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SC WORKING GROUP ON ECOSYSTEM SCIENCE AND ASSESSMENT – NOVEMBER 2016

Report of the 9th Meeting of the NAFO Scientific Council Working Group on Ecosystem Science and Assessment (WG-ESA)

IPMA, Lisbon, Portugal
9- 17 November 2016

Contents

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09-17 November 2016

INTRODUCTION

The NAFO SC Working Group on Ecosystem Science and Assessment (WG-ESA), formerly known as SC Working Group on Ecosystem Approaches to Fisheries Management (WG-EAFM), had its 9th meeting on 7-17 November 2016 at the offices of Instituto Português do Mar e da Atmosfera (IPMA) in Lisbon, Portugal.

The work of WGESA can be described under two complementary contexts:

a) work intended to advance the Roadmap, which typically involves medium to long-term research, and

b) work intended to address specific requests from Scientific Council (SC) and/or Fisheries Commission (FC), which typically involves short to medium-terms analysis, aligned to roadmap priorities.

WGESA revised and up-dated its long-term ToRs in 2016 to be implemented at its 2017 meeting and thereafter, accordingly:

Theme 1: Spatial considerations

> **ToR 1.** Update on identification and mapping of sensitive species and habitats in the NAFO area. In support of the Roadmap develop research and summarize new findings on the spatial structure and organisation of marine ecosystems with an emphasis on connectivity, exchanges and flows among ecosystem units in the NAFO Convention Area.

Theme 2: Status, functioning and dynamics of marine ecosystems

> **ToR 2.** Develop research and summarize new findings on the status, functioning, productivity of ecosystems (including modelling multi-species interactions) in the NAFO Convention Area.

Theme 3: Practical application EAFM

> **ToR 3.** Develop research and summarize new findings on long-term monitoring of status and functioning of ecosystem units (including ecosystem summary sheets) and the application of ecosystem knowledge for the assessment of impacts and management of human activities in the NAFO Convention Area.

Theme 4: Specific requests

> **ToRs 4+.** As generic ToRs, these are place-holders intended to be used when addressing expected additional requests from Scientific Council or Fisheries Commission that don't fit in to the standing ToRs above.

The following ToRs were addressed at the 9th meeting of WG-ESA:

THEME 1: SPATIAL CONSIDERATION

ToR 1.1 New preliminary data on VME in NAFO regulatory area (Divs. 3LMNO) from bottom trawl groundfish surveys: 2016 from the EU and EU-Spanish surveys, and 2015 from the Canadian multispecies surveys

During the 9th NAFO WGESA meeting new preliminary data on deep-water corals and sponges were presented from the 2016 EU and EU-Spanish bottom trawl groundfish surveys for 2016, and 2015 Canadian multispecies surveys. The data was made available to the NAFO WGESA to improve the mapping of Vulnerable Marine Species in the NAFO Regulatory Area (Divs. 3LMNO).

During the 6th meeting of the NAFO Scientific Council Working Group on Ecosystem Science and Assessment (WGESA), new quantitative spatial analyses were applied for corals and sponges for all available data (NAFO SCS, 2013). Outcomes from the analyses produced the following R/V thresholds: 75 kg per tow for sponges, 0.6 kg per tow for large gorgonians, 0.15 kg per tow for small gorgonians, and 1.4 kg per tow for sea pens. Based on these R/V thresholds deep-water coral and sponge data were identified and mapped, and overlaid with the current closed areas and modified kernel density polygons for sponge grounds and large gorgonian VMEs. Sea pen Kernel density polygon did not change from the original one. New closed area 14 is expected to be implemented by January 2017 on the Eastern Flemish Cap, and if implemented it will remain in place until December 31, 2018.

Data used in this study were collected from four surveys:

- The EU-Spain 3NO groundfish survey, conducted by the Instituto Español de Oceanografía (IEO), sampled the Grand Banks of Newfoundland (NRA, Divs. 3NO) between 44 - 1379 m depth, with a total of 116 tows.
- The EU-Spain and Portugal Flemish Cap groundfish survey, conducted by the IEO together with the Instituto de Investigaciones Marinas (IIM) and Instituto Português do Mar e da Atmosfera (IPMA), sampled the Flemish Cap (NAFO Div. 3M) between 136 -1433 m, with a total of 182 tows.
- The EU-Spain Fletán Negro-3L groundfish survey, conducted by the IEO, sampled northeast Grand Banks of Newfoundland (NRA Div. 3L) between 126 - 1447 m depth, with a total of 105 tows.
- The Canadian Multispecies Surveys, conducted by Fisheries Oceans Canada, sampled the Grand Banks of Newfoundland (NRA, Divs. 3NO) between 38 - 698 m depth, with a total of 77 tows.

A total of 480 bottom trawl tows were carried out during all bottom trawl groundfish surveys. For the 2016 Spanish/EU bottom trawl groundfish surveys a total of 403 bottom trawl tows were analyzed for 2016. For the 2015 Canadian multispecies fall survey a total of 77 bottom trawl tows were analyzed. Note for the Canadian surveys: 2015 spring survey data was included in the 8th NAFO WGESA final report (NAFO SCS, 2015), and 2016 spring survey data was not available at this time but will be included in next year's report.

Following previous methodologies used by WG-ESA, deep water corals were grouped by Orders including large gorgonians (Alcyonacea), small gorgonians (Alcyonacea) and sea pens (Pennatulacea); and sponges were grouped by Phylum (Porifera).

Distribution maps of presence and significant catches for large gorgonians, small gorgonians, sea pens, and sponges are presented below (Figs. 1.1.3-1.1.10). Locations of coral and sponge records were assigned by start position of each tow for 2016 EU/Spanish Surveys, and 2015 fall Canadian survey tows. Coordinates and weights of the significant catches are provided in Table 1.1.1.

Table 1.1.1 Significant catches of corals and sponges in the NRA (Divs. 3LMNO) with their corresponding depths and weights. Note tow start positions are in decimal degrees.

			Start position			
VME Indicator Groups with thresholds	**Year**	**Survey**	**Lat (N)**	**Long (W)**	**Depth (m)**	**Weight (kg)**
SPONGES ≥ 75 kg	2016	3L	46.006	-47.442	1365	2238.5
	2016	3L	46.478	-46.872	1281	1303.9
	2016	3M	47.803	-43.733	1103	1279.0
	2016	3NO	45.824	-47.645	1318	1234.3
	2016	3L	48.268	-46.875	1415	388.8
	2016	3NO	45.739	-47.797	1117	313.8
	2016	3NO	45.503	-48.114	1308	257.4
	2016	3M	48.958	-45.077	1433	231.8
	2016	3M	48.033	-46.227	1164	156.8
	2016	3LO	45.041	-48.657	1335	124.2
	2016	3M	46.260	-45.547	997	107.0
	2016	3LO	45.405	-48.304	1328	89.4
LARGE GORGONIANS ≥ 0.6 kg	2015	CAN(3L)	48.082	-46.810	651	3.7
	2015	CAN(3N)	45.394	-48.540	608	3.6
SMALL GORGONIANS ≥ 0.15 kg	2016	3NO	43.064	-51.315	609	0.98
	2016	3NO	42.742	-50.002	993	0.46
SEA PENS ≥ 1.4 kg	2016	3M	48.248	-44.432	824	2.39
	2016	3M	48.289	-45.774	977	1.95
	2016	3M	48.423	-45.321	716	1.87
	2016	3M	48.033	-46.227	1164	1.50

Sponges

For the Spanish/EU 2016 data, sponges were recorded in 248 of the total tows (61.5% of the total tows analyzed) with depths ranging between 53 and 1433 m.

Significant catches of sponge (≥ 75 kg/tow) were found in 12 EU tows (see Table 1.1.1 and Fig. 1.1.1). The majority of these catches (n = 7) were located in the southern part of Flemish Pass in closed area 2; the others were located around Flemish Cap including; 1 in closed area 5, 1 within Beothuk Knoll sponge polygon, 1 within the northern Flemish Cap polygon, 1 adjacent to closed area 10, and 1 on the Sackville Spur. Of the total 12 tows, 4 were recorded outside of the closed areas with 2 of those falling within sponge polygons. Sponge catches for these tows ranged between 89.4 and 2238.5 kg.

For the Canadian 2015 data, sponges were recorded in 38 of the total tows (49.3% of the total tows analyzed), with depths ranging between 44 - 673 m (Fig. 1.1.2).

There were no significant catches of sponge (≥ 75 kg/tow) found. Of the 38 sponge catches observed, all were < 19 kg; 2 were located within the NAFO closure 2, and 2 located within sponge polygon near closure 2.

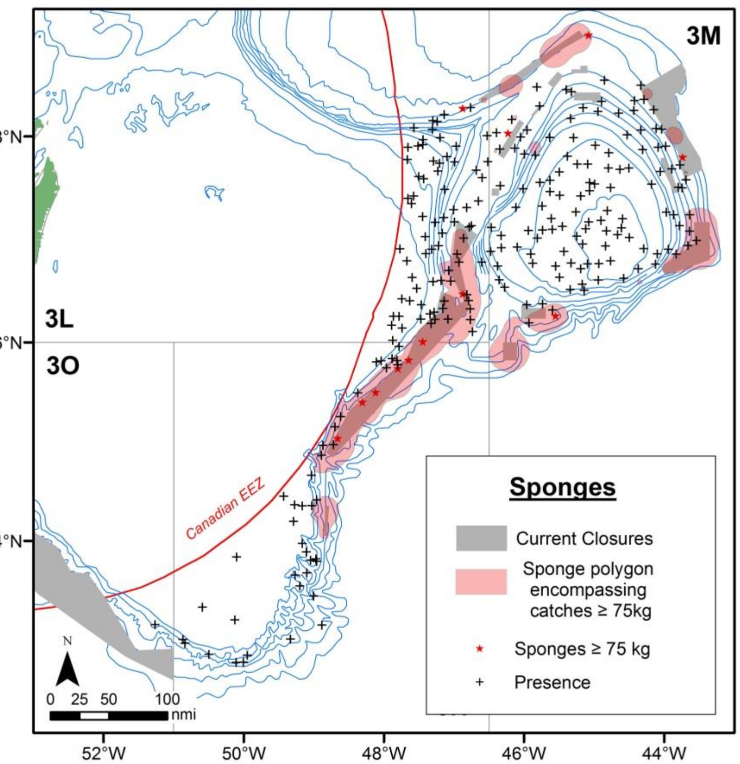

Fig. 1.1.1. Distribution of significant catches and presence of sponges in the study area from 2016 Spanish/EU surveys (NAFO Divs. 3LMNO).

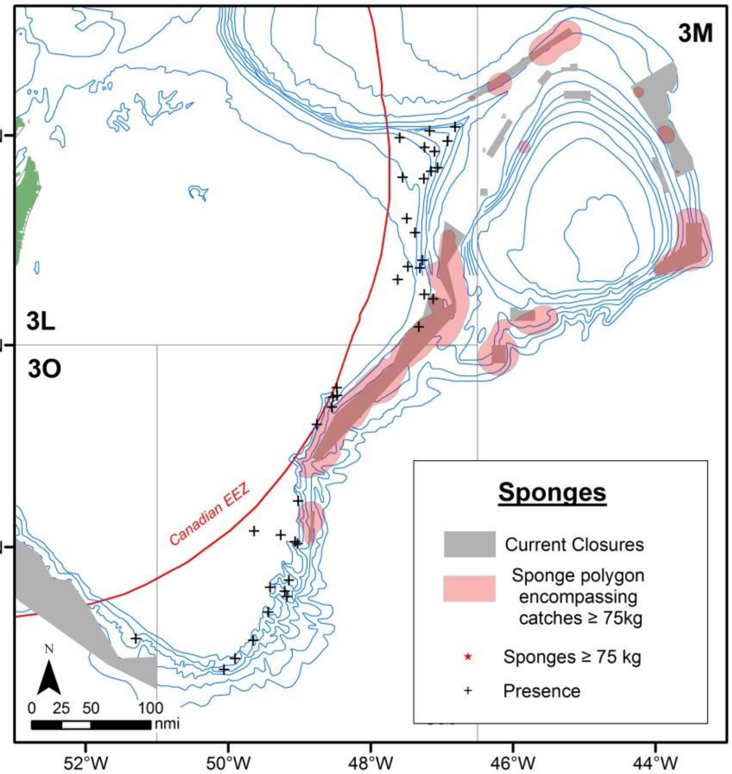

Fig. 1.1.2. Distribution of significant catches and presence of sponges in the study area from Canadian 2015 fall survey.

