtained by the sampling activity. Fisheries and Oceans Canada (DFO) has produced a Canadian National Framework to guide the evaluation of the scientific surveys within protected areas (DFO 2018, Benoît et al. 2020). The framework describes an information gathering process that will assist the management sectors in their review of proposed scientific activities using bottom-contacting gear in protected areas. The framework does not prescribe decisions to be taken. Rather it is intended to facilitate dialogue between the science survey proponent(s) and the decision-making sector(s).

The objective of this document is to apply to the scientific surveys that are carried out in the NRA the framework developed by the DFO for the collection of information that can help managers in the decision of whether the actual scientific surveys can sample or not in the sponge, coral, and sea pen closures protected areas.

DFO Framework

Fisheries and Oceans Canada (DFO) National Framework to guide the evaluation of the scientific surveys within protected areas comprises the following general elements (DFO 2018; Benoît et al. 2020):

- An evaluation of the potential impact of survey activities within protected areas. In the absence of specific directed studies, a quantitative metric of the harm to species, communities, and benthic habitat forming structures (e.g. biogenic structures) resulting from scientific survey activities in a protected area is not possible. A proposed proxy of the level of harm is the relative magnitude of the recurrence time interval of the activity and the expected recovery time of the benthic components.

- An evaluation of potential mitigation measures that could reduce the impact of scientific activities in the protected areas. These include using lower-impact gear, modifying sampling procedures to reduce benthic impacts, reducing the swept area of individual survey hauls, and reducing the sampling density, including by reducing the number of surveys that operate in an area.

- An evaluation of the benefits of survey activities to the management of protected areas. The benefits could include sampling within and outside protected areas that allows for a determination of the efficacy of protected areas for the conservation of key taxa (Kerr et al. 2019), sampling to better understand the distribution of taxa and diversity within protected areas, or the collection of samples to better understand the identity and biology of taxa in the areas.

- An evaluation of the potential consequences of excluding survey sampling in protected areas. These consequences include the generation of biases in abundance indices for taxa in the broader ecosystem, which are used to produce scientific advice for the management of fishery resources and depleted species, including species at risk, and for ecosystem monitoring and reporting.

Based on these elements, the DFO developed a framework to support decisions on authorization of scientific surveys with bottom-contacting gears in protected areas. The framework describes an information gathering process to assist the management sectors in their review of proposed scientific activities using bottom-contacting gear in protected areas. The application of the framework to the VME closed areas and scientific surveys in the NRA is the following:

1.- A description of protected areas which are within the survey domains of the proposed scientific surveys and the benthic conservation objectives of the protected areas. Protected Areas in the 3LMNO NAFO Regulatory Area (NRA).

In 2006, NAFO took the initial ecosystem management steps involved the protection of some seamounts in the NRA. In 2010, NAFO established the initial coral and sponge protection zones (NAFO, 2010), these closed areas were refined in 2014 (NAFO, 2015) and 2021 (NAFO, 2022). At the present time, NAFO has identified 26 areas within its Convention Area, as being vulnerable to bottom contact gears and subsequently closed these areas to bottom fishing (Figure 1). The closed areas are divided into two main categories, the seamount closures and the sponge, coral, and sea pen closures. The coordinates for these areas are provided in Article 17 of the NAFO CEM (NAFO 2022). The seamount closures are all outside the NRA fishery footprint while 18 sponge, coral, and sea pen closures (Figure 4 and Table 1) overlap all or part with the scientific survey domains.

The delimitation of the sponge, coral, and sea pen closed areas has been made based on the analyzes carried out by the NAFO Scientific Council Working Group on the Ecosystem Approach to Fisheries Management (WGEAFM) in 2008 and 2009 (NAFO 2008 and NAFO 2009) and the Working Group on Ecosystem Science and Assessment (WG-ESA) in 2013 and 2019 (NAFO 2013 and NAFO 2019). These analyzes tried to identify areas with high concentrations of Vulnerable Marine Ecosystems (VME) indicator species (sponge, coral, and sea pen) based on de scientific surveys data carried out in the NRA. For most VME indicator taxa, kernel density (KDE) analyses of the research vessel trawl catches and subsequent aerial expansion methods were applied. Table 2 presents the surface and main features of the NAFO Regulatory Area bottom fishing sponge, coral, and sea pen closed areas. The conservation objectives (Conservation target) indicates which is the main target taxon found in high density in the definition of each closed area. In the case of NAFO, all closed areas have the same restriction, closed these areas to bottom fishing activities. Areas 1-15 (Table 2) are the areas that were established in 2014, and it was agreed last year to increase their protection until 2026, while areas 16-19 are extensions of some of the previous areas and its protection is reviewable in the year 2023.

2.- A description of the proposed scientific activities to be undertaken in the protected area. Surveys in NRA Divisions 3LMNO.

2.1 Surveys relevant to the current evaluation: There are 4 annual surveys employing bottom-trawl gears that occur in in NRA Division 3LMNO overlapping all or part with the protected areas in this zone. In 2021, a long line survey was carried out in Division 3M, but it is not analyzed in this work since there is no data available and it is not known whether this survey will continue in the future.

The four trawl surveys are annual multi-specific surveys. A summary of the main characteristics of these surveys is presented in Table 3. The information collected in these surveys was key to identifying the aggregations of coral and sponges and to delimitate the actual closed Areas and the Vulnerable Marine Ecosystems in the NRA. Figure 4 shows the different NRA survey domain for each of the surveys. All surveys employ a similar random stratified design (Doubleday, 1981), with strata based on depth and area (Table 4 and Figure 3). Table 4 shows al the NRA strata, their surface (km^2), the surface overlapped with the closed areas (km^2) and the projected number of hauls of the different surveys in each stratum overlapped with the NRA.

2.1.1 European Union Flemish Cap Survey (EU_FC): The EU bottom trawl survey in Flemish Cap (Div. 3M) was carried since 1988 using the Lofoten gear in summer, mainly July. The objective of the survey is to know the stock status of target species: their abundance, biomass and demographic structure, and the oceanographic conditions on the bank. The area surveyed was Flemish Cap Bank to depths up to 800 fathoms (1460 m) following the survey protocol (Vazquez et al. 2014). The normal annual number of hauls are around 180 of 30 minutes duration. The haul swept area by the survey gear (Lofoten) is estimated at 0.28 km^2.

2.1.2 Spanish 3NO and 3L surveys (EU_3LNO): The Spanish multi specific bottom trawl survey in NAFO Regulatory Area Div. 3NO started in 1995 cover a depth range of 43-1438 m according to a stratified random design. The actual gear is a Campelen otter trawl with 20 mm mesh size in the cod-end. The annual number of hauls are around 115 of 30 minutes duration. The haul swept area by the survey gear (Campelen 1800) is estimated at 0.14 km^2. For more details about the technical specifications of the surveys, see Walsh et al. (2001) and González Troncoso et al. (2004).

In 2003 it was decided to extend the Spanish 3NO survey toward Div. 3L (Flemish Pass) using the usual survey gear (Campelen 1800). The area surveyed is Flemish Pass to depths up 800 fathoms (1463 m). The annual number of hauls are 100 of 30 minutes duration. The haul swept area by the survey gear (Campelen) is estimated at 0.14 km^2.

2.1.3 Canadian Autumn Survey (Can_Fall): This survey began in the early seventies and currently covers the NAFO Divisions 2HJ3KLNO area to depth of 1500 meters. Programming annual hauls of 15 minutes duration is around 674 hauls using the Campelen trawl gear. The haul swept area by the survey gear (Campelen) is estimated at 0.07 km^2. Rideout and Ings (2020) present the temporal and spatial coverage of the Canadian Spring and Autumn Multi-Species bottom trawl surveys. The analysis of this survey carried out in this work is limited to the survey domain that overlaps with the NRA.

2.1.4 Canadian Spring Survey (Can_Spring): This survey began in the early seventies and currently covers the NAFO Divisions 3LNOPs area to depth of 730 meters. Programming annual hauls of 15 minutes duration is around 478 hauls using the Campelen trawl gear. The haul swept area by the survey gear (Campelen) is estimated at 0.07 km^2. Rideout and Ings (2020) present the temporal and spatial coverage of the Canadian Spring and Autumn Multi-Species bottom trawl surveys. The analysis of this survey carried out in this work is limited to the survey domain that overlaps with the NRA.

2.2 Swept area and proportion of areas impacted calculations.

Individual survey hauls swept area were calculated follow the recommendation made in DFO protocol (2018), which in the cases of bottom trawls gears includes the area swept between trawl doors, assuming complete contact (Target haul distance (km) x mean door spread (km)). The estimated survey haul swept area for the different surveys appears in Table 3. We can see that the haul swept area of the FC survey is the double that of the Spain 3LNO survey due to the greater opening of the gear doors due to the bridles. Lofoten gear have bridles while the Campelen gear has not. The haul swept area of the Canadian surveys is half the area swept by the Spain 3LNO survey although they use the same gear (Campelen). The towing time is 15 minutes in the Canadian surveys while in the Spain 3LNO survey it is 30 minutes.

The annual total swept area of a survey (Table 2) is estimated as the product of the total number of annual hauls and the haul-specific swept area divided by the interval periods between conducting the survey. In our caser the interval periods for all surveys is one since all are annual surveys. This annual total swept area was calculated for the whole survey domain of each survey and not only for the NRA. One of the things to note is that the annual swept area from the FC survey is the largest of all while its domain is much less than that of the Canadian surveys, this is due to the FC survey gear (Lofoten with bridles) which opens much more horizontally than the Campelen without bridles gear of the other surveys and the time duration of the sets, which in the Canadian surveys is 15 minutes , while in the EU surveys it is 30 minutes.

The average proportion of the bottom within a protected area which would be impacted by the bottom-contacting survey gear is dependent upon the sampling design for the surveys overlapping the closed area and the projected number of hauls of the different surveys in each stratum. In our case all surveys have random-stratified designed.

The mean annual number of sample hauls within a close area is the product of the sampling intensity (samples per km^2) of the corresponding survey domain (or stratum) and the surface area of the protected area overlapped by the domain/stratum, summed over all overlapping strata in the case of a stratified random design. Table 4 presents the NRA 3LNO survey strata, their area (km^2), the protected area (km^2) overlap with each stratum and the annual planned hauls in each stratum for each of the surveys. The domain of each of the surveys corresponds to the set of strata with two or more samples (Figure 5).

The average proportion per year of the bottom of the protected area which would be impacted by the bottom-contacting gear over all strata (K; with K=1 for a random survey) for all surveys (S) is calculated as (equation 1):

$$\text{Prop. Impact} = \frac{\sum_s^S \overline{swept\ area_s} * freq_s \sum_k^K \ sampling\ intensity_{s,k} * protected\ area\ size_{s,k}}{protected\ area\ size}$$

where *swept area*$_s$ is the average swept area for a haul (km^2) in survey *s*, *freq*$_s$ is the annual frequency (1 for annual surveys) of survey *s*, *sampling intensity*$_{s,k}$ is the average number of sampling stations per km^2 within stratum *k* for survey *s*, *protected area size*$_{s,k}$ is the quantity (km^2) of the protected area contained in stratum *k* of survey s, and the denominator is the total size (km^2) of the protected area. The proportion impacted has units of year^{-1}. Table 5 presents the average proportion per year of the bottom of the different protected area which would be impacted by the bottom-contacting gear for each of the surveys and for all surveys. It should be noted that the closed area 15 surface used in the estimation is only the NRA closed area surface and not the total closed area 15 surface. It was also estimated the impact for the closed areas 7+7a, 11+11a and 14a+a4b since they are extensions of areas closed in 2015.

The recurrence time interval (R; in years) for the different protected areas, defined as the average time between successive benthic sampling impacts at a given site, is the inverse of the annual proportion impacted (equation 2):

$$R = \frac{1}{\text{Prop.Impact}} = \frac{\textit{protected area size}}{\sum_s^S \overline{swept\ area_s} * freq_s \sum_k^K \ sampling\ intensity_{s,k} * protected\ area\ size_{s,k}}$$

In instances in which surveys overlap only partially with a protected area as it is our case for some close areas (Figure 3), it may be more appropriate to consider the recurrence time interval for the portion of the protected area which is overlapped such that (equation 3):

$$R = \frac{\textit{protected area size * proportion protected area overlapped}}{\sum_s^S \overline{swept\ area_s} * freq_s \sum_k^K \ sampling\ intensity_{s,k} * protected\ area\ size_{s,k}}$$

2.3 Recurrence time Calculations.

It was estimated the recurrence time for each survey and over all surveys for each of the closed areas. Table 6 presents recurrence time interval (R; in years) for the different protected areas for each of the surveys and for all surveys estimated taking in account all the closed areas surface (equation 2). It should be noted that the closed area 15 surface used in the estimation is only the NRA closed area surface and not the total closed area 15 surface. It was estimated the recurrence time for the closed areas 7+7a, 11+11a and 14a+a4b since they are extensions of areas closed in 2015. Figure 6 shows the recurrence time interval (R; in years) of each closed area for NRA surveys.

It was also estimated the recurrence time interval taking in account only the surface of the closed areas overlapped with the survey domains (equation 3). Table 7 presents recurrence time interval estimated with the equation 3 for the different protected areas for each of the surveys and for all surveys. Figure 7 shows the recurrence time interval of each closed area for all surveys estimated only with the overlapped area (equation 3).

3.- An assessment of the susceptibility of the valued benthic components in the protected areas to the proposed scientific surveys activities. Potential Impacts of Surveys in the Protected Areas.

The Canadian framework (DFO 2018) recommends that the evaluation of potential impacts of surveys should ideally be based on direct studies. These will typically be before-after-control impact (BACI) type studies in which the response of benthic and demersal species to the passage of bottom-contacting fishing gear is quantified.

In the absence of direct studies, the Framework recommends that metrics of potential disturbance and harm be evaluated with respect to the potential resilience of the ecological components of interest that are the focus of conservation objectives. Metrics of harm include the proportion of the protected area that is covered by a survey (Table 1), the average annual proportion of the area that is impacted by individual surveys and by all co-occurring surveys, and the mean recurrence time for survey activities at a particular location (Tables 5, 6 and 7). The relative magnitude of recurrence time and the longevity of the least resilient taxon or feature in a protected area provides a measure of the risk of potential long-term degradation caused by survey activities (DFO 2018). A proposed proxy of the level of harm to benthic habitat caused by scientific surveys with bottom-contacting gears is the relative magnitude of the recurrence time interval of the activity compared to the expected recovery time of the benthic components. Survey recurrence times that are longer than longevity by an order of magnitude or more are assumed to not result in long-term impact (DFO 2018; Benoît et al. 2020). The choice of needing recurrence time to be ten times larger than lifespan to avoid long-term degradation (or lack of recovery) is important given uncertainties and knowledge gaps of benthic invertebrate life histories, indirect effects of gear impacts not quantified in the swept area estimates, and knowledge gaps of benthic community recovery rate and factors. It is meant to help prevent overestimation of recovery potential. In the absence of information on longevity, other factors such as reproductive patterns and the breadth of distribution and environmental tolerance can provide an indication of resilience. Available information that can be used to assess the resilience of demersal and benthic ecological components of interest was summarized in by Benoît et al. 2020. We have adapted this information to NRA closed areas and for the taxa used to delimit closed areas (Table 8). Based on this information the potential impacts of the scientific surveys in the protected areas depending in the conservation target (taxa used to delimit the closed areas) are the following:

3.1 Closed areas delimited based on large concentrations of sponges.

Area 1. Tail of the Bank. This area was delimited based on large concentrations of sponges indicative of sponge grounds (Table 2). This closed area has a surface of 172 square km, of which 33% overlaps with the EU_3LNO survey domain (Table 1).

The average proportion of the area that is impacted annually is 2.00E-04 (Table 5). Recurrence time is around 4905 years if all the surface of the closed area is considered (Table 6 and Figure 5) and 1579 if we only take the surface of the closed area that overlaps with the survey domain (Table 7 and Figure 6).

Area 6. Sackville Spur. This area was delimited based on large concentrations of sponges indicative of sponge grounds (Table 2). This closed area has a surface of 987 square km, of which 44% overlaps with the EU_3FC survey domain, 3% with the Can_Fall and 3% with the EU_3LNO survey resulting in a total percentage of 47% for all surveys (Table 1 and Figure 4).

The average proportion of the area that is impacted annually is 3.50E-04 for the EU_FC survey, 1.00E-05 Can_Fall survey and 2.00E-05 for the EU_3LNO survey resulting in a total average of 3.80E-04 for all surveys (Table 5). Recurrence time is around 2614 years if all the surface of the closed area is used (Table 6 and Figure 5) and 1264 if we only take into account the surface of the closed area that overlaps with the survey domain (Table 7 and Figure 6).

All areas closed based on large concentrations of sponges are only in part within the domain of one or several of the analyzed surveys. The 56% of the surface of the closed areas based on large concentrations of sponges is not affected by any of the surveys carried out in the NRA. This is mainly due to the fact that the depths of these closed areas extend further than those of the domain of the surveys.

Many coral and sponge species have lifespans extending into 100s and 1000s of years. Glass sponge reefs, unique ecosystems in the Pacific Ocean, have ages that exceed several thousands of years; furthermore, the living portions of the reefs depend on the structural integrity of the underlying dead and buried structure which required a specific set of past geological conditions for its original formation and thus cannot recover when damaged (Conway 1999). There are not many studies of sponge growth in the NRA area. Measures of resiliency of the sponge species require further investigation. Results from a single pass trawling experiment in the Gulf of Alaska suggest a reduction of 15% in the density of *Mycale loveni* sponge and incremental damage rate of around 32% of individuals that persisted at least 13 years post-trawling (Malecha and Heifetz 2017). However, it is important to note that growth forms of *M. loveni* are different from those of *Mycale* species in the Atlantic Coast and the results of this study may not accurately reflect recovery potential here (Benoit et al. 2020).

There is no clear knowledge about the longevity of corals and sponges, it is known that it is very variable depending on the species and that they can live for several hundred years. The estimated recurrence times for the analyzed surveys are between 1000-1600 considering only the overlap surface between the closed area and the surveys domains and between 2600 and 5000 considering the entire surface of the closed areas. These times may not be enough for recovery of taxa with lifespans or benthic features with ages that are greater than one-tenth the estimated recurrence times and could be susceptible to long-term degradation and lack of recovery.

3.2 Closed areas delimited based on large concentrations of large gorgonians and sponges.

Area 2. Flemish Pass/Eastern Canyon. This area was delimited based on large gorgonians and large survey catches (>1000 kg/haul) of sponges (Table 2). This closed area has a surface of 5775 square km, of which 78% overlaps with the EU_3LNO survey domain, 49% with the Can_Fall and 8% with the Can_Spring survey (Table 1 and Figure 4).

The average proportion of the area that is impacted annually is 3.80E-04 for the EU_3LNO survey, 2.00E-05 Can_Spring survey and 8.00E-05 for the Can_Fall survey resulting in a total average of 4.80E-04 for all surveys (Table 5). There is a very small part of this close area that overlaps with the domain of the EU_FC survey that we will not consider since it is minimal. Recurrence time for all surveys is around 2105 years if all the surface of the closed area is considered (Table 6 and Figure 5) and 1652 if we only take the surface of the closed area that overlaps with the survey domain (Table 7 and Figure 6).

Area 3. Beothuk Knoll. This area was delimited based on abundant large gorgonians and large survey catches of sponges (Table 2). This closed area has a surface of 308 square km, of which only the 13% overlaps with the EU_3FC survey domain (Table 1 and Figure 4).

The average proportion of the area that is impacted annually is 1.00E-04 for the EU_FC survey (Table 5). Recurrence time consider all surveys is around 10015 years if all the surface of the closed area is considered (Table 6 and Figure 5) and 1269 if we only take the surface of the closed area that overlaps with the survey domain (Table 7 and Figure 6).

Area 4. Eastern Flemish Cap. This area was delimited based on abundant large gorgonians and large survey catches of sponges (Table 2). This closed area has a surface of 1358 square km, of which the 81% overlaps with the EU_3FC survey domain (Table 1 and Figure 4).

The average proportion of the area that is impacted annually is 5.00E-04 for the EU_FC survey (Table 5). Recurrence time consider all surveys is around 2000 years if all the surface of the closed area is considered (Table 6 and Figure 5) and 1001 if we only take the surface of the closed area that overlaps with the survey domain (Table 7 and Figure 6).

Area 5. Northeast Flemish Cap. This area was delimited based on abundant large gorgonians and large survey catches of sponges (Table 2). This closed area has a surface of 2879 square km, of which the 45% overlaps with the EU_3FC survey domain (Table 1 and Figure 4).

The average proportion of the area that is impacted annually is 4.00E-04 for the EU_FC survey (Table 5). Recurrence time consider all surveys is around 2485 years if all the surface of the closed area is considered (Table 6 and Figure 5) and 1119 if we only take the surface of the closed area that overlaps with the survey domain (Table 7 and Figure 6).

Area 13. Beothuk Knoll. This area was delimited based on abundant large gorgonians and large survey catches of sponges (Table 2). This closed area has a surface of 338 square km, of which the 100% overlaps with the EU_3FC survey domain (Table 1 and Figure 4).

The average proportion of the area that is impacted annually is 8.00E-04 for the EU_FC survey (Table 5). Recurrence time consider all surveys is around 1246 years if all the surface of the closed area is considered (Table 6 and Figure 5) and the same if we only considered the surface of the closed area that overlaps with the survey domain (Table 7 and Figure 6).

Area 15. Coral Closure Division 3O. This area was delimited based on information about large concentrations of corals although there is not much survey information available in this area (Table 2). This closed area has a total surface of 14236 square km^2, of which 3709 km^2 overlap with the NRA. A very small part of the total close area 15 (2%) and the NRA close area 15 (10%) overlaps with the EU_3LNO survey domain (Table 1 and Figure 4).

The average proportion of the total area that is impacted annually is 1.00E-05 and 3.70E-05 for the NRA close area 15 (Table 5). Recurrence time consider all surveys is around 103308 years if all the surface of the closed area is considered and 26915 if we only take the area overlapped with the NRA (Table 6 and Figure 5) and 1998 if we only considered the surface of the closed area that overlaps with the survey domain (Table 7 and Figure 6).

All areas closed based on large gorgonians high density and large survey catches (>1000 kg/haul) of sponges are only in part within the domain of one or several of the analyzed surveys. The 35% of the surface of the closed areas based on large gorgonians high density and large survey catches of sponges is not affected by any of the surveys carried out in the NRA. This is mainly due to the fact that the depths of these closed areas extend further than those of the domain of the surveys. This is mainly due to the fact that the depths of these closed areas extend further than those of the domain of the surveys.

Mortensen and Mortensen (2005) studied the morphology and growth of the gorgonian corals *Paragorgia arborea* and *Primnoa resedaeformis* from different locations in Atlantic Canada. The limited previously reported data on age and growth of *P. arborea* indicate an average growth rate of 1 cm year-1. This gives an age of about 180 years for the largest colony in this study. The time-series photographs, however, indicated a much higher growth rate (varying between 2 and 6 cm year-1 within the colony), which may be more representative for colonies of an intermediate size. The oldest *P. resedaeformis* colony was 61 years. Andrews et al. (2002) founded that for this species the age estimates were over 100 yr for sections near the heavily calcified base. These growth rates suggest that the fishery habitat created by red tree coral is extremely vulnerable to bottom fishing activities and may take over 100 years to recover.

Many coral and sponge species have lifespans extending into 100s and 1000s of years. Glass sponge reefs, unique ecosystems in the Pacific Ocean, have ages that exceed several thousands of years; furthermore, the living portions of the reefs depend on the structural integrity of the underlying dead and buried structure which required a specific set of past geological conditions for its original formation and thus cannot recover when damaged (Conway 1999). There are not many studies of sponge growth in the NRA area. Measures of resiliency of the sponge species require further investigation. Results from a single pass trawling experiment in the Gulf of Alaska suggest a reduction of 15% in the density of *Mycale loveni* sponge and incremental damage rate of around 32% of individuals that persisted at least 13 years post-trawling (Malecha and Heifetz 2017). However, it is important to note that growth forms of *M. loveni* are different from those of *Mycale* species in the Gulf and the results of this study may not accurately reflect recovery potential here (Benoit et al. 2020).