Large Gorgonians

For the Spanish/EU 2016 data, large gorgonians were recorded in 9 tows (2.2% of the total tows analyzed) with depths ranging between 516 - 1433 m (Table 1.1.1; Fig.1.1.3).

There were no significant catches but of the 9 tows that recorded large gorgonians (weights between 0.004-0.4 kg), 3 tows were located within closures (2 in closure 2, and 1 in closure 4), 1 within Beothuk Knoll polygon, and 4 records in close proximity to closures.

For the Canadian 2015 data, large gorgonians were recorded in 5 tows (6.5% of the total tows analyzed) with depths ranging between 243-651 m (Table 1.1.1; Figure 1.1.4).

There were 2 significant catches, 1 adjacent to the southern portion of closure 2 and the other located on the Sackville Spur. Other catches, below the threshold, were observed on Sackville Spur and 2 on the tail of the Grand Bank.

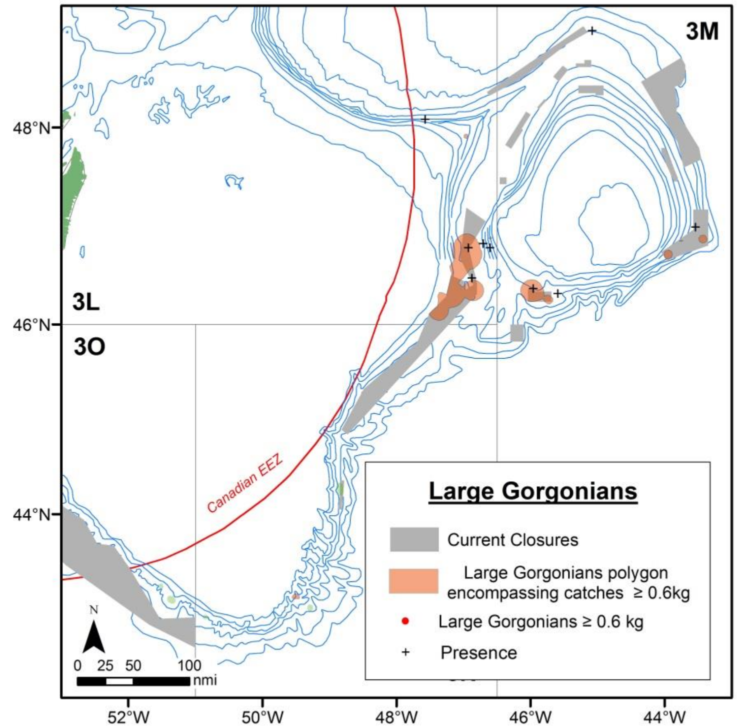

Fig. 1.1.3. Distribution of significant catches and presence of large gorgonians in the study area from Spanish/EU 2016 survey (NAFO Divs. 3LMNO).

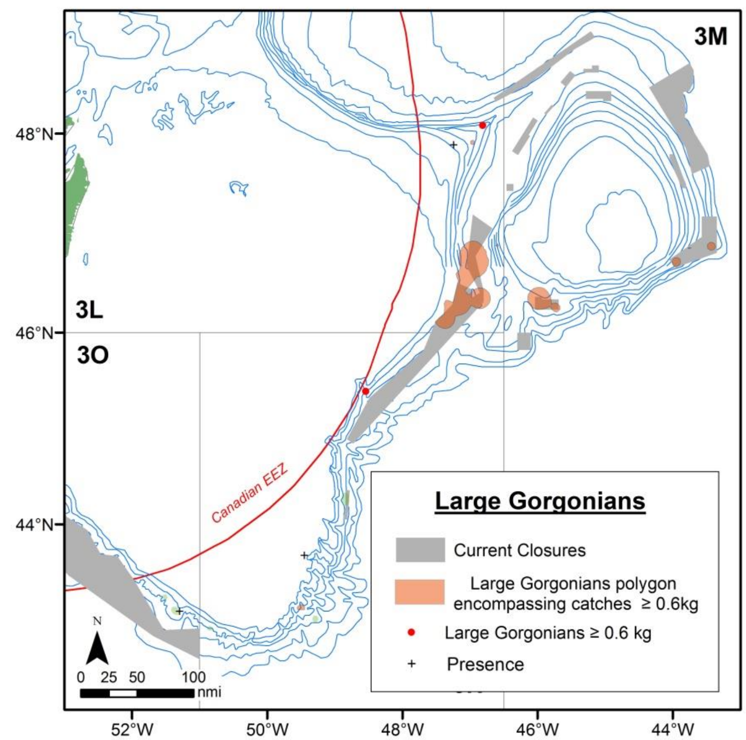

Fig.1.1.4. Distribution of significant catches and presence of large gorgonians in the study area from Canadian 2015 fall survey

Small Gorgonians

For the Spanish/EU 2016 data, small gorgonians were recorded in 42 tows (10.4 % of the total tows analyzed), with depths ranging between 137 - 1415 m (Table 1.1.1; Fig. 1.1.5).

Significant catches (≥ 0.15 kg/tow) were recorded in 2 tows (0.5% of the total tows) with both located on the tail of the Grand Bank. Other observations of small gorgonians were recorded throughout the NRA with 5 tows found within current closures (closures 2 and 5), and many others found adjacent to closures.

For the Canadian 2015 data, small gorgonians were recorded in 2 tows (2.6 % of the total tows analyzed), with depths of 223 - 307 m (Fig.1.1.6).

There were no significant catches (≥ 0.15 kg/tow) recorded, and 2 observations were found on the tail of the Grand Bank.

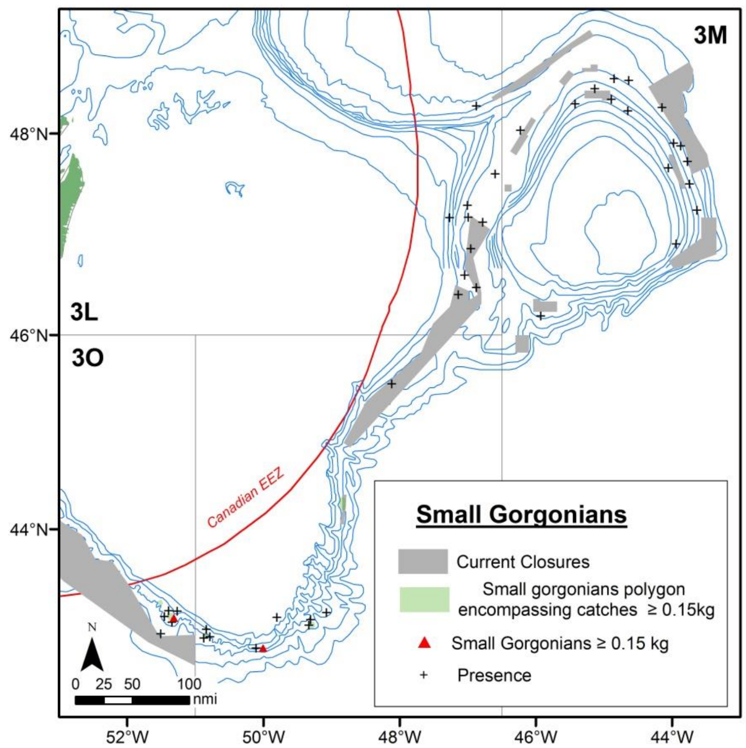

Fig. 1.1.5. Distribution of significant catches and presence of small gorgonians in the study area from Spanish/EU 2016 surveys (NAFO Divs. 3LMNO).

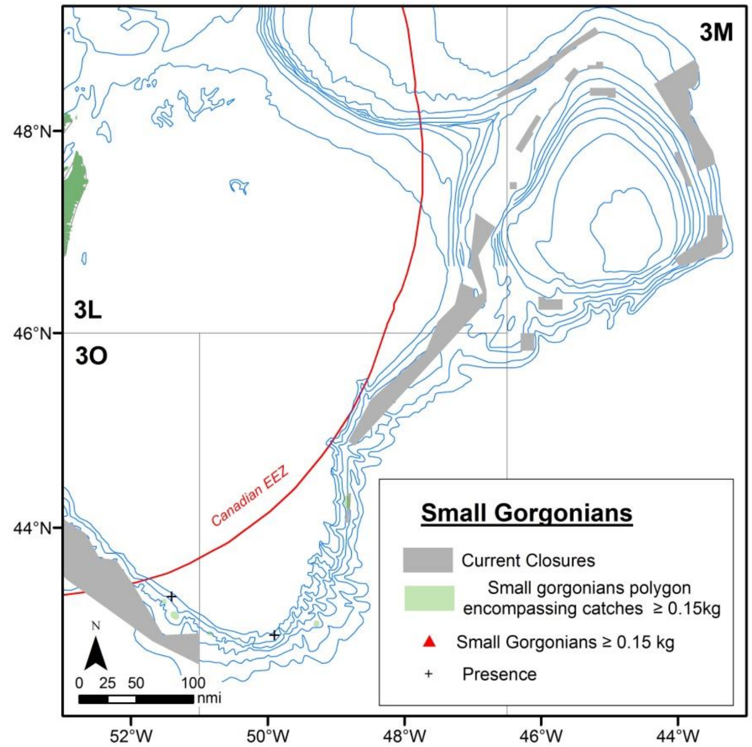

Fig. 1.1.6. Distribution of significant catches and presence of small gorgonians in the study area from Canadian 2015 fall survey.

Sea Pens

For the Spanish/EU 2016 data, sea pens were recorded in 133 tows (33% of the total tows analyzed) with depths ranging between 824 - 1164 m (Table 1.1.1; Fig. 1.1.7).

Significant catches (≥ 1.4 kg/tow) were recorded in 4 tows (1.5- 2.39 kg) with all located outside closed areas. Three of these significant catches were found within two adjacent polygons and the 4th located between the polygons. Other observations of sea pens were recorded throughout the NRA with 6 tows found within closure 2, 1 tow in closure 4, and 20 found within sea pen polygons.

For the Canadian 2015 data, sea pens were recorded in 7 tows (9% of the total tows analyzed) with depths ranging between 241 - 651 m (Fig.1.1.8).

There were no significant catches (≥ 1.4 kg/tow) recorded. Other sea pen observations were documented with 2 in the vicinity of Sackville Spur, 1 in Flemish Pass and a cluster of 4 observations on the tail of the Grand Bank near the Canadian EEZ.