There is no clear knowledge about the longevity of corals and sponges, it is known that it is very variable depending on the species and that they can live for several hundred years. The estimated recurrence times for the analyzed surveys are between 1000-1600 considering only the overlap surface between the closed area and the surveys domains and between 1200 and 10000 considering the entire surface of the closed areas. These times may not be enough for taxa with lifespans or benthic features with ages that are greater than one-tenth the estimated recurrence times and could be susceptible to long-term degradation and lack of recovery.

3.3 Closed areas delimited based on high density of pennatulaceans.

Area 7 and 7a. Northern Flemish Cap. This area was delimited based on high density of pennatulaceans, alcyonaceans and antipatharians and, to a lesser extent, solitary scleractinians and small gorgonians. (Table 2). This closed area has a surface of 258 (7) and 795 (7a) square km, of which the 100% overlaps with the EU_3FC survey domain (Table 1 and Figure 4).

The average proportion of the area 7 that is impacted annually by the EU_FC survey is 9.70E-04 and for the area 7a is 9.30E-04 and 9.40E-04 for the area 7+7a (Table 5). Recurrence time consider all surveys is around 1033 years for the closed area 7, 1074 for the closed area 7a and 1063 for the join 7+7a if all the surface of the closed area is considered (Table 6 and Figure 5) and the same if we only considered the surface of the closed area that overlaps with the survey domain (Table 7 and Figure 6).

Area 8. Northern Flemish Cap. This area was delimited based on high density of pennatulaceans, alcyonaceans and antipatharians and, to a lesser extent, solitary scleractinians and small gorgonians. (Table 2).

This closed area has a surface of 155 square km, of which the 100% overlaps with the EU_3FC survey domain (Table 1 and Figure 4).

The average proportion of the area 8 that is impacted annually by the EU_FC survey is 1.01E-03 (Table 5). Recurrence time is around 986 years for the closed area 8 (Table 6 and Figure 5) and the same if we only considered the surface of the closed area that overlaps with the survey domain (Table 7 and Figure 6).

Area 9. Northern Flemish Cap. This area was delimited based on high density of pennatulaceans, alcyonaceans and antipatharians and, to a lesser extent, solitary scleractinians and small gorgonians. (Table 2). This closed area has a surface of 320 square km, of which the 100% overlaps with the EU_3FC survey domain (Table 1 and Figure 4).

The average proportion of the area 9 that is impacted annually by the EU_FC survey is 1.01E-03 (Table 5). Recurrence time is around 994 years for this closed area (Table 6 and Figure 5) and the same if we only considered the surface of the closed area that overlaps with the survey domain (Table 7 and Figure 6).

Area 10. Northwest Flemish Cap. This area was delimited based on high density of pennatulaceans, alcyonaceans and antipatharians and, to a lesser extent, solitary scleractinians and small gorgonians. (Table 2). This closed area has a surface of 527 square km, of which the 100% overlaps with the EU_3FC survey domain (Table 1 and Figure 4).

The average proportion of the area 10 that is impacted annually by the EU_FC survey is 8.40E-04 (Table 5). Recurrence time is around 1186 years for this closed area (Table 6 and Figure 5) and the same if we only considered the surface of the closed area that overlaps with the survey domain (Table 7 and Figure 6).

Area 11 and 11a. Northwest Flemish Cap. This area was delimited based on high density of pennatulaceans, alcyonaceans and antipatharians and, to a lesser extent, solitary scleractinians and small gorgonians. (Table 2). The closed area 11 has a surface of 61 square km and the closed area 11a has a surface of 159 square km. The surface area of both areas (11+11a) together is 220 square km. of which the 100% overlaps with the EU_3FC survey domain (Table 1 and Figure 4).

The average proportion of the area 11 that is impacted annually by the EU_FC survey is 9.70E-04, for area 11a 1.00E-03 and for the whole area 11+11a 9.90E-04 (Table 5). Recurrence time is around 1033 years for the 11 area, 1001 for the 11a closed area and 1009 for the whole 11+11a closers area (Table 6 and Figure 5) and the same if we only considered the surface of the closed area that overlaps with the survey domain (Table 7 and Figure 6).

Area 12. Northwest Flemish Cap. This area was delimited based on high density of pennatulaceans, alcyonaceans and antipatharians and, to a lesser extent, solitary scleractinians and small gorgonians. (Table 2). This closed area has a surface of 35 square km, of which the 100% overlaps with the EU_3FC survey domain (Table 1 and Figure 4).

The average proportion of the area 10 that is impacted annually by the EU_FC survey is 1.02E-03 (Table 5). Recurrence time is around 977 years for this closed area (Table 6 and Figure 5) and the same if we only considered the surface of the closed area that overlaps with the survey domain (Table 7 and Figure 6).

Area 14a and 14b. Eastern Flemish Cap. This area was delimited based on high density of pennatulaceans, alcyonaceans and antipatharians and, to a lesser extent, solitary scleractinians and small gorgonians. (Table 2). The closed area 14a has a surface of 50 square km and the closed area 14b has a surface of 104 square km. The surface area of both areas (14a+11b) together is 154 square km. of which the 100% overlaps with the EU_3FC survey domain (Table 1 and Figure 4).

The average proportion of the area 14a that is impacted annually by the EU_FC survey is 8.90E-04, for area 14b 8.80E-04 and for the whole area 14a+14b 8.80E-04 (Table 5). Recurrence time is around 1125 years for the 14a area, 1135 for the 14b closed area and 1132 for the whole 14a+14b closers area (Table 6 and Figure 5) and the same if we only considered the surface of the closed area that overlaps with the survey domain (Table 7 and Figure 6).

All areas closed based on high concentrations of pennatulaceans, alcyonaceans and antipatharians and, to a lesser extent, solitary scleractinians and small gorgonians are 100% within the domain of the EU_FC survey and do not overlap with the domains of the other NRA scientific surveys.

Taxa with lifespans or benthic features with ages that are less than one-tenth (order of magnitude or approximately 10-fold) of the estimated recurrence times of the benthic impacting science activity are likely to have time to recover to the levels that existed prior to the benthic impact of the sampling activity. Murillo et al. (2018), estimated ages ranging from 5 and 28 years for *A. grandiflorum* colonies outside the Gulf. Based on mean lengths in colonies in the Gulf of St. Lawrence multi-species surveys, this would correspond to colonies 15-16 and approximately 21 years old respectively. Estimated maximum ages fell within previously published ranges for pennatulids of between 15 and 50 years, though the authors cautioned that the age determination for the sea pens required additional validation. Estimated age at maturation and maximum observed age of the *Halipteris finmarchica* in the NW Atlantic at 4 and 22 years, respectively (Neves et al. 2015). Murillo et al. (2018), estimated ages ranging between 2 and 21 years for *P. aculeata*. Mean colony lengths observed in the Gulf of St. Lawrence surveys by the authors correspond to *P. aculeata* colonies younger than 9 years old. Estimated maximum ages fell within previously published ranges for pennatulids of between 15 and 50 years, though the authors cautioned that the age determination for the sea pens required additional validation. Known to be able to burrow and crawl, which may afford some protection from trawling and potential for rapid recolonization of disturbed areas.

The estimated recurrence time for the closed areas based on the large concentrations of pennatulaceans are between 977 and 1186. These recurrence times are well over ten times greater than the 50 years of maximum ages estimated for pennatulaceans and therefore could be interpreted that the pennatulaceans impacted by the survey hauls would have time to recover to the levels prior to the benthic impact of the sampling activity.

4.- Measures to mitigate harm caused by bottom-contacting scientific surveys

In cases for which the spatial distribution of the features is discrete and known, it may be desirable to exclude these locations from the sampling domain for the scientific surveys. This was one of the reasons why the EU_FC survey domain was modified in past years excluding the Beothuk Knoll strata from the survey domain due to the large presence of corals and some of the deeper southern Flemish Cap strata due to the presence of large amounts of sponges and mud that made trawl hauls impossible.

In lieu of completely excluding surveys from protected areas, a switch to alternative monitoring methods or modifications to existing survey gear or procedures may be used to mitigate impacts of bottom-contacting gear on benthic components. There are two key factors to consider in evaluating possible mitigation measures. First, alternative methods should provide the type of data presently collected by ongoing surveys that are used in the provision of scientific advice. Second, it should be possible to calibrate the methods or correct the data post hoc to ensure the existing and modified methods provide a standardized measure of the properties being monitored.

Observational survey methods based on visual observations from divers, towed cameras, or remotely operated vehicles can sample benthic and demersal macrofauna with often little impact on the bottom. Those methods provide information on benthic epifauna characterization and distribution, benthic habitat characterization, and identification of seabed type. However, available evidence and a lack of successful examples to date indicate that these methods are not effective for monitoring mobile and lower density organisms and are unlikely to be a suitable replacement for multispecies surveys currently undertaken using bottom trawls.

The development and implementation of these new methods as well as their calibration with current methods will take time and investment and until these new methods are available, the collection of the necessary data for the study of the species and ecosystems should continue with current methods.

The impact of bottom-contacting gear can be reduced by reducing the overall size of the sampling gear, reducing the physical pressure of bottom contact (i.e. reducing weight of gear components, such as the doors) (Valdemarsen et al. 2007). For scientific surveys that are part of the time series, any changes in survey gear would require calibration to ensure the temporal integrity of the time series indices. Other option to reduce the harm caused is shortening the tow durations in the case of mobile gear. Trawl surveys typically employ pre-determined minimum acceptable and target tow durations; a mitigation option in closed areas may be the use of the minimum acceptable duration for survey sets. Canadian surveys in the NRA have a fairly short haul time per set (15 min) while European surveys have a haul time per set of 30 min. and all those that the towing time is greater than 20 min. are considered valid hauls (Vazquez et al. 2014). Table 9 and Figure 8 shows the values of recurrence time estimated for the different closed areas if the haul time of the European surveys within the closed areas is reduced from 30 to 20 minutes, considering only the closed area that overlaps with the different strata. With this small change, the results show that all the closed areas have a recurrence time greater than 1500 years, which would ensure a sufficient recovery time at least for the areas closed by large concentrations of pennatulaceans and reduce the impact on the closed areas with large concentrations of corals and sponges but that would allow to continue with the collection of current information.

5.- Evaluation of the consequences of excluding survey activities from protected areas.

As the DFO protocol summarizes, regular ongoing scientific surveys provide monitoring for temporal changes in the abundance and distribution of marine taxa. In the broader ecosystem, monitoring is required to evaluate the efficacy of management measures employed to meet objectives related to the sustainable use of renewable marine resources and the recovery of depleted species and species of conservation concern. Monitoring is also crucial for evaluating ecosystem-level effects of human activities and for understanding the consequence of large-scale environmental changes such as climate change and ocean acidification.

5.1 Consequences to science and conservation within protected areas

Monitoring is required within protected areas to ensure the efficacy of the management measures with respect to their defined conservation objectives. For the NRA, existing bottom-contacting scientific surveys are the only source of data on background conditions prior to and immediately following the closure, both within the protected area and neighboring areas. While the surveys may not be suitable for monitoring many or all benthic components in a protected area, they may be used for assessing other ecological components that could benefit from the protection, such as demersal fish. Excluding surveys from protected areas can impair these benefits. The benefits of obtaining such information may render acceptable, in some circumstances, the associated harm caused by bottom-contacting scientific gear to the benthic components in the protected area.

To this it should be added that NAFO periodically reviews the closed areas and that their delimitation may vary according to the data collected in the surveys, so it would be convenient for a correct protection and delimitation that the data collected included the closed areas.

One of the main uses of this information is in stock assessment to provide scientific advice for sustainable fisheries management although the survey information is essential for other different purposes (species biology, diversity and distribution, conservation areas studies, ecosystem indicators, etc). Surveys provide indices of abundance for analytical assessments, they provide information on species diversity and species distribution, which are used in identifying conservation areas and developing ecosystem indicators and they are the sole source of information on abundance and distribution of secondary commercial species, which have no analytical assessment, and on bycatch species, which must be monitored in relation to the potential impacts of commercial fishing.

5.2 Consequences to the survey indices quality

The utility of a survey in providing a reliable index of abundance for a species or size group depends critically on the temporal stability of catchability. Modifications to survey gear, protocols or operations that cause a systematic change in catchability will result in a change in the abundance indices. It is for this reason that efforts are made to maintain consistency in survey design. A particular concern is that exclusion of the information of the closed areas could lead to time-varying biases in abundance indices. The main method for evaluating the likelihood of this outcome is via retrospective simulation, in which original abundance indices are compared to recalculated indices in which data for sampling sets with geographic coordinates occurring within the boundaries of the protected area(s) are excluded.

To simulate the potential impacts of excluding survey sampling in protected areas in the indices used in the assessment, Rideout and Ollerhead (2017) and González-Troncoso et al. (2022) examined the Canadian and European surveys indices for fish stocks located all or partially in NAFO Divisions 3LNO, using all available data from appropriate surveys but excluding data collected from sites that fall within protected areas. Potential impacts of exclusion were evaluated by comparing the two-time series, with and without exclusion, and by examining trends in the annual log of the ratio of the series with exclusions to the series without. This provides a measure of potential bias. We were particularly interested in the potential for time-varying biases as these may compromise the scientific advice produced from the surveys (Benoît et al. 2020).

Rideout and Ollerhead (2017) examined the Canadian spring and autumn surveys and concluded that in general the closed areas overlapped with these surveys are deeper than the main distribution areas for Atlantic cod, American plaice, yellowtail flounder, witch flounder, redfish, thorny skate and white hake and removing the fishing sets located in these areas had little impact on survey indices. The results for Greenland halibut and roughhead grenadier, both generally considered deepwater species, differed from one and other. Excluding survey sets from the closed areas did not influence survey indices for Greenland halibut, whereas autumn survey indices for roughhead grenadier declined slightly in some years when sets in closed areas were excluded from the analyses. Because some deep strata are located almost entirely (85% or more) within the closed areas it was also examined if the loss of these strata from the Canadian survey design would influence the size composition of Greenland halibut and roughhead grenadier. No discernable impact was observed.

González-Troncoso et al. (2022) examined the European surveys indices and th results of the analysis show that there are two species, Greenland halibut and roughhead grenadier, in which their biomass and/or age/length indices are affected in all the surveys analyzed. This is due to the fact that these two species are distributed at greater depths and that the closed areas are mainly found in deep areas, so the suppression of survey hauls in closed areas has a greater impact on the indices of these two species. There are other species in which their global biomass indices do not change very much, but their age or length indices change appreciably when hauls from closed areas are removed from the calculations

Sources of Uncertainty

The Framework cites different sources of uncertainty to be able to interpret the results. Among which are the following:

In the majority of cases, knowledge on benthic invertebrate life histories, recruitment dynamics, and colonization constraints and rates are limited, which in turn limits quantitative assessments of the recovery potential.

Recovery time may be affected by the time required for substrate to become suitable for colonization, larval dispersal, age-at-maturity, and population connectivity. The use of longevity as the default proxy for recovery potential is an estimate and it may under- or overestimate the recovery potential depending on the organism or habitat in question. Adding an order of magnitude buffer to the longevity when comparing to the recurrence time, as proposed herein, is meant to help prevent overestimation of recovery potential.

There is currently insufficient knowledge to make informed quantitative assessments of the impacts of bottom-contacting gear types on benthic species status (which could theoretically range from decline in fitness to mortality). There is also uncertainty around estimates of bottom-contacting gear impact footprints.

Biases in survey indices resulting from the exclusion of survey activities in protected areas can only be quantified retrospectively or from simulation.

Calculations of recurrence times are subject to uncertainties. Mitigation options associated with excluding specific locations in closed areas may be constrained by physical features of the habitat. In these situations, the sample location selection can be forced to a smaller survey area than the survey domain.

As new technology becomes available and new methods are developed, visual methods may become more effective for monitoring mobile, lower density organisms. In the future, data collected using visual survey methods should be compared with that collected using traditional survey methods, including side-by-side gear trials and calibrations.

CONCLUSIONS AND ADVICE

The spatial delimitation of the sponge, coral, and sea pen closed areas (VME closed areas) has been made based on identify areas with high concentrations of indicator species of Vulnerable Marine Ecosystems (VME) based on de scientific surveys data carried out in the NRA. There is not a clear objective to delimit closed areas other than to protect large concentrations of VME indicator species. This together with the revision of the delimitation of the closed areas that is carried out every 4 years makes it difficult to analyze the impact of the scientific surveys in the closed areas since these areas can change every four years without a clear objective for their delimitation as can be the Target 11 set by Convention on Biological Diversity Aichi Biodiversity. Currently, the surface of the closed protected areas within the NRA footprint represents 8% of the total footprint surface. And the total surface of the closed areas between the total surface of the footprint gives a result of 0.24

NRA VME closed areas overlap with existing annual multispecific scientific trawl surveys conducted in the NRA by Canada and European Union. There are presently no existing frameworks or approaches in NAFO to assist in determining under what conditions scientific surveys employing bottom-contacting gear can be permitted in protected areas. These regular trawl surveys contribute to the maintenance of a large diversity of scientific advice that supports, among other things, sustainable fisheries management, the assessment of stock status, the monitoring and recovery of depleted species and species at risk, the identification of conservation areas and the development of ecosystem indicators for ecosystem-approaches to management.

Impacts of survey activities with bottom-contacting gear on benthic species include both immediate mortality or harm to benthic species and long-term habitat modifications. These effects can be cumulative over time. Potential for recovery of benthic fauna following disturbance by bottom-contacting gear is determined by the characteristics of the benthic components that affect their productivity, including linked biological parameters such as longevity, age-at-maturity, growth, as well as structuring and accumulating benthic habitat features (glass sponge reefs).

In the absence of more specific or direct measures, longevity is the proposed proxy of recovery time. The proposed measure of the extent of negative impacts of scientific sampling activities on the valued benthic components is the relative magnitude of the recurrence time interval of the activity compared to the recovery time of the benthic components. Taxa with lifespans or benthic features with ages that are less than one-tenth (order of magnitude or approximately 10-fold) of the estimated recurrence times of the benthic impacting science activity are likely to have time to recover to the levels that existed prior to the benthic impact of the sampling activity.

The current recurrence time results of the surveys carried out in the NRA show that the benthic impact of the surveys activity are likely to have time to recover to the levels that existed prior to the benthic impact of the sampling activity at least for the closed areas delimited based on high density of pennatulaceans (Closed areas 7, 8, 9, 10, 11, 12, and 14). For the closed areas delimited based on large gorgonians high density and large survey catches of sponges (Closed Areas 1, 2, 3, 4, 5, 6 and 13) the conclusions are not so clear due to the lack of information about the longevity of some of the coral and sponges species.

Reducing the trawling time in European surveys from 30 to 20 minutes for the sets that are made within the closed areas would considerably reduce the benthic impact ensuring a sufficient recurrence time for closed areas based on pennatulaceans and extending the recurrence time to more than 1500 years for all closed areas based on high concentrations of large gorgonians and sponges.

The study of the impact of excluding the scientific surveys in the closed areas on the abundance indices of different stocks shows that there are no major problems and that their quality is very similar with and without the data of the sets carried out in the closed areas for most stocks series. Only the indices for two stocks, Greenland halibut Subarea 2 and Division 3LMNO and roughhead grenadier Subarea 2 and 3, show a loss of quality when information on sets made within closed areas is omitted.

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References

Andrews, Allen & Cordes, Erik & Mahoney, Melissa & Munk, Kristen & Coale, Kenneth & Cailliet, Gregor & Heifetz, Jonathan. (2002). Age, growth and radiometric age validation of a deep-sea, habitat-forming gorgonian (Primnoa resedaeformis) from the Gulf of Alaska. Hydrobiologia. 471. 101-110. 10.1023/A:1016501320206.

Benoît, H.P., Asselin, N.C., Surette, T., and Juillet, C. 2020. An assessment to support decisions on authorizing scientific surveys with bottom-contacting gears in protected areas in the Estuary and Gulf of St. Lawrence. DFO Can. Sci. Advis. Sec. Res. Doc. 2020/007. Xi + 80 p.

Benoît, H.P., Dunham, A., Macnab, P., Rideout, R., Wareham, V., Clark, D., Duprey, N., Maldemay, É.-P., Richard, M., Clark, C., and Wilson, B. 2020. Elements of a framework to support decisions on authorizing scientific surveys with bottom contacting gears in protected areas with defined benthic conservation objectives. DFO Can. Sci. Advis. Sec. Res. Doc. 2020/011. ix + 98 p.

Conway, K.W. 1999. Hexactinellid sponge reefs on the British Columbia continental shelf: geological and biological structure with a perspective on their role in the shelf ecosystem. DFO Can. Stock Assess. Sec. Res. Doc. 99/192.

DFO. 2018. Framework to support decisions on authorizing scientific surveys with bottom contacting gears in protected areas with defined benthic conservation objectives. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2018/043.

Doubleday, W.G. 1981. Manual on groundfish surveys in the Northwest Atlantic. NAFO Sci.Coun.Studies, 2, 55.

González Troncoso, D., X. Paz and C. González, 2004. Atlantic cod population indices obtained from the Spring surveys conducted by Spain in the NAFO Regulatory Area of Divisions 3NO, 1995-2003. NAFO SCR Doc. 04/12, Serial No. N4957, 21 pp.

Kerr, L.A., Kritzer, J.P., and Cadrin, S.X. 2019. Strengths and limitations of before-after-control-impact analysis for testing the effects of marine protected areas on managed populations ICES J. Mar. Sci. 76: 1039-1051.

Malecha, P., and Heifetz, J. 2017. Long-term effects of bottom trawling on large sponges in the Gulf of Alaska. Cont. Shelf Res. 150: 18-26.

Mortensen, P.B., Buhl-Mortensen, L. Morphology and growth of the deep-water gorgonians Primnoa resedaeformis and Paragorgia arborea. Marine Biology 147, 775–788 (2005).

Murillo, F.J., MacDonald, B.W., Kenchington, E., Campana, S.E., Sainte-Marie, B., and Sacau, M. 2018. Morphometry and growth of sea pen species from dense habitats in the Gulf of St. Lawrence, eastern Canada. Mar. Biol. Res. 14: 366-382.

NAFO. 2008. Report of the NAFO SC Working Group on Ecosystem Approach to Fisheries Management (WGEAFM) Response to Fisheries Commission Request 9.a Serial No. N5592 NAFO SCS Doc. 08/24.

NAFO. 2009. Report of the Working Group on the Ecosystem Approach to Fisheries Management (WGEAFM). Serial No. N5627 NAFO SCS Doc. 09/6.

NAFO. 2010. Northwest Atlantic Fisheries Organization Conservation and Enforcement Measures. Serial No. N5740 NAFO/FC Doc. 10/1.

NAFO. 2013. Report of the 6th Meeting of the NAFO Scientific Council Working Group on Ecosystem Science and Assessment (WGESA) [Formerly SC WGEAFM]. NAFO SCS Doc. 13/024, Serial No. N6277, 209 pp.

NAFO. 2015. Northwest Atlantic Fisheries Organization Conservation and Enforcement Measures. Serial No. N6409 NAFO/FC Doc. 15/01.

NAFO. 2017. Report of the Scientific Council Meeting, 01 -15 June 2017, Halifax, Nova Scotia. Serial No. N6718 NAFO SCS Doc. 17-16 REV.

NAFO. 2019. Report of the 12th Meeting of the NAFO Scientific Council Working Group on Ecosystem Science and Assessment (WG-ESA). Serial No N7027 NAFO SCS Doc. 19/25

NAFO. 2022. Northwest Atlantic Fisheries Organization Conservation and Enforcement Measures. 2022. Serial No. N7254 NAFO/COM Doc. 22-01.