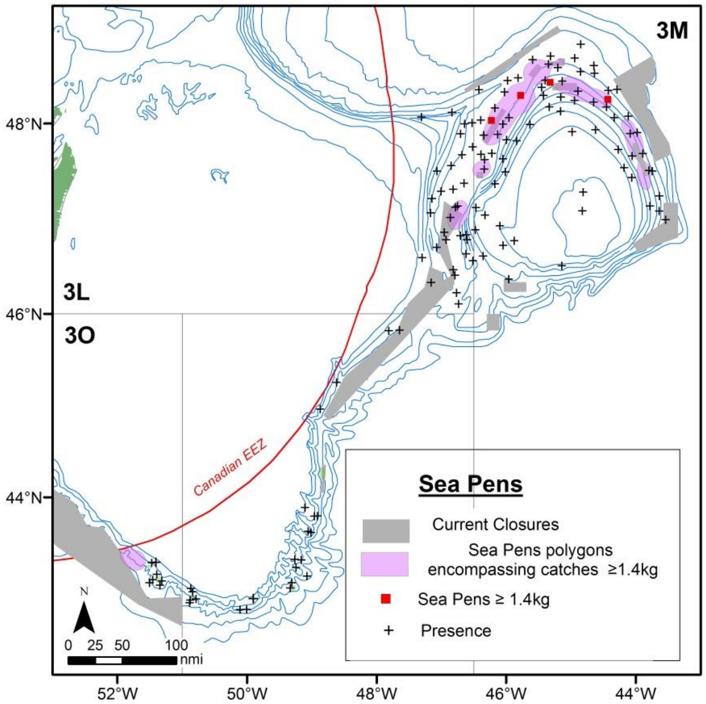

Fig. 1.1.7. Distribution of significant catches and presence of sea pens in the study area from Spanish/EU 2016 surveys (NAFO Divs. 3LMNO).

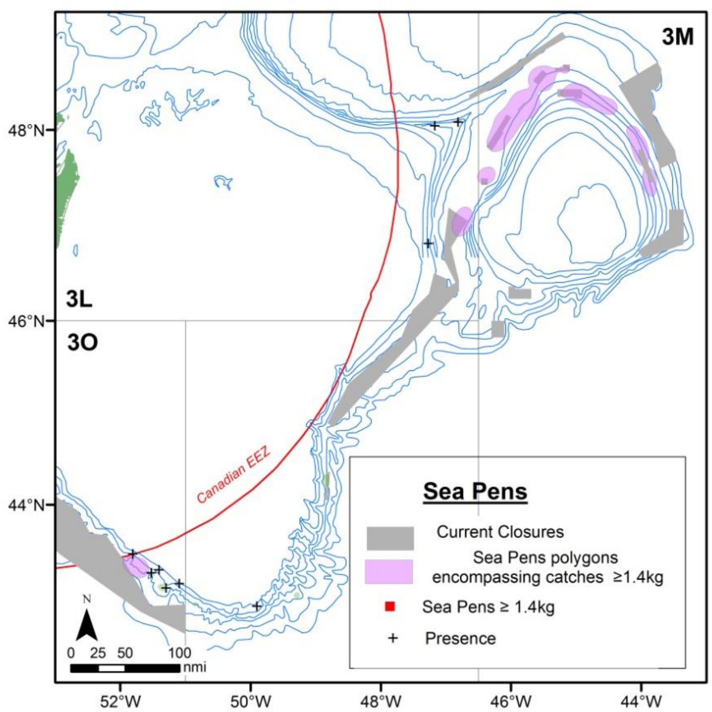

Fig. 1.1.8. Distribution of significant catches and presence of sea pens in the study area from Canadian 2015 fall survey.

Table 1.1.2. Summary of deep-water corals and sponges records for the NRA from Spanish-EU 2016 data and Canadian 2015 fall survey data.

Spanish-EU data 2016	Presence (# of tows)	Total Tows (%)	Significant Concentrations (# of tows)	Significant Concentrations (% of tows)
Sponges	248	61.5%	12	2.9%
Large Gorgonians	9	2.2%	0	0%
Small Gorgonians	42	10.4%	2	0.5%
Sea Pens	133	33%	4	1%

Canadian data 2015	Presence (# of tows)	Total Tows (%)	Significant Concentrations (# of tows)	Significant Concentrations (% of tows)
Sponges	38	49.3%	0	0%
Large Gorgonians	5	6.5%	2	2.6%
Small Gorgonians	2	2.6%	0	0%
Sea Pens	7	9%	0	0%

ToR 1.2 Update on the work of the Joint ICES/NAFO Working Group on Deep-water Ecology (WG-DEC) – update from WG-DEC Chair.

The current Chair (Neil Golding) of WG-DEC, an ICES/NAFO Joint Working Group that deals with the biology and conservation of deep-sea habitats in the North Atlantic, presented an update to WGESA on the Working Groups activities in recent years. Whilst providing a general background to the work of WG-DEC, the presentation focused on two significant achievements. Firstly the development of an online ICES VME Data Portal[1] launched this year and secondly, the development of a system to weight records of Vulnerable Marine Ecosystem (VME) Indicators.

The ICES VME Data Portal is a central portal for data on the distribution and abundance of VMEs (and organisms considered to be indicators of VMEs) across the North Atlantic. It is underpinned by the ICES VME Database, which now contains almost 15,000 records, and has evolved during several WGDEC meetings and a dedicated workshop in December 2015 (ICES, 2016). The database is comprised of; 1) 'VME habitats' which are records for which there is unequivocal evidence for a VME, e.g. ROV observations of a coral reef, and 2) VME indicators which are records that suggest the presence of a VME with varying degrees of uncertainty. The VME Database Format Description is provided in Annex A.

In the VME Data Portal, all VME indicator data has been gridded using a 0.05° grid and is presented in map form. Web services allow users to export data from the portal to their GIS[2]. It is also possible to download the underlying (public) VME records via the download page. As well as showing gridded VME, it is also possible on the same map to overlay the recommendations made by WGDEC for bottom fishing closures, formal ICES advice which is provided to ICES clients, and the actual bottom fishing closures enacted by the regional fisheries management organisations. Displaying all VME data being used by the group in this way ensures that all data underpinning WGDEC recommendations (such as bottom fishing closures) are visible, improving the transparency of the groups work.

Over the last three years, WG-DEC has developed a system to weight the records of VMEs. The weighting system looks at a number of variables associated with VME indicator records in a particular area (using the same 0.05°x 0.05° c-square grid cells used in the VME Data Portal) in order to evaluate the likelihood of a VME being present. These variables include the number of VME indicator records, where the indicators have come from, and the survey method used (trawl, longline bycatch or camera). On the new portal, this evaluation for each grid cell has been displayed as yellow for a low likelihood of a VME, orange for medium, and red for high.

[1] http://ices.dk/marine-data/data-portals/Pages/vulnerable-marine-ecosystems.aspx

Records of known VME habitats are shaded blue. Further details of how the VME weighting system has been developed and implemented can be found in the WG-DEC reports (ICES, 2015 & ICES, 2016)

WG-ESA discussed the proposal by the WG-DEC Chair to expand the ICES VME data portal to include data on the occurrence of VME Indicators collated by NAFO, which received broad agreement from the group. Principally, data used by WG-ESA originates from research fishing surveys undertaken by Portuguese and Spanish research institutions, where VMEs are recorded. In the future, WGESA may consider data on VME distribution from seabed imaging systems such as from remotely operated vehicles (ROVs) and drop camera frames. With this in mind, the Group agreed that utilisation of a database format, such as that used by the Joint ICES/NAFO Working Group, would be useful and there was merit in considering further. The WG-DEC Chair took an action to discuss integration of the WG-ESA database within the Joint ICES/NAFO WG-DEC database with the WGESA Chair, relevant representatives from the Working Group and the ICES Data Centre. Following these discussions, a correlation between WG-ESA VME data fields and ICES VME Database fields was drafted (see Table 1.2.1 below). The full ICES VME Database format description is listed in Annex A. It should now be feasible for WG-ESA to fully utilise the ICES VME Database which will in essence create a database of VME records for the entire North Atlantic.

Table 1.2.1. Correlation between VME database fields used by WG-ESA (left) and their equivalent in the ICES VME database (right).

WG-ESA data field	**Equivalent field in ICES VME Database**
Survey Code (campaign name)	*SurveyName* and/or *CruiseID*
Haul No	*Station ID*
Lat (start)	*StartLatitude*
Long (start)	*StartLongitude*
Lat (end)	*EndLatitude*
Long (end)	*EndLongitude*
Depth (m) at beginning of tow	*DepthShoot*
Depth (m) at end of tow	*DepthHaul*
Species/Taxon ID	Various taxon ID fields for use
Weight (kg)	*Weight*
Count (no of individuals)	*Number*
VME Indicator Species (Common name of taxonomic group)	*VME_Indicator*: Note that there are VME Indicators specifically used by WGESA which are also listed in *VME_IndicatorSubtype*

Annex A: VME Database Format Description

The format consists of 4 separate records for File Information, VME Cruise, VME Sample, and VME Data. Note that the File Information record is created automatically in the template.

To report 'absence' data (for example if you are reporting a research trawl survey where there was no VME by-catch), this VME Data record should be left empty, and only VME Cruise and VME Sample should be completed.

Note: in the 'Obligation' column, M stands for mandatory, O stands for optional and C stands for conditional (i.e. conditional on information being provided in the previous fields)

In case of questions about data reporting format, vocabulary codes, etc., please contact accessions@ices.dk

1. File Information (Mandatory record, created automatically from the data submission template)

FIELD NAME	FIELD TYPE	OBLIGATION	DESCRIPTION	GUIDANCE
RecordType	Text	M	Record Type code 'FI'	The field will be autofilled during data export to xml.
Country	Text	M	Survey country 2-alpha ISO code	The field will be autofilled from the Cruise record
EntryDateTime	Date	M	Data entry date time	The field will be autofilled during data export to xml.

- VME Cruise (Mandatory record)

FIELD NAME	FIELD TYPE	OBLIGATION	DESCRIPTION	GUIDANCE
RecordType	Text	M	Record Type code 'VC'	The field will be autofilled during data export to xml.
SurveyName	Text	M	Survey name	Survey (campaign) name and acronym.
Country	Text	M	Survey country 2-alpha ISO code	Use codes from the list: http://vocab.ices.dk/?ref=337
VesselType	Text	M	Vessel type from which the sample was collected.	Choose from the list: http://vocab.ices.dk/?ref=57
Ship	Text	O	Code of vessel on which sample was collected (for ROV or AUV, provide reference to the parent vessel).	Field is strongly recommended for reporting. Report vessel code from the list at http://vocab.ices.dk/?ref=315
CruiseID	Text	M	Local Cruise ID	To be provided by the data supplier – cruise reference code. If CSR exists, report the CSR cruise reference for traceability http://seadata.bsh.de/csr/retrieve/sdn2_index.html