Neves, B.R.D.M., Edinger, E., Layne, G.D., and Wareham, V.E. 2015. Decadal longevity and slow growth rates in the deep-water sea pen Halipteris finmarchica (Sars, 1851) (Octocorallia: Pennatulacea): implications for vulnerability and recovery from anthropogenic disturbance. Hydrobiologia 759: 147-170.

Rideout, R.M and N. Ollerhead. 2017. Examining the impact that excluding RV surveys from coral and sponge protection areas in Divisions 3LNO would have on Canadian RV survey trends for NAFO-managed fish stocks. Serial No. N6679 NAFO SCR Doc. No. 17-027REV.

Rideout, R.M. and Ings, D.W. 2020. Temporal And Spatial Coverage Of Canadian (Newfoundland And Labrador Region) Spring And Autumn Multi-Species RV Bottom Trawl Surveys, With An Emphasis On Surveys Conducted In 2019. Serial No. N7041 NAFO SCR Doc. 20/002.

Valdemarsen, J.W., Jergensen, T., and Engas, A. 2007. Options to mitigate bottom habitat impact of dragged gears. FAO Fisheries Technical Paper. No. 506. Rome, FAO. 29.

Vázquez, A., J. Miguel Casas, R. Alpoim. 2014. Protocols of the EU bottom trawl survey of Flemish Cap. Scientific Council Studies, 46: 1–42. doi:10.2960/S.v46.m1

Walsh, J.S., X. Paz and P. Durán. 2001. A preliminary investigation of the efficiency of Canadian and Spanish Survey bottom trawls on the Southern Bank. NAFO SCR Doc., 01/74, Serial No. N4453, 18 pp.

Table 1. NAFO Regulatory Area bottom fishing sponge, coral, and sea pen closed areas. CEM Number, CEM Description and Conservation Target are the information of the NAFO CEM (NAFO, 2022). The table include the the percentage of the total close area surface overlap with the survey domain (EU_FC = EU Flemish Cap Survey, EU_3LNO = EU Spain 3LNO survey, Can_Spring = Canadian Spring Survey and Cam_Fall = Canadian Autumn survey).

		% Overlap of the close area with the survey domain				
CEM Number	**CEM Description**	**EU_FC**	**EU_3LNO**	**Can_ Spring**	**Can_Fall**	**All NRA**
1	Tail of the Bank		32%			32%
2	Flemish Pass/Eastern Canyon		78%	8%	49%	78%
3	Beothuk Knoll	13%				13%
4	Eastern Flemish Cap	81%				81%
5	Northeast Flemish Cap	45%				45%
6	Sackville Spur	44%	3%		3%	47%
7	Northern Flemish Cap	100%				100%
8	Northern Flemish Cap	100%				100%
9	Northern Flemish Cap	100%				100%
10	Northwest Flemish Cap	100%				100%
11	Northwest Flemish Cap	100%				100%
12	Northwest Flemish Cap	100%				100%
13	Beothuk Knoll	100%				100%
15	3O Coral Closure		2%			2%
7a	Northern Flemish Cap	100%				100%
11a	Northwest Flemish Cap	100%				100%
14a	Eastern Flemish Cap	100%				100%
14b	Eastern Flemish Cap	100%				100%

Table 2. NAFO Regulatory Area bottom fishing sponge, coral, and sea pen closed areas. Figure Number is the number of the each closed area in Figure 1. CEM Number, CEM Description and Conservation Target are the information of the NAFO CEM (NAFO, 2022). The table also include the total close area surface (km2), the conservation target and the restrictions of each closed areas.

Figure Number	CEM Number	CEM Description	Div	Area (km2)	Conservation Target	Prohibitions and restrictions
1	1	Tail of the Bank	3N	172	Sponge	bottom contacting gear
2	2	Flemish Pass/Eastern Canyon	3LN	5775	Sponge, Sea Pens, Large Gorgonians	bottom contacting gear
3	3	Beothuk Knoll	3M	308	Sponge	bottom contacting gear
4	4	Eastern Flemish Cap	3M	1358	Sponge, Large Gorgonians	bottom contacting gear
5	5	Northeast Flemish Cap	3M	2879	Sponge, Large Gorgonians	bottom contacting gear
6	6	Sackville Spur	3M	987	Sponge	bottom contacting gear
7	7	Northern Flemish Cap	3M	258	Sea Pens	bottom contacting gear
8	8	Northern Flemish Cap	3M	155	Sea Pens	bottom contacting gear
9	9	Northern Flemish Cap	3M	320	Sea Pens	bottom contacting gear
10	10	Northwest Flemish Cap	3M	527	Sea Pens	bottom contacting gear
11	11	Northwest Flemish Cap	3M	61	Sea Pens	bottom contacting gear
12	12	Northwest Flemish Cap	3M	35	Sea Pens	bottom contacting gear
13	13	Beothuk Knoll	3M	338	Large Gorgonians	bottom contacting gear
15	15	3O Coral Closure	3O	14236	No data	bottom contacting gear
16	7a	Northern Flemish Cap	3M	795	Sea Pens	bottom contacting gear
17	11a	Northwest Flemish Cap	3M	159	Sea Pens	bottom contacting gear
18	14a	Eastern Flemish Cap	3M	50	Sea Pens	bottom contacting gear
19	14b	Eastern Flemish Cap	3M	104	Sea Pens	bottom contacting gear

Table 3. NAFO Regulatory Area 3LMNO annual bottom trawl surveys. The Canadian surveys cover the NAFO Convention Area while the EU and Spanish surveys only cover the NRA of Divisions 3LNO.

Survey	Division	Objetives	First year	Gear	Freq	Hauls	Survey Study area (km2)	Haul swept area (km2)	Survey swept area (km2)
EU_FC	3M	Multi-species	1988	OTB (Lofoten)	Y	180	41621	0.28	50.4
EU_3NO	NRA 3NO	Multi-species	1995	OTB (Campelen)	Y	115	26784	0.14	16.1
EU_3L	NRA 3L	Multi-species	2003	OTB (Campelen)	Y	100	16801	0.14	14.0
Can_Fall	2HJ3KLNO	Multi-species	1978	OTB (Campelen)	Y	674	515000	0.07	46.1
Can_Spring	3LNOPs	Multi-species	1978	OTB (Campelen)	Y	478	324000	0.07	32.7

Table 4. NAFO Regulatory Area 3LMNO stratification with NAFO Division, area (km^2), area of the protected area overlapped with the strata (km^2) and the planned annual hauls of the different surveys in each stratum.

Strata	Div.	Area_Strata_km2	CloseArea_km2	Hauls FC	Hauls S_3LNO	Hauls C_Spring	Hauls C_Fall
385	3L	450	0	0	2	8	8
386	3L	7	0	0	0	3	3
387	3L	705	0	0	4	2	2
388	3L	1194	0	0	5	2	2
389	3L	1988	0	0	7	3	3
390	3L	2986	0	0	12	5	5
391	3L	1012	0	0	4	2	2
392	3L	534	0	0	2	2	2
729	3L	628	15	0	3	2	2
730	3L	618	429	0	2.75	2	2
731	3L	748	0	0	3	2	2
732	3L	757	0	0	4	2	2
733	3L	841	0	0	4	2	2
734	3L	516	0	0	2	2	2
741	3L	468	0	0	2	0	2
742	3L	274	0	0	2	0	2
743	3L	233	1	0	2	0	2
744	3L	344	29	0	2	0	2
745	3L	1234	0	0	5	0	2
746	3L	1336	0	0	6	0	2
747	3L	2479	347	0	10	0	2
748	3L	636	499	0	2	0	2
749	3L	483	326	0	2	0	2
750	3L	1944	921	0	8	0	2
751	3L	779	284	0	3	0	2
357	3N	570	0	0	2	2	2
358	3N	771	0	0	3	2	2
359	3N	1686	0	0	5	2	2
360	3N	9004	0	0	17	10	8
361	3N	16	0	0	0	6	5
374	3N	668	0	0	2	3	3
375	3N	979	0	0	3	5	4
376	3N	4429	0	0	8	5	4
377	3N	343	0	0	2	2	2
378	3N	373	0	0	2	2	2
379	3N	399	0	0	2	2	2
380	3N	370	0	0	2	2	2
381	3N	505	0	0	2	2	2
382	3N	1349	0	0	4	2	2

723	3N	446	0	0	2	2	2
724	3N	507	0	0	2	2	2
725	3N	394	0	0	2	2	2
726	3N	312	0	0	2	2	2
727	3N	462	0	0	2	2	2
728	3N	533	0	0	2	2	2
752	3N	393	0	0	2	0	0
753	3N	471	36	0	2	0	0
754	3N	677	395	0	2	0	0
755	3N	1301	1159	0	3	0	0
756	3N	321	0	0	2	0	0
757	3N	287	0	0	2	0	0
758	3N	389	14	0	2	0	0
759	3N	457	161	0	2	0	0
760	3N	465	0	0	2	0	0
761	3N	639	0	0	2	0	0
762	3N	772	0	0	2	0	0
763	3N	965	0	0	3	0	0
353	3O	920	0	0	3	4	4
354	3O	823	0	0	3	2	2
355	3O	253	0	0	2	2	2
356	3O	166	0	0	2	2	2
721	3O	255	0	0	2	2	2
722	3O	340	0	0	2	2	2
764	3O	357	0	0	2	0	0
765	3O	455	8	0	2	0	0
766	3O	529	21	0	2	0	0
767	3O	567	246	0	2	0	0
769	3O	4	4	0	0	0	0
770	3O	8	8	0	0	0	0
771	3O	88	88	0	0	0	0
501	3M	1175	0	4	0	0	0
502	3M	2913	0	10	0	0	0
503	3M	2206	0	7	0	0	0
504	3M	1162	0	4	0	0	0
505	3M	2367	0	8	0	0	0
506	3M	1748	0	6	0	0	0
507	3M	2916	0	9	0	0	0
508	3M	2182	0	7	0	0	0
509	3M	1218	0	3	0	0	0
510	3M	3298	0	11	0	0	0
511	3M	2825	0	9	0	0	0
512	3M	2350	0	8	0	0	0

513	3M	816	0	3	0	0	0
514	3M	2091	32	7	0	0	0
515	3M	2424	0	8	0	0	0
516	3M	2196	512	7	0	0	0
517	3M	741	69	2	0	0	0
518	3M	774	248	2	0	0	0
519	3M	1399	263	5	0	0	0
520	3M	1789	434	6	0	0	0
521	3M	1677	294	6	0	0	0
522	3M	1801	637	6	0	0	0
523	3M	1090	425	3	0	0	0
524	3M	838	260	3	0	0	0
525	3M	804	383	3	0	0	0
526	3M	614	221	0	0	0	0
527	3M	681	194	0	0	0	0
528	3M	1813	44	6	0	0	0
529	3M	1651	682	6	0	0	0
530	3M	3753	565	11	0	0	0
531	3M	714	355	2	0	0	0
532	3M	777	0	2	0	0	0
533	3M	371	7	2	0	0	0
534	3M	1776	42	5	0	0	0
535	3M	346	55	0	0	0	0
536	3M	429	85	0	0	0	0
537	3M	362	0	0	0	0	0
538	3M	665	0	0	0	0	0
539	3M	459	3	0	0	0	0

Table 5. Average proportion per year of the bottom of the different protected area which would be impacted by the bottom-contacting gear for each of the surveys and for all surveys.

CEM Number	CEM Description	Area (km2)	Conservation Target	ProImpArea FC	ProImpArea 3LNO	ProImpArea Spring	ProImpArea Fall	ProImpArea All
1	Tail of the Bank	172	Sponge	0.00000	0.00020	0.00000	0.00000	0.00020
2	Flemish Pass/Eastern Canyon	5775	Sponge, Sea Pens, Large Gorgonians	0.00000	0.00038	0.00002	0.00008	0.00048
3	Beothuk Knoll	308	Sponge	0.00010	0.00000	0.00000	0.00000	0.00010
4	Eastern Flemish Cap	1358	Sponge, Large Gorgonians	0.00050	0.00000	0.00000	0.00000	0.00050
5	Northeast Flemish Cap	2879	Sponge, Large Gorgonians	0.00040	0.00000	0.00000	0.00000	0.00040
6	Sackville Spur	987	Sponge	0.00035	0.00002	0.00000	0.00001	0.00038
7	Northern Flemish Cap	258	Sea Pens	0.00097	0.00000	0.00000	0.00000	0.00097
8	Northern Flemish Cap	155	Sea Pens	0.00101	0.00000	0.00000	0.00000	0.00101
9	Northern Flemish Cap	320	Sea Pens	0.00101	0.00000	0.00000	0.00000	0.00101
10	Northwest Flemish Cap	527	Sea Pens	0.00084	0.00000	0.00000	0.00000	0.00084
11	Northwest Flemish Cap	61	Sea Pens	0.00097	0.00000	0.00000	0.00000	0.00097
12	Northwest Flemish Cap	35	Sea Pens	0.00102	0.00000	0.00000	0.00000	0.00102
13	Beothuk Knoll	338	Large Gorgonians	0.00080	0.00000	0.00000	0.00000	0.00080
15*	3O Coral Closure_NRA	3709	No data	0.00000	0.00004	0.00000	0.00000	0.00004
7a	Northern Flemish Cap	795	Sea Pens	0.00093	0.00000	0.00000	0.00000	0.00093
11a	Northwest Flemish Cap	159	Sea Pens	0.00100	0.00000	0.00000	0.00000	0.00100
14a	Eastern Flemish Cap	50	Sea Pens	0.00089	0.00000	0.00000	0.00000	0.00089
14b	Eastern Flemish Cap	104	Sea Pens	0.00088	0.00000	0.00000	0.00000	0.00088
7+7a	Northern Flemish Cap	1053	Sea Pens	0.00094	0.00000	0.00000	0.00000	0.00094
11+11a	Northwest Flemish Cap	220	Sea Pens	0.00099	0.00000	0.00000	0.00000	0.00099
14a+14b	Eastern Flemish Cap	154	Sea Pens	0.00088	0.00000	0.00000	0.00000	0.00088

* closed area 15 surface used in the estimation is only the NRA closed area surface and not the total closed area 15 surface.

Table 6. Recurrence time interval (R; in years) for the different protected areas for each of the surveys and for all surveys estimated with the whole closed area surface (equation 2). It should be noted that the surface of the closed area 15 used in the estimation is the total closed area and not the NRA part which is much smaller.

CEM Number	CEM Description	Area (km2)	Conservation Target	RecTime FC	RecTime 3LNO	RecTime Spring	RecTime Fall	RecTime All
1	Tail of the Bank	172	Sponge	NA	4905	NA	NA	4905
2	Flemish Pass/Eastern Canyon	5775	Sponge, Sea Pens, Large Gorgonians	2441721	2627	57427	13069	2105
3	Beothuk Knoll	308	Sponge	10015	NA	NA	NA	10015
4	Eastern Flemish Cap	1358	Sponge, Large Gorgonians	2000	NA	NA	NA	2000
5	Northeast Flemish Cap	2879	Sponge, Large Gorgonians	2485	NA	NA	NA	2485
6	Sackville Spur	987	Sponge	2897	40115	NA	80230	2614
7	Northern Flemish Cap	258	Sea Pens	1033	NA	NA	NA	1033
8	Northern Flemish Cap	155	Sea Pens	997	NA	NA	NA	997
9	Northern Flemish Cap	320	Sea Pens	998	NA	NA	NA	998
10	Northwest Flemish Cap	527	Sea Pens	1184	NA	NA	NA	1184
11	Northwest Flemish Cap	61	Sea Pens	1012	NA	NA	NA	1012
12	Northwest Flemish Cap	35	Sea Pens	982	NA	NA	NA	982
13	Beothuk Knoll	338	Large Gorgonians	1247	NA	NA	NA	1247
15*	3O Coral Closure	3709	No data	NA	26915	NA	NA	26915
7a	Northern Flemish Cap	795	Sea Pens	1076	NA	NA	NA	1076
11a	Northwest Flemish Cap	159	Sea Pens	989	NA	NA	NA	989
14a	Eastern Flemish Cap	50	Sea Pens	1120	NA	NA	NA	1120
14b	Eastern Flemish Cap	104	Sea Pens	1121	NA	NA	NA	1121
7+7a	Northern Flemish Cap	1053	Sea Pens	1065	NA	NA	NA	1065
11+11a	Northwest Flemish Cap	220	Sea Pens	996	NA	NA	NA	996
14a+14b	Eastern Flemish Cap	154	Sea Pens	1121	NA	NA	NA	1121

* closed area 15 surface used in the estimation is only the NRA closed area surface and not the total closed area 15 surface.

Table 7. Recurrence time interval (R; in years) for the different protected areas for each of the surveys and for all surveys estimated with the overlap closed area surface (equation 3).

CEM Number	CEM Description	Area (km2)	Conservation Target	RecTime FC	RecTime 3LNO	RecTime Spring	RecTime Fall	RecTime All
1	Tail of the Bank	172	Sponge	NA	1579	NA	NA	1579
2	Flemish Pass/Eastern Canyon	5775	Sponge, Sea Pens, Large Gorgonians	1269	2061	4411	6383	1652
3	Beothuk Knoll	308	Sponge	1269	NA	NA	NA	1269
4	Eastern Flemish Cap	1358	Sponge, Large Gorgonians	1001	NA	NA	NA	1001
5	Northeast Flemish Cap	2879	Sponge, Large Gorgonians	1119	NA	NA	NA	1119
6	Sackville Spur	987	Sponge	1264	1212	NA	2423	1219
7	Northern Flemish Cap	258	Sea Pens	1033	NA	NA	NA	1033
8	Northern Flemish Cap	155	Sea Pens	997	NA	NA	NA	997
9	Northern Flemish Cap	320	Sea Pens	998	NA	NA	NA	998
10	Northwest Flemish Cap	527	Sea Pens	1184	NA	NA	NA	1184
11	Northwest Flemish Cap	61	Sea Pens	1012	NA	NA	NA	1012
12	Northwest Flemish Cap	35	Sea Pens	982	NA	NA	NA	982
13	Beothuk Knoll	338	Large Gorgonians	1247	NA	NA	NA	1247
15	3O Coral Closure	14236	No data	NA	1998	NA	NA	1998
7a	Northern Flemish Cap	795	Sea Pens	1076	NA	NA	NA	1076
11a	Northwest Flemish Cap	159	Sea Pens	989	NA	NA	NA	989
14a	Eastern Flemish Cap	50	Sea Pens	1120	NA	NA	NA	1120
14b	Eastern Flemish Cap	104	Sea Pens	1121	NA	NA	NA	1121
7+7a	Northern Flemish Cap	1053	Sea Pens	1065	NA	NA	NA	1065
11+11a	Northwest Flemish Cap	220	Sea Pens	996	NA	NA	NA	996
14a+14b	Eastern Flemish Cap	154	Sea Pens	1121	NA	NA	NA	1121

Table 8. Sponge, coral, and sea pen VME indicators of interest and their characteristics that help define their resilience to perturbation produced by the scientific surveys carried out in the NRA.

	Closed Area	Taxon	Characteristics
Sea Pens	6, 7, 8, 9, 10, 11, 12, 16, 17, 18 and 19	Anthoptilum spp.	Murillo et al. (2018), estimated ages ranging from 5 and 28 years for A. grandiflorum colonies outside the Gulf. Based on mean lengths in colonies in the sGSL and nGSL multi-species surveys, this would correspond to colonies 15-16 and approximately 21 years old respectively. Estimated maximum ages fell within previously published ranges for pennatulids of between 15 and 50 years, though the authors cautioned that the age determination for the sea pens required additional validation.
		Halipteris finmarchica	Estimated age at maturation and maximum observed age in the NW Atlantic at 4 and 22 years, respectively (Neves et al. 2015)
		Pennatula aculeata	Murillo et al. (2018), estimated ages ranging between 2 and 21 years for P. aculeata. Mean colony lengths observed in the sGSL surveys by the authors correspond to P. aculeata colonies younger than 9 years old. Estimated maximum ages fell within previously published ranges for pennatulids of between 15 and 50 years, though the authors cautioned that the age determination for the sea pens required additional validation. Known to be able to burrow and crawl, which may afford some protection from trawling and potential for rapid recolonization of disturbed areas.
		Pennatula grandis	Not known. However, the published range of maximum ages for pennatulids is between 15 and 50 years (Murillo et al. 2018)
		Distichoptilum gracile	
		Funiculina quadrangularis	
		Halipteridae	
		Kophobelemnon stelliferum	
		Umbellula spp.	
Large gorgonians	2, 4, 5 and 13	Acanthogorgia sp.	
		Acanthogorgiidae	
		Paragorgia arborea	Mortensen and Mortensen (2005) studied the morphology and growth of the gorgonian corals Paragorgia arborea and Primnoa resedaeformis from different locations in Atlantic Canada. The limited previously reported data on age and growth of P. arborea indicate an average growth rate of 1 cm year-1. This gives an age of about 180 years for the largest colony in this study.The time-series photographs, however, indicated a much higher growth rate (varying between 2 and 6 cm year-1 within the colony), which may be more representative for colonies of an intermediate size.
		Paragorgia spp.	
		Paramuricea placomus	
		Paramuricea spp.	
		Primnoa resedaeformis	Mortensen and Mortensen (2005) studied the morphology and growth of the gorgonian corals Paragorgia arborea and Primnoa resedaeformis from different locations in Atlantic Canada. The oldest P. resedaeformis colony was 61 years. Andrews et al. (2002) founded that for this species the age estimates were over 100 yr for sections near the heavily calcified base. These growth rates suggest that the fishery habitat created by red tree coral is extremely vulnerable to bottom fishing activities and may take over 100 years to recover.
Sponges	1, 2, 3, 4, 5 and 6	Multiple species	There are not many studies of sponge growth in the area. Measures of resiliency of the sponge speciesrequire further investigation.
		Asconema spp.	Glass sponge (Class Hexactinellida) which grows as a complex bouquet of tubes. Measures of resiliency of this species requires further investigation.
		Mycale	Results from a single pass trawling experiment in the Gulf of Alaska suggest a reduction of 15% in the density of Mycale loveni sponge and incremental damage rate of around 32% of individuals that persisted at least 13 years post-trawling (Malecha and Heifetz 2017). However it is important to note that growth forms of M. loveni are different from those of Mycale species in the Gulf and the results of this study may not accurately reflect recovery potential here (Benoit et al. 2020).
		Astrophorida	
		Axinellidae	
		Cladorhiza abyssicola	
		Craniella spp.	
		Euplectillidae	
		Geodidae	
		Isodictya palmata	
		Phakellia sp.	
		Polymastidae	
		Radiella hemisphaerica	
		Rhizaxinella spp.	
		Stryphnus sp	
		Stylocordyla spp.	
		Tentorium spp	
		Tetillidae	
		Thenea spp.	

Table 9. Recurrence time interval (R; in years) for the different protected areas for each of the surveys and for all surveys estimated with the overlap closed area surface (equation 3) and 20 minutes haul trawl time for the European surveys.