StartDate	Date	M	Cruise start date	All dates must be supplied as text in the format YYYY-MM-DD (ISO date format).
EndDate	Date	M	Cruise end date	All dates must be supplied as text in the format YYYY-MM-DD (ISO date format).
PlaceName	Text	O	Name of place in reference to the data collection.	Free text; e.g. "Rockall Bank"
ShipPositionPrecision	Integer	O	An estimate of the precision of the lat/long provided by the spatial positioning systems of the vessel/ROV	Calculated or estimated precision of the vessel/ROV position in metres. Take into account whether position is determined from the ship position or from ROV. For example when two separate spatial reference systems are in use such as vessel position GPS (+/- 10m) and ROV USBL (+/- 20m) position, the precision of both the vessel and ROV systems should be added together to give a precision of +/- 30m.
ResponsibleOrganisation	Text	M	EDMO code of the organization responsible for the data.	Please select the organization from the list at http://vocab.ices.dk/?ref=EDMO
ResponsibleOrganisation Role	Text	M	Role of the responsible organization for the data.	Choose from the list: http://vocab.ices.dk/?ref=1434
ScientistInCharge	Text	O	Name of SIC (Scientist in Charge) or PI (Principle Investigator.	Free text. Name of the scientist with overall responsibility for data collection and achieving science objectives during survey.
FundingProject	Text	O	Project name	Free text. Name of the funding project
PointOfContact	Text	M	Name of the point of contact for queries about the data.	Free text. Who should be contacted about the data
ContactEmail	Text	M	E-mail address for the point of contact about the data.	Valid e-mail address
Reference	Text	O	A reference to the data source.	Complete citation for the data source e.g. "Mortensen et al., 2006"
FileName	Text	O	Name of the excel or shape file submitted.	Link to the related metadata files, if available. The files should be sent to accessions@ices.dk
DataAccess	Text	M	Data access constraints.	e.g. "public" or "restricted". Please use "public" if you are content with the data being downloaded in its raw form from the ICES data portal. Alternatively, the data will not be downloadable if you select "restricted". Subset of the controlled vocabulary: http://vocab.ices.dk/?ref=1435

2. VME Sample (Mandatory record)

FIELD NAME	FIELD TYPE	OBLIGATION	DESCRIPTION	GUIDANCE
RecordType	Text	M	Record Type code 'VS'	The field will be autofilled during data export to xml.
CruiseID	Text	M	Local Cruise ID	To be provided by the data supplier – cruise reference code. If CSR exists, report the CSR cruise reference
StationID	Text	O	ID of the survey station, if known.	May be numeric, text or a combination of numbers and text.
SampleKey	Text	M	Key for each discernible sampling/analysis event.	A unique key for each sampling event like: • A single trawl • A single long line set • A single photograph from a photographic tow • A segment of analysed video from a video tow • A video tow, if video is unanalyzed • A sediment grab or core. To be created by data supplier. May be numeric, text or a combination of numbers and text, which may relate back to original data management convention for traceability.
ObservationDate	Date	C	Date the species or habitat was recorded.	Report the date of observation, if available. All dates must be supplied as text in the format YYYY-MM-DD (ISO date format).
ObservationDateType	Text	M	Precision of the reported ObservationDate	A one or two character code that identifies the types of dates used in ObservationDate. Explicitly stating the code avoids any ambiguity, which might lead to subtly different interpretations. Choose from the list: http://vocab.ices.dk/?ref=1429
DataCollectionMethod	Text	M	Reference to the data collection method used.	Specify the data collection method for the sample based on the vocabulary list **N.B. If several samples were taken on site by the variety of methods, report them separately with different sample keys** Choose from: • Multibeam echo sounder (unknown platform) • Multibeam echo sounder (vessel mounted)

				• Multibeam echo sounder (AUV mounted) • Multibeam echo sounder (ROV mounted) • Single beam echo sounder • Side scan sonar (Unknown platform) • Side scan sonar (AUV mounted) • Sub-bottom profiler • CTD • Grab (please specify type from link below) • Core (please specify type from link below) • Trawl (please specify type from link below) • Dredge (please specify type from link below) • Longline • Seabed imagery - towed camera system • Seabed imagery - drop camera system • Seabed imagery – ROV system This list is a subset of the ICES Sampler Type vocabulary. If your survey method is not listed, please select from: http://vocab.ices.dk/?ref=152
StartLatitude	Double	C	Start latitude of the record, if line (if point, use MidLatitude and leave this blank).	Use World Geodetic System 1984 (WGS84) geographic coordinate system, and decimal degrees.
StartLongitude	Double	C	Start longitude of the record, if line (if point, use MidLongitude and leave this blank).	Use World Geodetic System 1984 (WGS84) geographic coordinate system, and decimal degrees.
MiddleLatitude	Double	M	Midpoint latitude of the record if line (if point, use this field for position).	Use World Geodetic System 1984 (WGS84) geographic coordinate system, and decimal degrees.
MiddleLongitude	Double	M	Midpoint longitude of the record if line (if point, use this field for position).	Use World Geodetic System 1984 (WGS84) geographic coordinate system, and decimal degrees.
EndLatitude	Double	C	End latitude of the record (if point, use MidLatitude and leave this blank).	Use World Geodetic System 1984 (WGS84) geographic coordinate system, and decimal degrees.
EndLongitude	Double	C	End longitude of the record (if point, use MidLongitude and leave this blank).	Use World Geodetic System 1984 (WGS84) geographic coordinate system, and decimal degrees.
GeometryType	Text	M	Sampling geometry type	Point or line - subset of the controlled vocabulary http://vocab.ices.dk/?ref=1430
SamplePositionAccuracy	Integer	O	Accuracy of spatial position of record in metres.	For example, trawl by-catch of coral along a 5km trawl track would have a RecordPositionAccuracy of 5000 metres **whereas** an observation of a cold-water coral reef observed on an ROV/drop-camera frame transect may be have a RecordPositionAccuracy of 20 metres (this being the accuracy of the USBL positioning being

				used on the ROV/drop-frame) Value in metres; e.g. “10” means the given position of the record is accurate to ± 10 metres.
DepthUpper	Double	O	Upper depth in metres	For transect data (video or trawl) indicate the shallowest depth in metres. e.g. 110
DepthLower	Double	O	Lower depth in metres	For transect data (video or trawl) indicate the deepest depth in metres. e.g. 150
DepthShoot	Double	O	Depth at the beginning of the tow in metres	For trawling data, report depth in metres at the beginning of the tow
DepthHaul	Double	O	Depth at the end of the tow in metres	For trawling data, report depth in metres at the end of the tow

3. VME Data Record (Optional record – If you wish to report 'absence' data (for example if you are reporting a research trawl survey where there was no VME by-catch), this record should be left empty).

FIELD NAME	FIELD TYPE	OBLIGATION	DESCRIPTION	GUIDANCE
RecordType	Text	M	Record Type code 'VD'	The field will be autofilled during data export to xml.
SampleKey	Text	M	Key for each discernible sampling/analysis event.	A unique key for each sampling event like: • A single trawl • A single long line set • A single photograph from a photographic tow • A segment of analysed video from a video tow • A video tow, if video is unanalyzed • A sediment grab or core. To be created by data supplier. May be numeric, text or a combination of numbers and text, which may relate back to original data management convention for traceability.
RecordKey	Text	M	Unique key for each data record (row) within a submitted dataset.	To be created by data supplier. May be numeric, text or a combination of numbers and text, which may relate back to original data management convention for traceability. If no original data management key exists, this can be added as a sequential numeric list (1,2,3, etc.)
VME_Indicator	Text	C	Grouping of species/habitats used by WGDEC.	A VME indicator must be chosen if no *bona fide* VME habitat type is known to occur, e.g. a sponge from trawl by-catch. This field can also be used to record species records as additional detail for records of VME habitats. To do this, the VME indicator record(s) should be on a separate line from the VME habitat record, and should have the same VMEKey. VME indicators should match the list shown below. Controlled vocabulary http://vocab.ices.dk/?ref=1409 Choose from: • Black coral • Cup coral • Gorgonian • Stylasterids • Sea-pen • Soft coral

				• Sponge • Stony coral • Anemones • Xenophyophores • Stalked crinoids • Chemosynthetic species (seeps and vents)
VME_IndicatorSubtype	Text	O	Indicator subtype code	These are additional VME Indicator types used by NAFO Working Groups, and are not represented in VME Indicator field above. Controlled vocabulary: http://vocab.ices.dk/?ref=1492
VME_HabitatType	Text	C	VME habitat types used by WGDEC.	A VME habitat type should be chosen if the record occurs within a *bona fide* VME habitat e.g. From an ROV transect surveying a cold water coral reef. All datapoints representing the known extent of a VME habitat type along a transect or tow should be recorded within one line of the database (e.g. a video tow split into sections of cold-water coral reef; bathyal rock; cold-water coral reef, would represent two VME habitat records of cold-water coral reef in the database). Controlled vocabulary http://vocab.ices.dk/?ref=1410 Choose from: • Cold-water coral reef • Coral garden • Deep-sea sponge aggregations • Sea-pen fields • Anemone aggregations • Mud and sand emergent fauna • Bryozoan patches • Hydrothermal vents/fields • Cold seeps
VME_HabitatSubtype	Text	O	VME sub habitat types used by WGDEC.	If no VME_habitat_type is filled in, this field should be left blank. If VME_habitat_type is filled in, this field is optional. Controlled vocabulary http://vocab.ices.dk/?ref=1411 Choose from: • *Lophelia pertusa/Madrepora oculata* reef • *Solenosmilia variabilis* reef • Hard-bottom coral garden *Note that these records can be further classified*

				as one of the following: ○ Hard-bottom coral garden: Hard-bottom gorgonian and black coral gardens ○ Hard-bottom coral garden: Colonial scleractinians on rocky outcrops ○ Hard-bottom coral garden: Non-reefal scleractinian aggregations ○ Hard-bottom coral garden: Stylasterid corals on hard substrata • Soft-bottom coral garden *Note that these records can be further classified as one of the following:* ○ Soft-bottom coral garden: Soft-bottom gorgonian and black coral gardens ○ Soft-bottom coral garden: Cup-coral fields ○ Soft-bottom coral garden: Cauliflower Coral Fields • Soft-bottom sponge aggregations • Hard-bottom sponge aggregations • Soft-bottom anemone aggregations • Hard-bottom anemone aggregations
VMEKey	Double	C	Key to identify VME habitat and VME indicator records belonging to a single habitat patch.	Sequential number to identify records that come from the same block of habitat, e.g. Consecutive points on an ROV or video transect that are on the same coral reef. This is mandatory for any records of VME habitats. If each record comes from a separate habitat patch, or if this is not known, use a different number for each record. Also optional for records of VME indicator species, where it can be used to show that these come from a patch of VME habitat. See guidance on the VME_indicator field for more details.
GeneralTaxonDescriptor	Text	O	Most detailed name of taxon (according to HighestTaxonomicResolution).	e.g. Porifera, *Lophelia pertusa*, soft coral
TaxonLatinName	Text	C	Latin name of the most detailed taxon identified.	Report the taxon Latin name whenever possible. Report the taxon Latin name whenever possible. If reported in the Excel template, the AphiaID would be matched

				automatically. In case of ambiguities in the results, the data submitter should specify the AphiaID instead.
AphiaID	Integer	C	WoRMS Species reference code	We strongly recommend reporting of valid species AphiaIDs as in http://www.marinespecies.org/. In the excel template, either AphiaID or TaxonLatinName should be reported (same field). If the field is left blank, AphiaID=2 (Animalia) would be automatically assigned.
DeadAlive	Text	O	Indication of whether most of sample was dead or alive.	Choose either "Dead" or "Alive". Subset of the controlled vocabulary: http://vocab.ices.dk/?ref=64
Number	Double	O	Number of individuals associated with the record.	If not known, use "Null".
Weight	Double	O	Mass of indicator, in kg, associated with the record.	Weight in kilograms. This is likely to be relevant to by-catch/ data. If not known or not relevant, use "Null". Do not include if the record is a VME habitat type.
Density	Double	O	Number of individuals per square metre (m^2).	If not known or not relevant, use "Null".
PercentCover	Double	O	Percentage cover of indicator (relevant to underwater imagery data, e.g. ROV or drop down video).	If not known or not relevant, use "Null".
SACFOR	Text	O	Semi-quantitative abundance scale (relevant to underwater imagery data, e.g. ROV or drop down video).	Controlled vocabulary http://vocab.ices.dk/?ref=1491. Scale description: http://jncc.defra.gov.uk/page-2684 If not known or not relevant, use "Null".
TaxonDeterminer	Text	O	Name of organization that identified the GeneralTaxonDescriptor.	Please select the organization from the list at http://vocab.ices.dk/?ref=EDMO
TaxonDeterminationDate	Date	O	Date of identification of the GeneralTaxonDescriptor.	All dates must be supplied as text in the format YYYY-MM-DD (ISO date format).
Comments	Text	O	Any other relevant comments or information.	e.g. “sample was 60% live coral and 40% dead”

ToR 1.3. Update where appropriate boundaries of ecosystem- based management areas.

At the 2016 NAFO annual meeting a decision was taken to establish a temporary VME fishery closure to protect sea pen located in the east of the Flemish Cap (NAFO/FC Doc. 16-20). The closure is to be reviewed in 2018 pending the availability of new evidence on the status of sea pen VME. An important task as part of this review is to up-date the KDE analysis and to re-evaluate the KDE modelled VME boundaries using VME indicator species (specifically sea pen) survey data from recent survey years. The existing KDE polygon analysis, used to define sea pen VME biomass at 1.4 kg, was based on an analysis reported in Kenchington *et al.,* (2014), see Table 1.3.1 and Fig. 1.3.1. It is proposed that an additional 3 years of sample data (2014 – 2016) be added to the original data and the KDE analysis repeated for each of the coral and sponge VME types (e.g. sponge, large gorgonian and sea pen).

It should be noted that the biomass threshold defining the extent of VME for each of the VME indicator species may change as a result of the up-dated analysis, giving rise to possibly either an increase or decrease in VME extent.

The result so the up-date KDE analysis should be presented at WG-ESA in 2017.

Table 1.3.1 Survey haul data used to perform KDA of VMEs in NAFO footprint (Kenchington, et al., 2014).

Programme	Period	NAFO Division	Trawl gear type	Mesh size in codend liner (mm)	Trawl duration (min)	Average wingspread (m)
Spanish 3NO Survey (IEO)	2002–2013	3NO	Campelen 1800	20	30	24.2–31.9
EU Flemish Cap Survey (IEO, IIM, IPIMAR)	2003–2013	3M	Lofoten	35	30	13.89
Spanish 3L Survey (IEO)	2003–2013	3L	Campelen 1800	20	30	24.2–31.9
DFO NL Multi-species Surveys (DFO)	1995–2012	3LNO	Campelen 1800	12.7	15	15–20

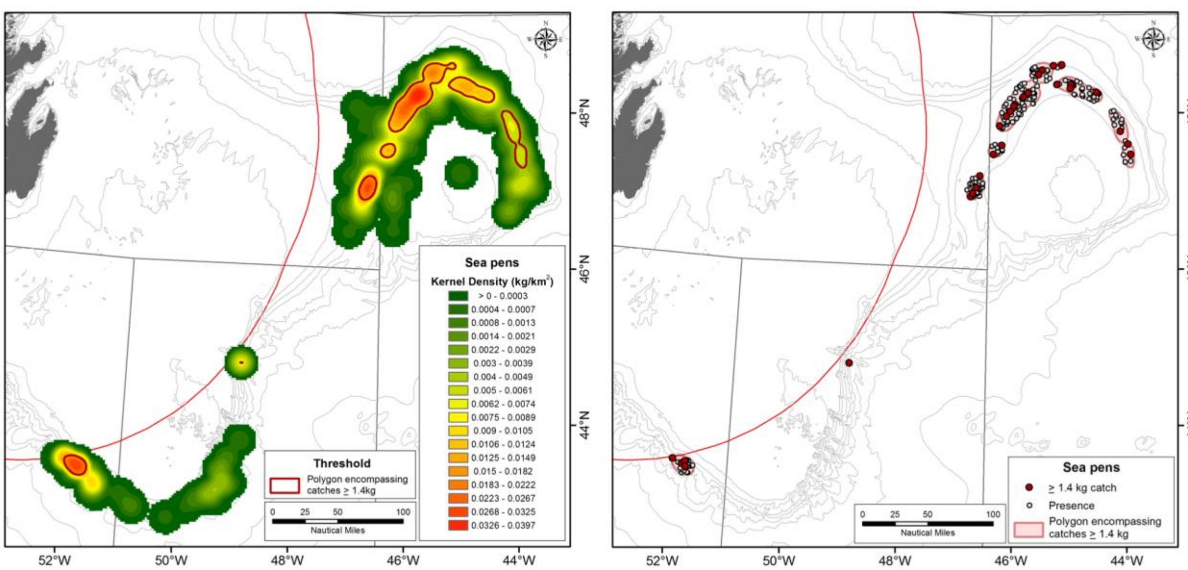

Fig. 1.3.1. Sea pen KDE analysis.

ToR 1.4.Update on identification and mapping of sensitive species and habitats in the NAFO area.

Preliminary results of 2015 Canadian in situ photographic survey in the NAFO Regulatory Area

In June 2015, Fisheries and Oceans, Canada (DFO) conducted 19 *in situ* benthic surveys in the NAFO convention area on board the CCGS Hudson (Table 1.4.1). Two underwater camera systems were deployed. Most of the work was done with the 4KCam. This system, built in 2008 by the Geological Survey of Canada (GSC), is an aluminium frame that contains a Canon Rebel Eos Ti 12 megapixel camera with two Canon flashes. The 4KCam was lowered with a winch from the CTD deck until an attached lead weight hit the bottom, automatically triggering the camera. The camera was then raised off bottom and lowered again in 30 second intervals along the drift line. This continued until approximately 1 km of seabed was surveyed, unless there were problems which required a premature retrieval of the system. Three transect lines were completed using Deep Imager to collect high resolution video. Recently developed by the GSC, the Deep Imager houses a vertically-mounted Canon video recorder that records high-resolution video footage of the seabed with live feed. The system is also equipped with a vertically-mounted digital still camera system that automatically takes digital photos of the seabed at 15 second intervals. This system was used as a trial for detailed benthic imagery collection during this DFO mission. In the future, this system would be useful for capturing habitat diversity and the scale and regularity of VME along transects, while the detailed high resolution images from the 4KCam have proven effective in quantifying biodiversity within VME.

The cruise track is illustrated in Fig. 1.4.1 and includes benthic work completed in Canadian waters. A summary of the benthic transects completed in the NAFO area is presented in Table 1.4.1. Details of the surveys conducted on the tail of the Grand Bank are discussed in the WG-ESA response to FC Request #15 in the 2015 WG-ESA Report (NAFO, 2015). Details of the other transects from the 2015 survey that are relevant to current VME issues are documented below.

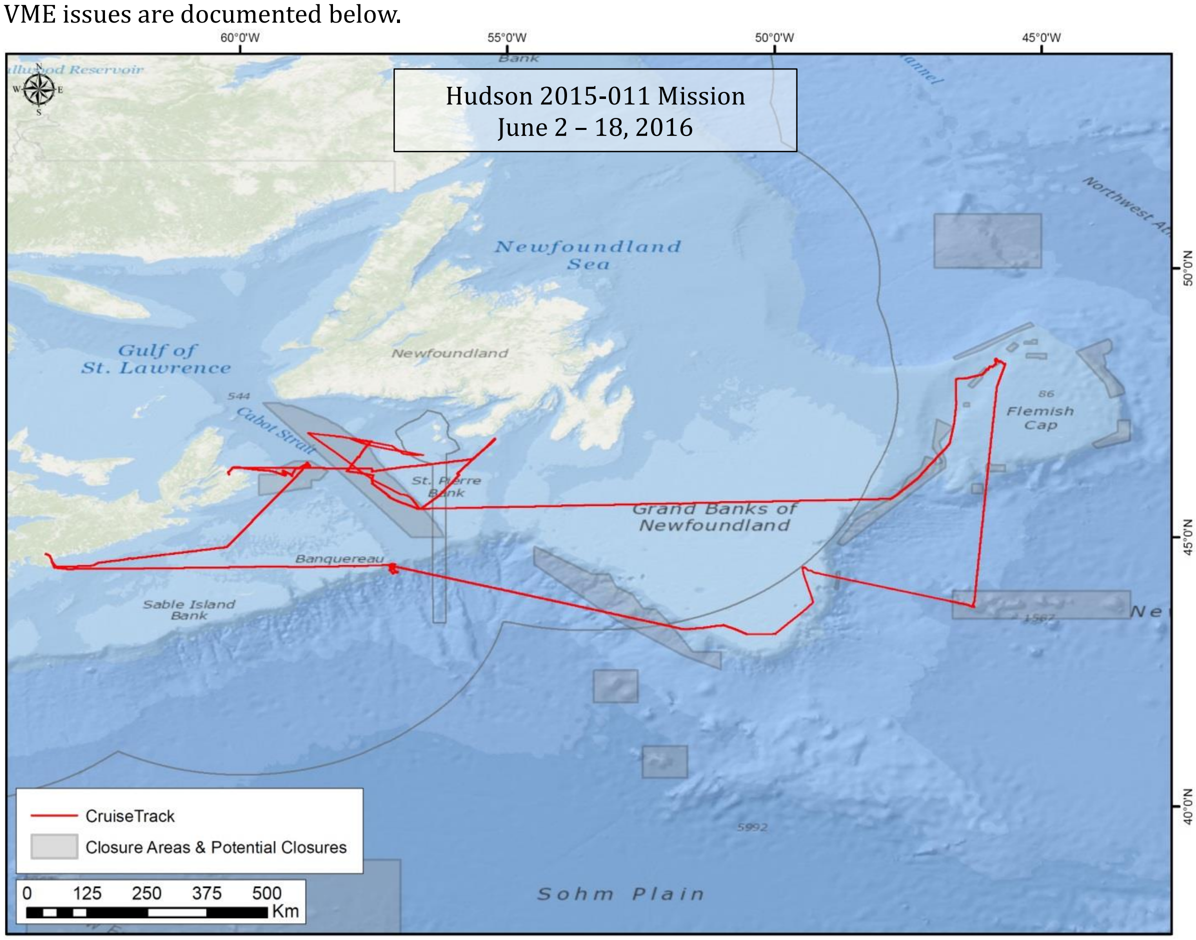

Fig. 1.4.1. Cruise track of CCGS Hudson mission conducted by Fisheries and Oceans, Canada in 2015.

Table 1.4.1. Summary of the benthic imagery transects collected by Fisheries and Oceans, Canada in 2015 from the NAFO area.