CEM Number	CEM Description	Area (km2)	Conservation Target	RecTime FC	RecTime 3LNO	RecTime Spring	RecTime Fall	RecTime All
1	Tail of the Bank	172	Sponge	NA	2393	NA	NA	2393
2	Flemish Pass/Eastern Canyon	5775	Sponge, Sea Pens, Large Gorgonians	1922	3122	4411	6383	2272
3	Beothuk Knoll	308	Sponge	1922	NA	NA	NA	1922
4	Eastern Flemish Cap	1358	Sponge, Large Gorgonians	1517	NA	NA	NA	1517
5	Northeast Flemish Cap	2879	Sponge, Large Gorgonians	1696	NA	NA	NA	1696
6	Sackville Spur	987	Sponge	1915	1836	NA	2423	1817
7	Northern Flemish Cap	258	Sea Pens	1566	NA	NA	NA	1566
8	Northern Flemish Cap	155	Sea Pens	1511	NA	NA	NA	1511
9	Northern Flemish Cap	320	Sea Pens	1512	NA	NA	NA	1512
10	Northwest Flemish Cap	527	Sea Pens	1793	NA	NA	NA	1793
11	Northwest Flemish Cap	61	Sea Pens	1533	NA	NA	NA	1533
12	Northwest Flemish Cap	35	Sea Pens	1489	NA	NA	NA	1489
13	Beothuk Knoll	338	Large Gorgonians	1889	NA	NA	NA	1889
15	3O Coral Closure	14236	No data	NA	3027	NA	NA	3027
7a	Northern Flemish Cap	795	Sea Pens	1631	NA	NA	NA	1631
11a	Northwest Flemish Cap	159	Sea Pens	1499	NA	NA	NA	1499
14a	Eastern Flemish Cap	50	Sea Pens	1697	NA	NA	NA	1697
14b	Eastern Flemish Cap	104	Sea Pens	1698	NA	NA	NA	1698
7+7a	Northern Flemish Cap	1053	Sea Pens	1614	NA	NA	NA	1614
11+11a	Northwest Flemish Cap	220	Sea Pens	1508	NA	NA	NA	1508
14a+14b	Eastern Flemish Cap	154	Sea Pens	1698	NA	NA	NA	1698

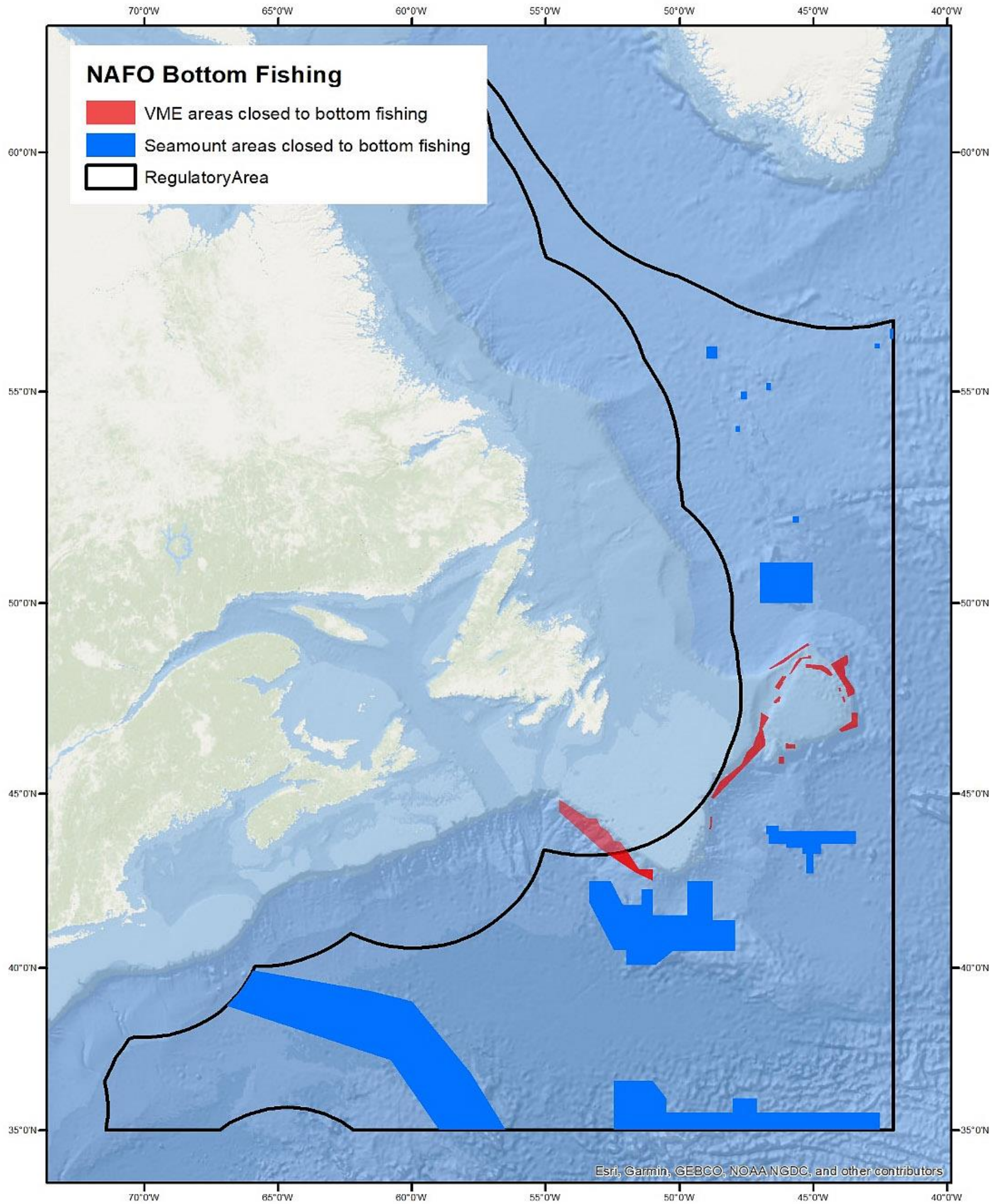

Figure 1. NAFO Convention closed areas to bottom fishing activities. In red areas represent the sponge, coral, and seapen (VME) closures. In blue the seamount closures. Map extracted from https://www.nafo.int/Fisheries/VME.

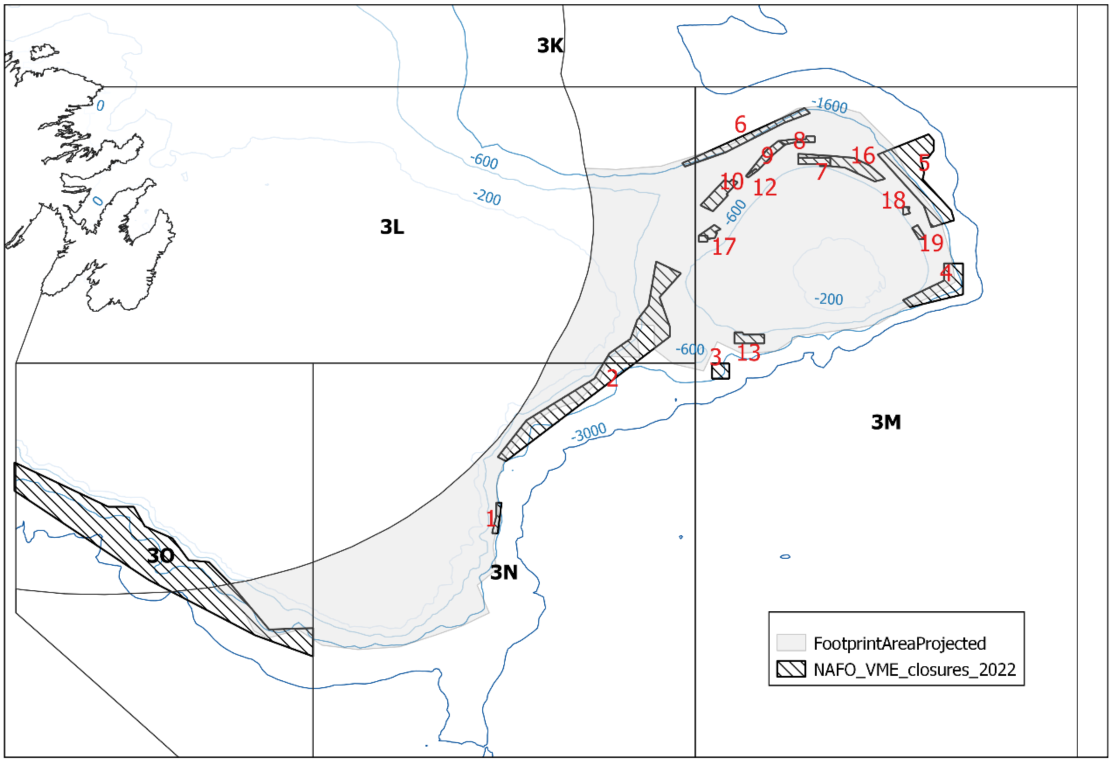

Figure 2. NAFO Regulatory Area fishery footprint (shaded area) and bottom fishing sponge, coral, and sea pen closed areas. In red the number assigned to each of the closed areas.

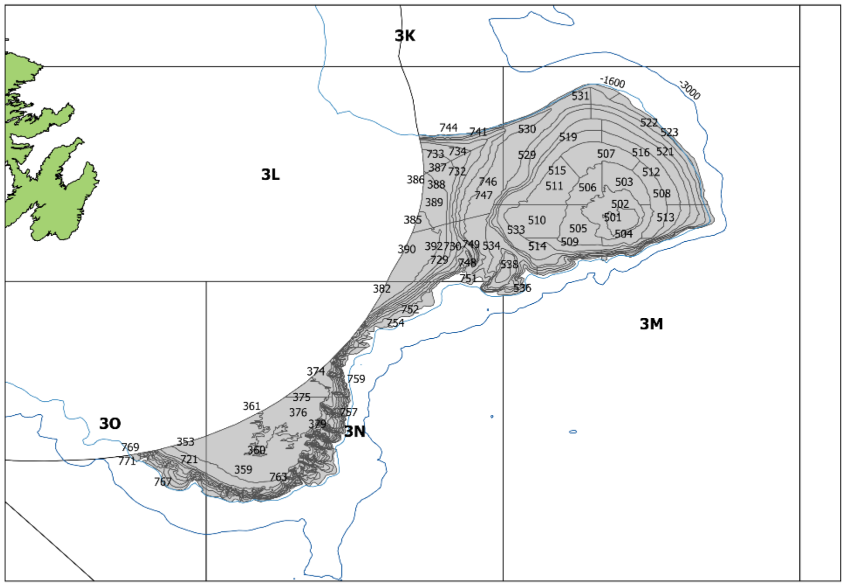

Figure 3. NAFO 3LMNO Regulatory Area surveys strata.

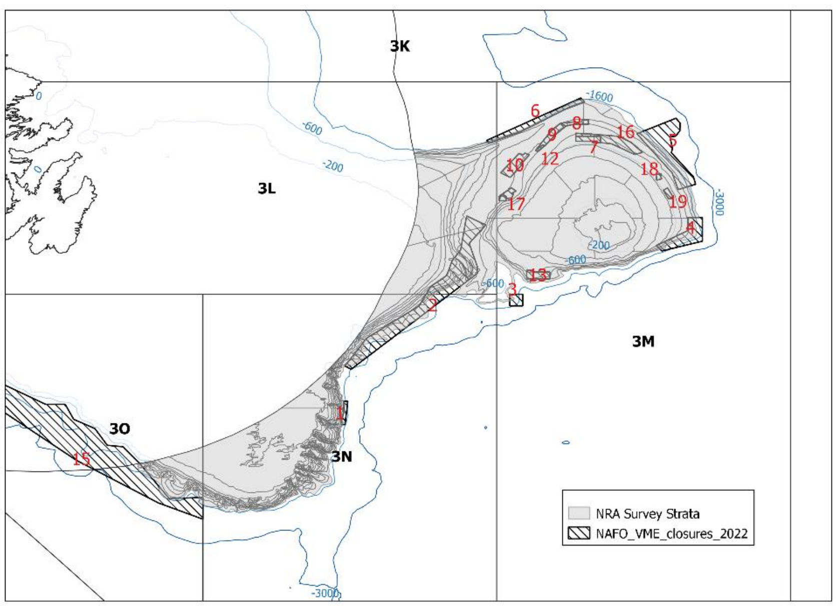

Figure 4. NAFO 3LMNO Regulatory Area surveys strata and bottom fishing sponge, coral, and sea pen closed areas. In red the number assigned to each of the closed areas.