General location	Transect ID	Gear	Coordinates		Approximate transect length (km)	Start - End depth (m)	Number of photos
			Start	End			
Flemish Pass/Eastern Canyon	41	Deep Imager	45.9044/ -47.5626	45.8948/ -47.5728	1.5	1317 - 1316	315*
	42	4KCam	45.7210/ -47.8215	45.7084/ -47.8325	1.7	1160 - 1149	43
(Mizzen Well)	39	Deep Imager	47.9553/- 46.4385	47.9497/- 46.4518	1.6	1160 - 1160	221*
Northwest Flemish Cap	32	4KCam	48.2284/- 45.6870	48.2185/- 45.6980	1.5	802 - 804	63
	33	4KCam	48.2698/ -45.7765	48.2579/ -45.7938	1.9	943 - 949	61
	34	4KCam	48.3201/- 45.8553	48.3115/- 45.8695	1.5	1147 - 1149	60
	35	4KCam	48.2211/ - 45.8627	48.2116/ -45.8717	1.3	961 - 597	65
	36	4KCam	48.1718/- 45.9394	48.1685/- 45.9446	1.5	802 - 804	66
	37	4KCam	48.1246/ -46.0146	48.1148/ -46.0300	1.0	978 - 976	70
	38	4KCam	48.0361/ -46.1088	48.0280/ -46.1141	1.0	1074 - 1073	58
Southwest Tail of Grand Bank (3O Notch)	21	4KCam	43.2931/- 51.7229	43.2966/- 51.7013	2.1	802 - 745	43
Central Tail of Grand Bank	23	Deep Imager	43.3670- 50.9493	43.3676/- 50.9549	0.5	76 - 75	84*
	25	4KCam	43.2028- 50.5023	43.2026- 50.5160	1.2	75 - 74	50
	26	4KCam	43.2020/- 49.9704	43.2023/- 49.9834	1.1	63 - 63	52
Southeast Shoal	27	4KCam	43.7905/ - 49.2794	43.8004/ -49.2785	1.2	103 - 109	50
	28	4KCam	44.4318/ - 49.4430	44.4395/ -49.4360	1.1	50 - 51	42
	29	4KCam	44.3811/ - 49.3557	44.3810/ -49.3406	1.2	52 - 50	41
	30	4KCam	44.3365/ - 49.2168	44.3373/ -49.2025	1.2	52 - 52	49
Newfoundland Seamounts	31	4KCam	43.7204/ - 46.2700	43.7225/ -46.2803	0.9	2671 - 2703	52

* The majority of these photos are of poor quality as this camera system was not intended to be used on these transect lines to capture details of the seafloor. Continuous video was recorded to evaluate habitat diversity and larger megafauna for identification of VME.

Sea pen VME Polygon on the Southwest Tail of Grand Bank (3O Notch)

This 2.1 km long transect line (Fig. 1.4.2) was positioned within the sea pen kernel density derived polygon (NAFO, 2013) in this area to determine whether significant concentrations of sea pens were present to warrant the designation of this area as a VME. Two species of sea pens and small gorgonian corals (VME) were seen in 45% of the photos (N=45; Fig. 1.4.3). This is considered a very high percentage given the field of view (~ 0.47 m^2) and indicative of sea pen field VME. The cup coral *Flabellum*, a non-VME stony coral, was locally common.

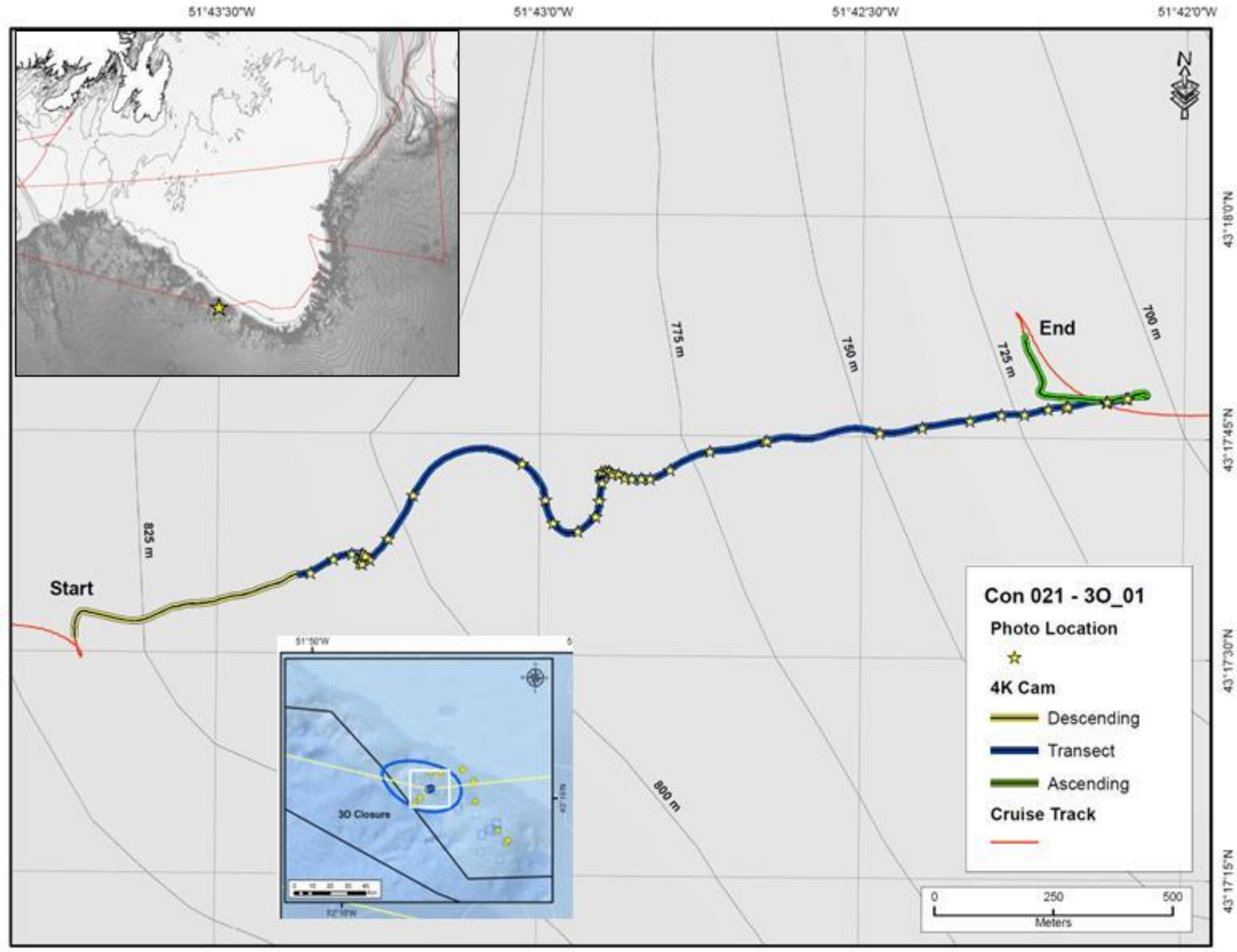

Fig. 1.4.2 Position of Transect 21 near the 3O Closed Area. Details of the transect position are found in Table 1.4.1.

Fig. 1.4.3. Two species of sea pens (*Pennatula aculeata* and *Anthoptilum grandiflorum* were observed in 45% of the photos within the significant concentration polygon for sea pens. The area seen in this photo is approximately 0.47 m^2.

Newfoundland Seamount Chain

The first underwater images were collected from the Newfoundland Seamounts along a transect line positioned over the top of one of the seamounts in the closed area (Fig. 1.4.4.). The depth was between 2600 and 2700 metres (Table 1.4.1). This transect was over a sandy bottom (Fig. 1.4.5) with forams and a few crustaceans (crabs) and numerous echinoderms (brittlestars). A number of photos (Fig. 1.4.6) showed round spherical objects consistent with xenophyophores, a group of large single-celled protists that are important as ecosystem engineers in deep water sedimentary habitats, but they could also be mineral in origin (nodules of some type). Xenophyophores have been listed as VME indicator taxa by FAO (FAO, 2009) and as can be seen in Fig. 1.4.7, show a strong similarity to the objects viewed on the Newfoundland Seamounts. There are many species of xenophyophores and *Syringammina fragillissima* is the largest known to date, reaching 20 cm in diameter.

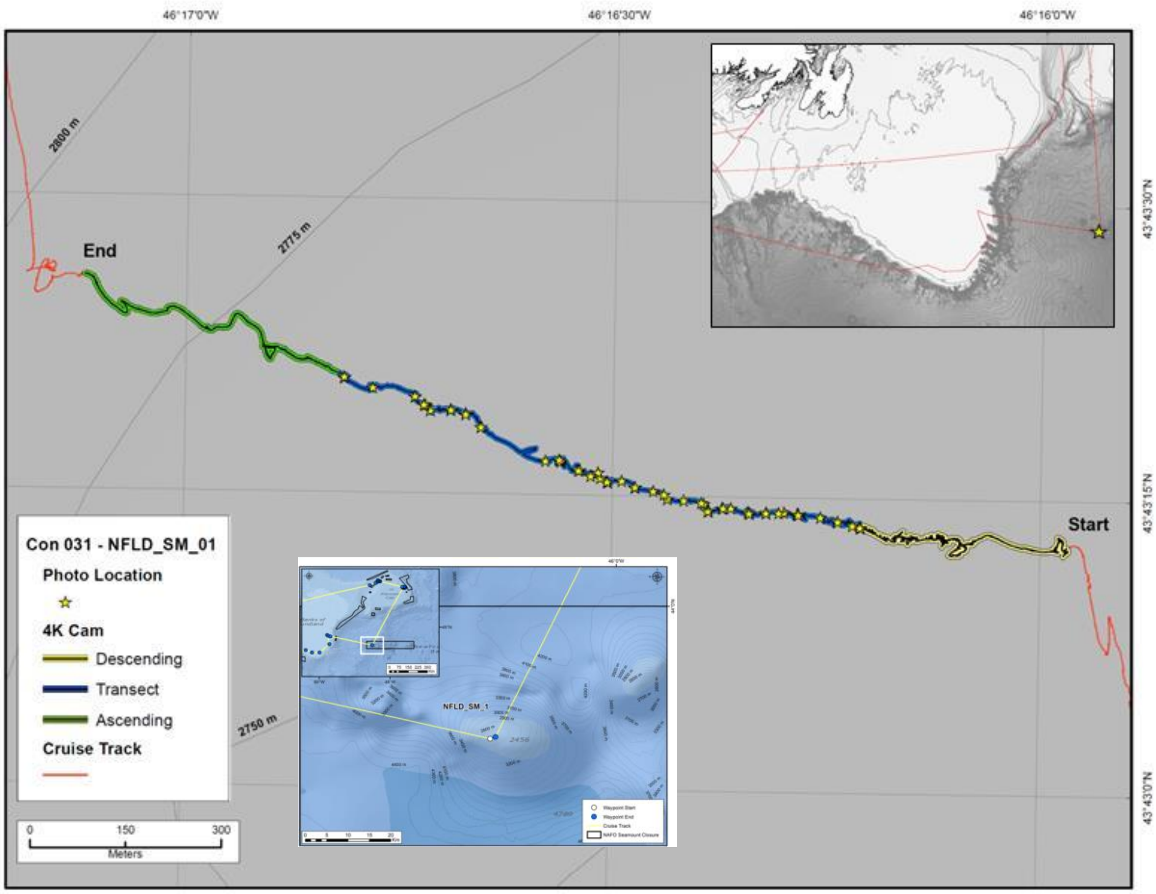

Fig. 1.4.4. Position of Transect 31 on the Newfoundland Seamount chain. Details of the transect position are found in Table 1.4.1.