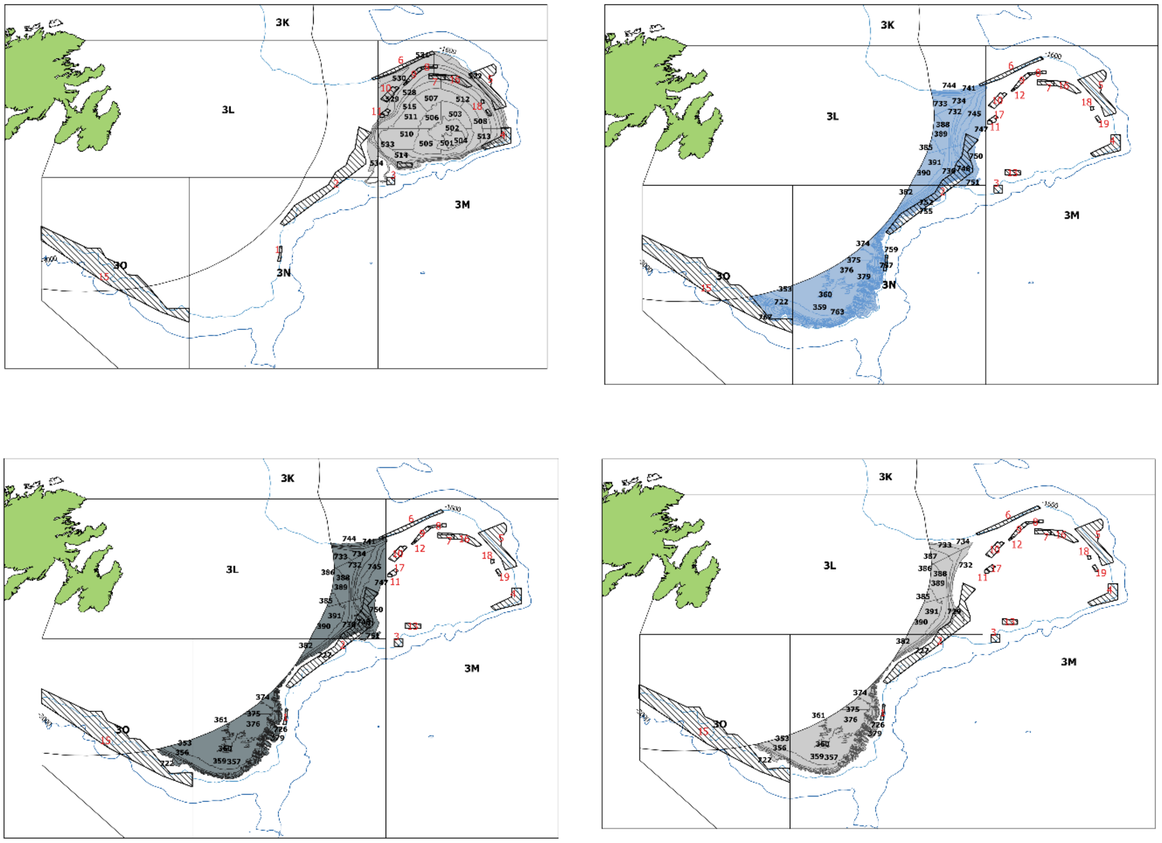

Figure 5. NAFO 3LMNO Regulatory Area surveys strata domain (shading) and bottom fishing sponge, coral, and sea pen closed areas. In red the number assigned to each of the closed areas. EU_FC survey domain upper left figure, EU_3LNO upper right figure, Can_Fall bottom left figure and Can_Spring bottom right figure.

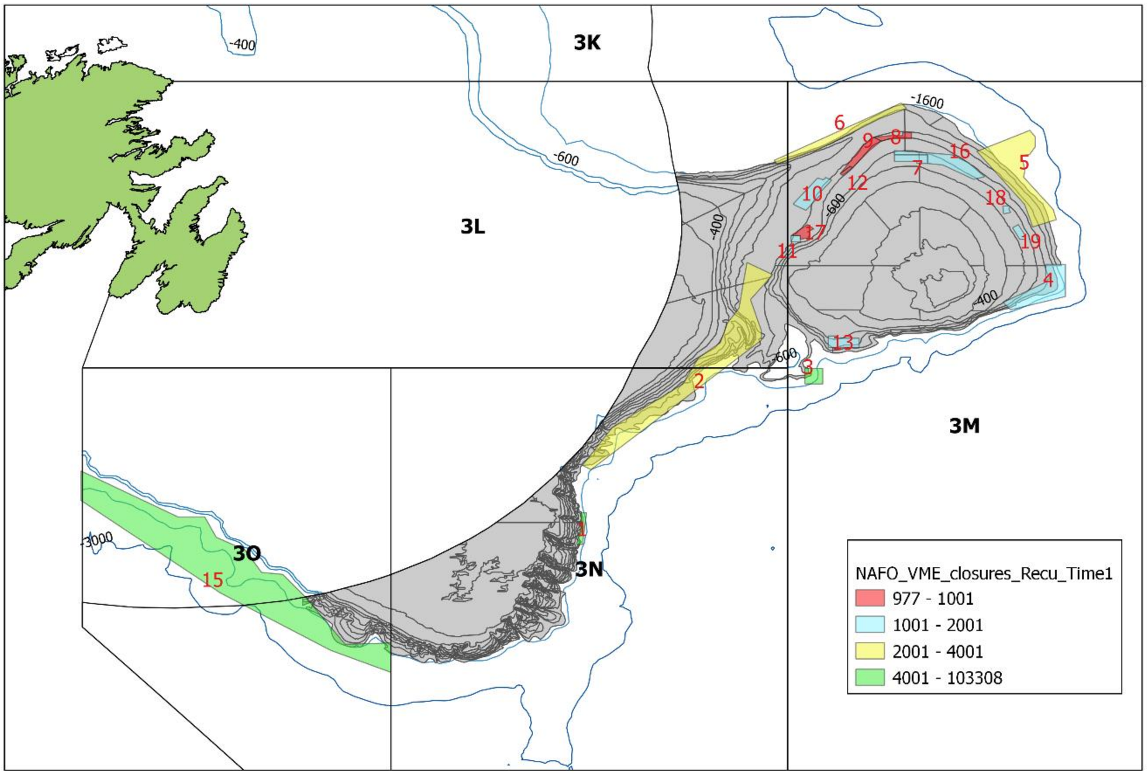

Figure 6. NRA closed areas recurrence time interval (years) estimated with all surveys and with the total surface of the closed areas (equation 2).

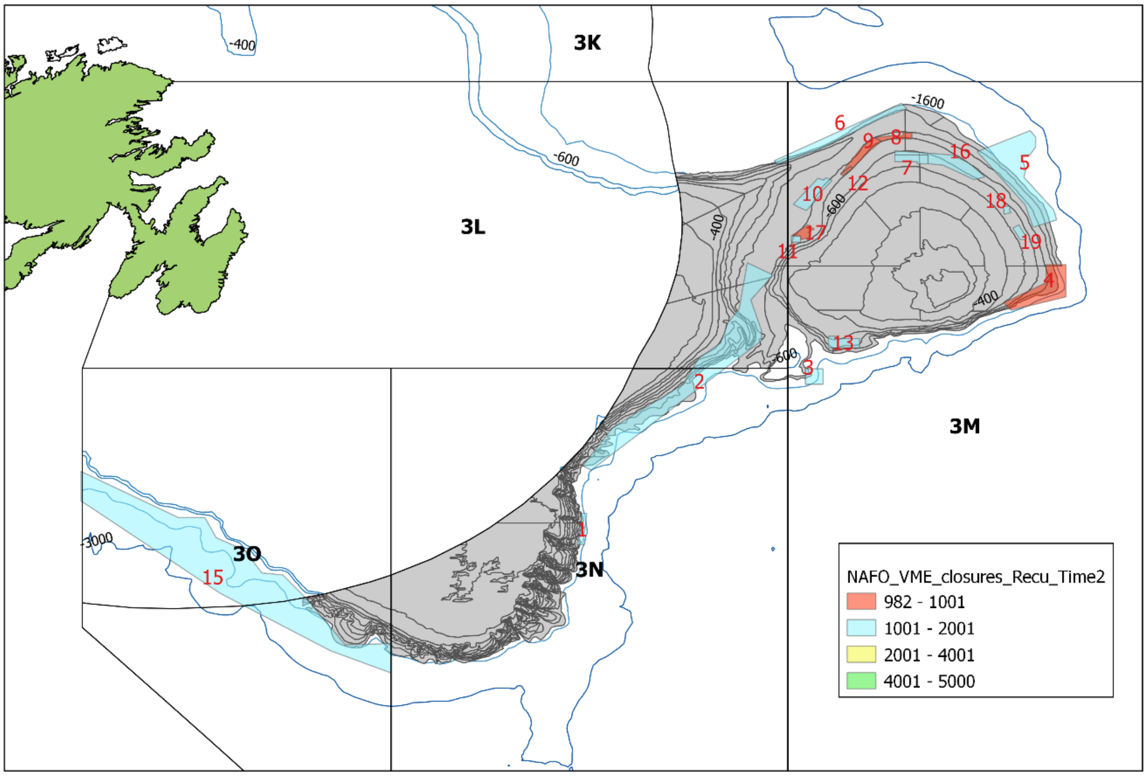

Figure 7. NRA closed areas recurrence time interval (years) estimated with all surveys and with surface of the closed areas overlapped with the survey domains (equation 3).

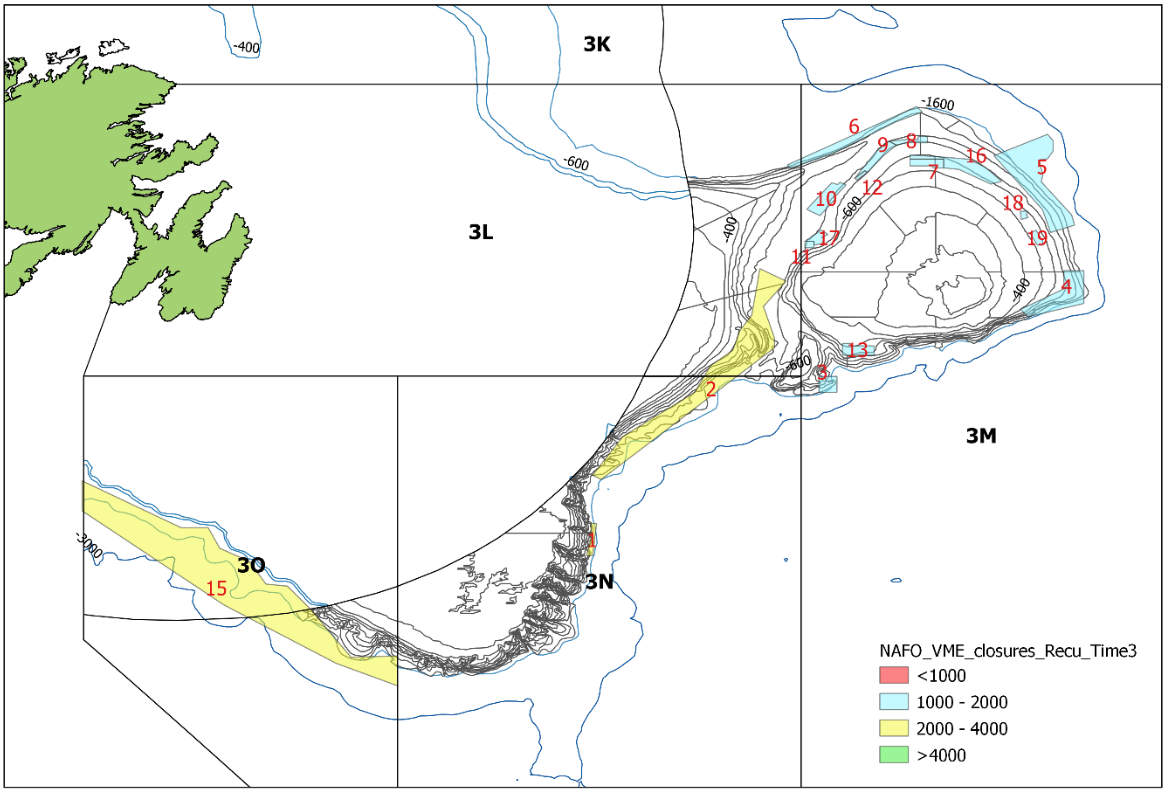

Figure 8. NRA closed areas recurrence time interval (years) estimated with all surveys and with surface of the closed areas overlapped with the survey domains (equation 3) and the haul time trawl of 20 minutes for the European surveys.