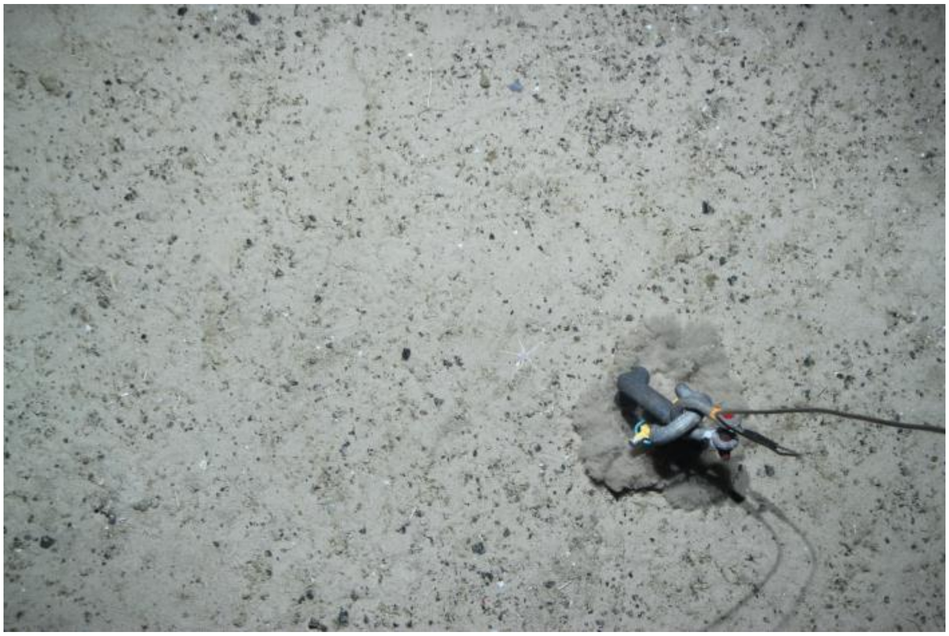

Fig. 1.4.5. The top of the Newfoundland Seamount was a soft bottom. The area seen in this photo is approximately 0.4 m^2.

Fig. 1.4.6. Numerous photos from the top of the Newfoundland Seamount showed spherical objects that could be of biological or mineral origin. They were approximately 5 cm in diameter and if biological could be xenophyophores which are considered VME indicators by FAO (2009).

Fig. 1.4.7. Xenophyophores from the Gully Marine Protected Area (Kenchington et al., 2014). These have been identified as *Syringammina* cf. *fragillissima*.

Northwest Flemish Cap

Seven transects were collected from the northwest Flemish Cap area (Table 1.4.1). The purpose of collecting those transects was to evaluate the impact of fishing on sea pen VME. Transects were conducted inside the closed areas (Fig. 1.4.8.; see also ToR 3.8) and in adjacent medium fished areas. Evidence of trawling was seen in the medium fished area where none of the photos had any megafauna. In contrast inside the closed area sea pen fields were observed.

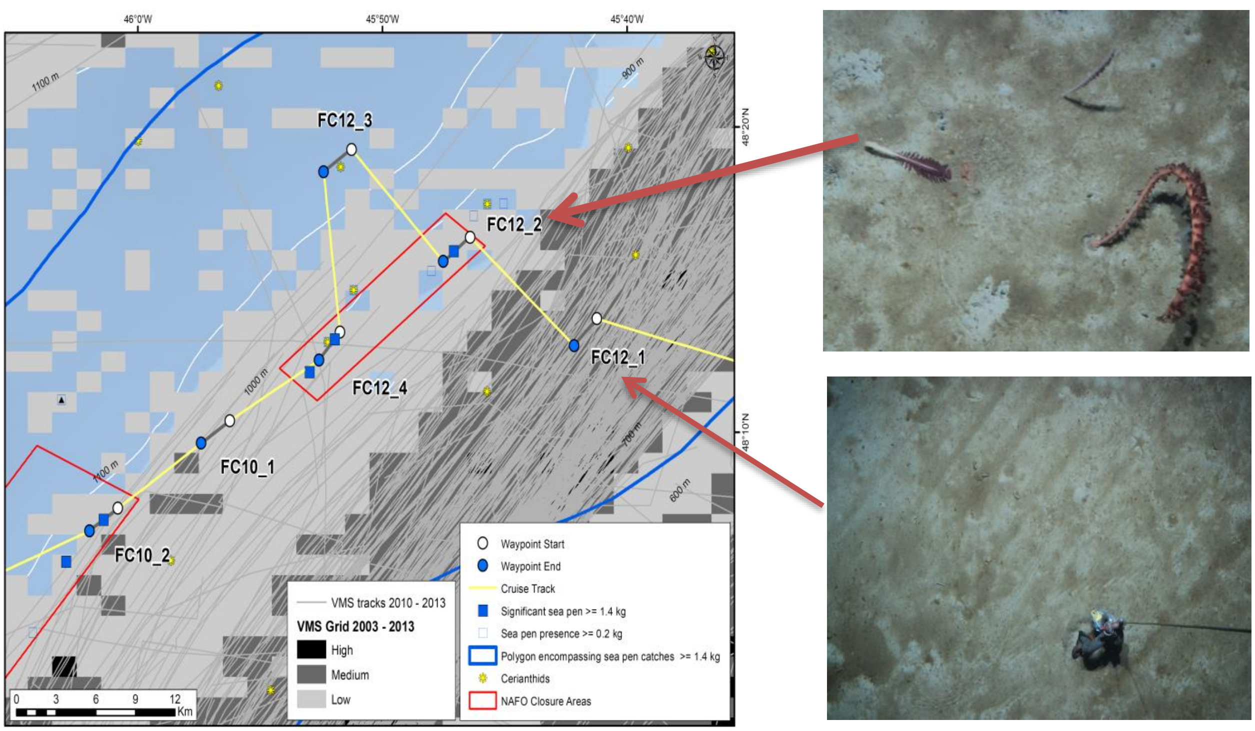

Fig 1.4.8. Planned transect positions from the northwest Flemish Cap which were conducted inside and outside the closed areas to protect sea pen VME and to evaluate the impact of fishing.

Flemish Pass P78 Oil Well

In March 2015, a spill of up to 14,000 l of synthetic-based drilling mud was spilled from the P78 (Mizzen) oil well, located in the northern Flemish Pass (Fig. 1.4.9, 1.4.10) The well is located approximately 11 km west of NAFO Closure 10. A Deep Imager video transect ~1.6 km in length was conducted over the location of the well head in order to document the effects of the spilled drilling mud on the surrounding megafaunal community. Preliminary examination of the video and photos from this Deep Imager transect showed no overt remnants of the drilling mud. More detailed examination of the imagery will be required to fully determine any effects of the spill on the benthos.

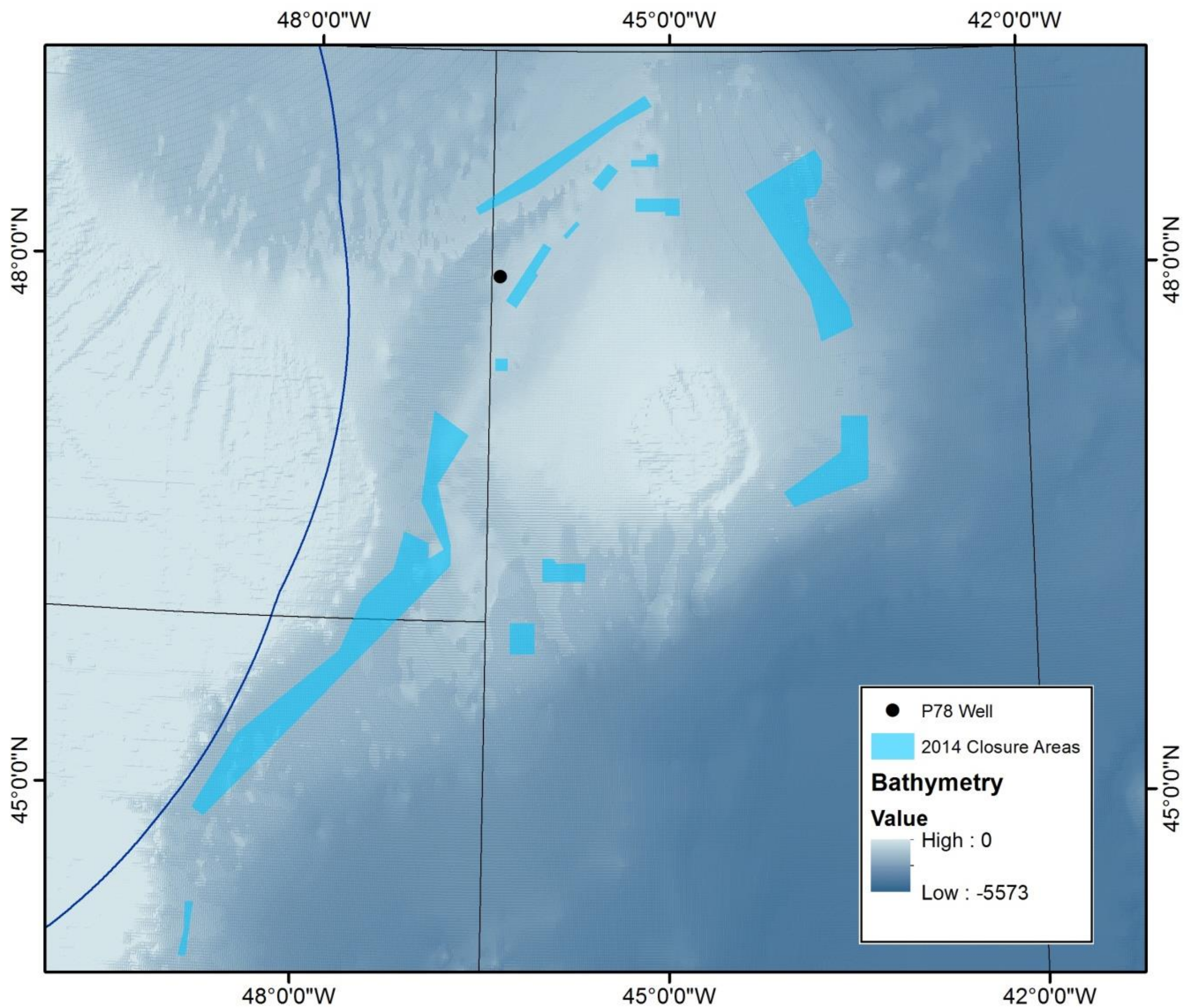

Fig. 1.4.9. Location of P78 (Mizzen) oil well (black circle) in relation to the NAFO Closure Areas

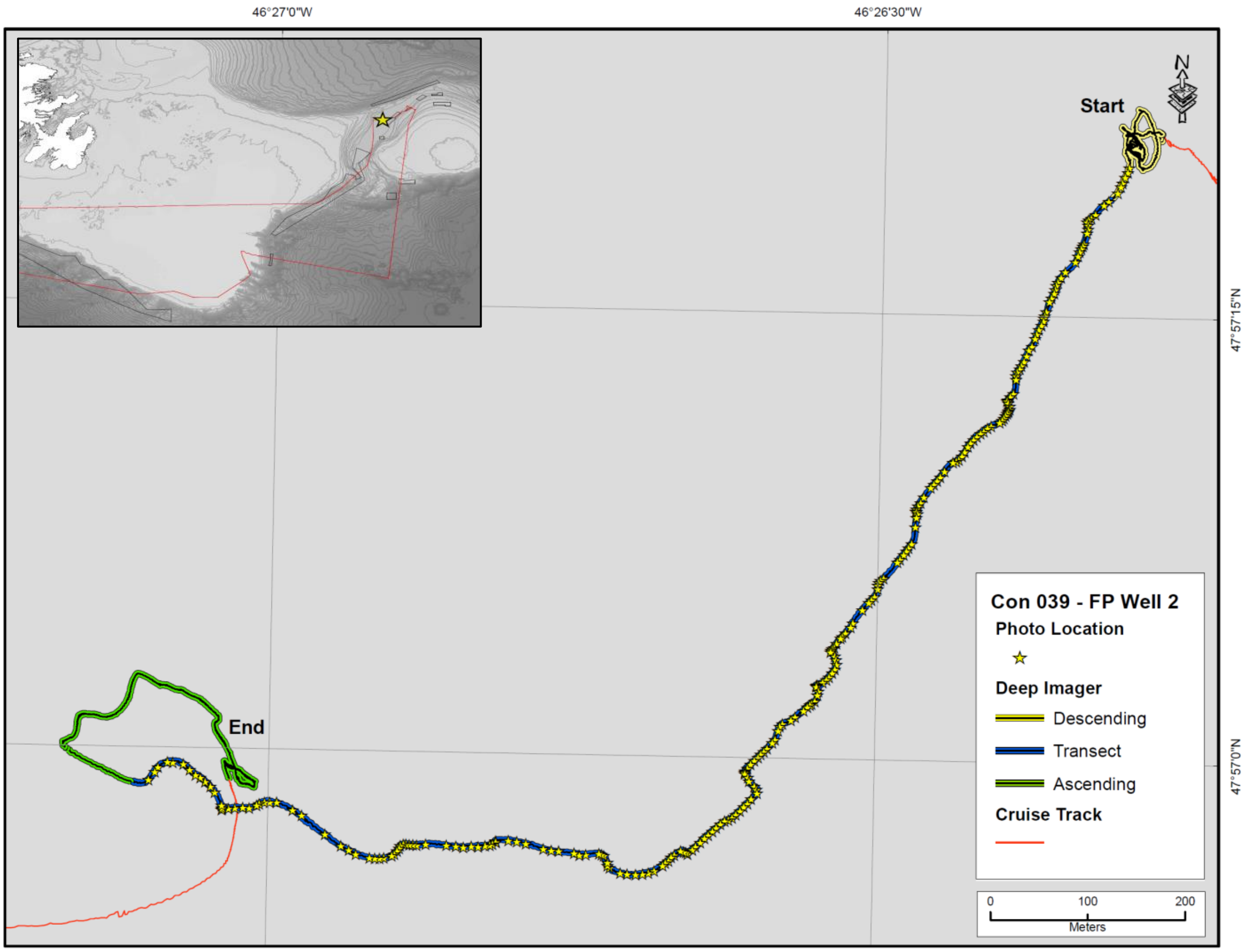

Fig. 1.4.10. Position of Transect 39 on the P78 (Mizzen) oil well. Details of the transect position are found in Table 1.4.1.

ToR 1.5. Preliminary results of 2016 Canadian in situ photographic survey on Kelvin Seamount and review of available data in the context of seamount conservation

Fisheries and Oceans, Canada in collaboration with NEKTON (https://nektonmission.org/), SponGES (http://www.deepseasponges.org/), and ATLAS (http://www.eu-atlas.org/) conducted an *in situ* photographic survey on Kelvin Seamount during the Joint DFO-Nekton XL Catlin Deep Ocean Survey from Halifax to Bermuda, July 19 – August 16th, 2016. This seamount belongs to the New England Seamount chain and is partially covered by the NAFO Seamount Closures (Fig. 1.5.1, upper panel). Video transects with a remotely operated vehicle (ROV) were designed to survey both outside and inside the NAFO New England Seamount Closure boundary in order to evaluate the boundaries of the closure and its effectiveness in protecting VME on Kelvin Seamount. However, due to strong currents in the area the ROV was not used and only one photographic transect, outside of the seamount closure was completed, using the 4K Camera ('4KCam') (Fig. 1.5.1, lower panel). This system, built in 2008 by the Geological Survey of Canada, is an aluminium frame that contains a Canon Rebel Eos Ti 12 megapixel camera with two Canon flashes. The 4KCam was lowered with a winch until an attached lead weight hit the bottom, automatically triggering the camera. Subsequent photos were taken by raising and lowering the camera off the sea bed. The transect lines covered 1.3 km and 90 photos of good quality were collected (Table 1.5.1). Three additional video transects were deployed in the area but the bottom was not reached by the gear.

Table 1.5.1. Summary of *in situ* Benthic Transect on Kelvin Seamount

Transect ID	Station	Depth (m) (Start/End)	Length
CON_79	K2a	1680.42/ 1843.75	1.3 km

The seamount is of volcanic origin and the basalt rocks were common in all images. Preliminary analysis of the photos taken revealed at least 65 unique taxa across 8 phyla. Cnidaria was the dominant phylum with 23 taxa, most of them being octocorals with at least 15 species observed (Table 1.5.2). The gorgonians coral were the dominant group. The second dominant phylum in terms of species richness was Echinodermata, with at least different 19 taxa comprised mainly of brittle-stars and crinoids. They were found attached to rocks, sediment, and over the gorgonians, and on some occasions were covering them almost completely (Fig. 1.5.2). At least 10 species of sponges were observed, some of them of about 20 cm in length and width, indicating that structure forming sponges are present in the area. In addition, more than 70 xenophyophores (Phylum Foraminifera) were recorded, which indicates a high density of this particular taxon. Xenophyophores are a VME indicator taxa (FAO, 2009).

Houghton et al. (1977) suggested that the surfaces of the New England Seamounts are covered with pelagic foram ooze and are rich in pteropod tests. Data collected with the 4KCam corroborate this observation.

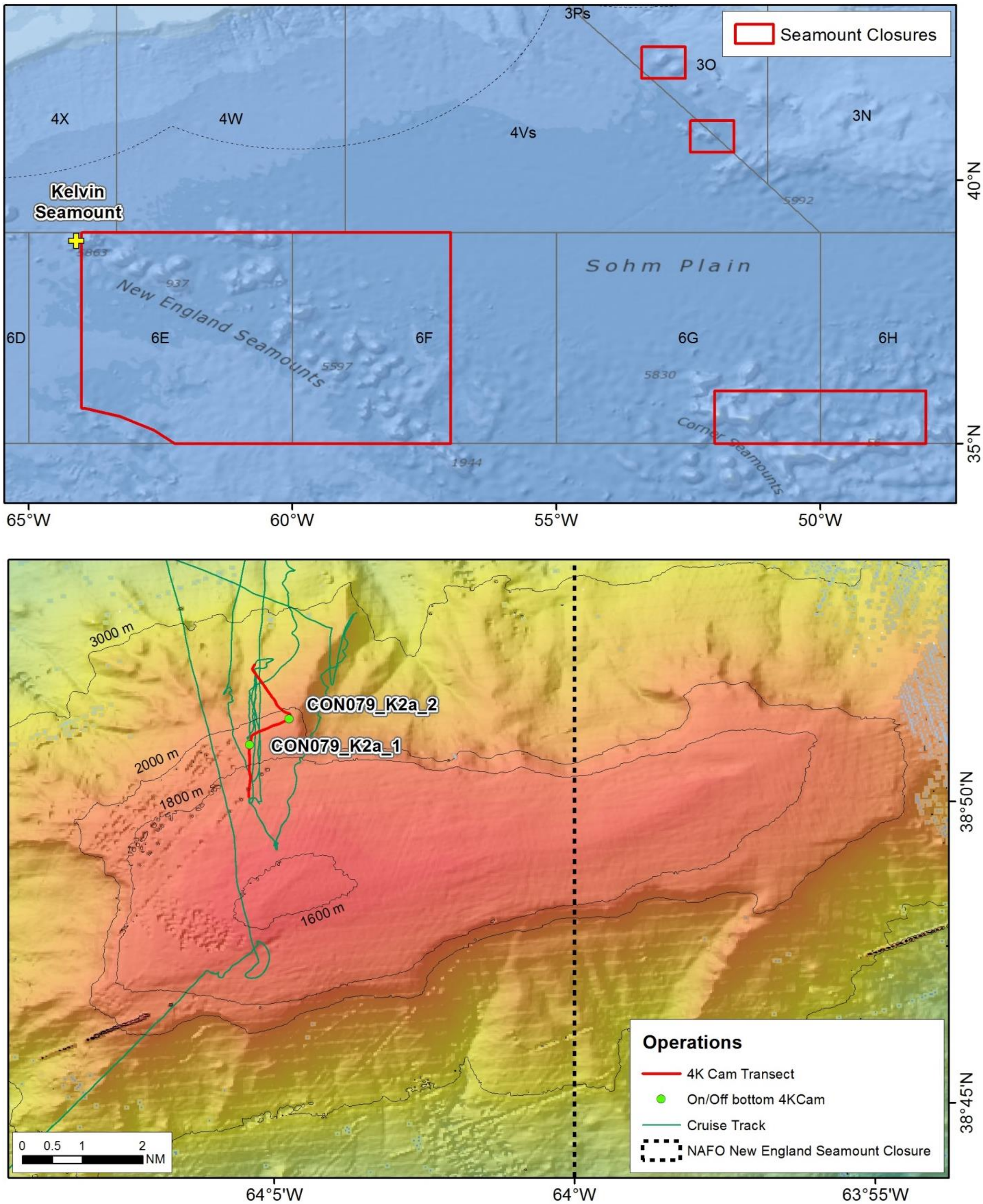

Fig. 1.5.1. Upper panel, Seamount Closures in the NAFO Regulatory Area. Lower panel, location of CON_79 in relation to Kelvin Seamount and the NAFO New England Seamount Closure.

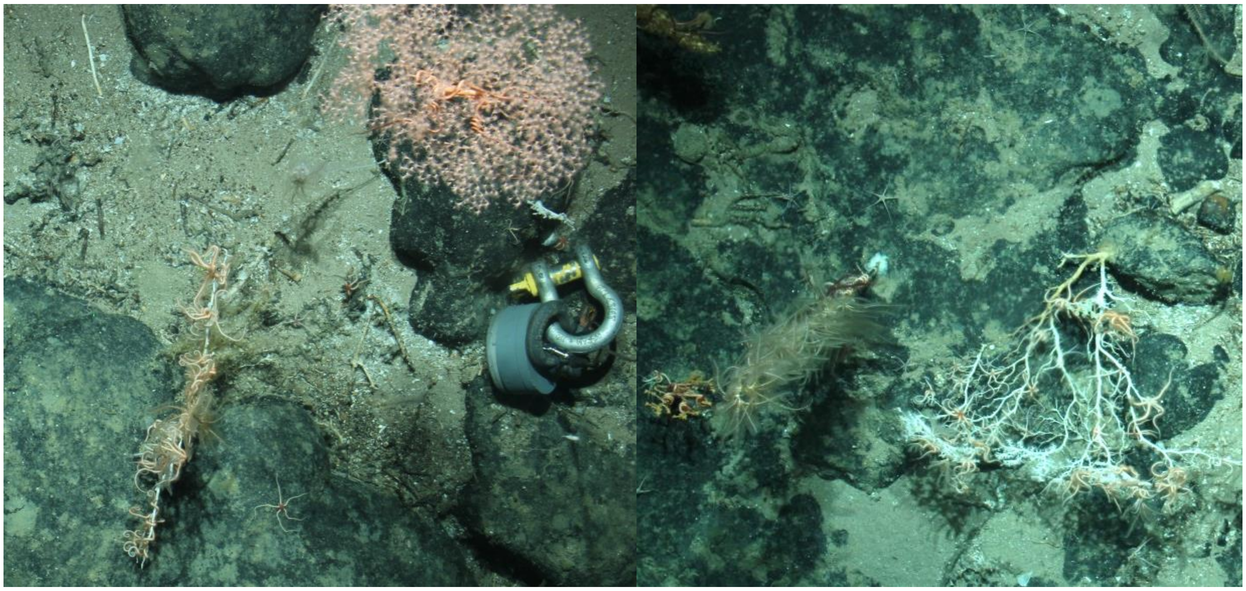

Fig. 1.5.2. Gorgonian corals and associated epifauna, mainly brittle-stars and crinoids. At the upper right corner of the left panel, the gorgonian coral Metallogorgia melanotrichos, can be observed with the associated brittle star Ophiocreas oedipus (Mosher and Watling, 2009). Corallium sp. (white gorgonian) and another gorgonian of the family Plexauridae covered by crinoids and brittle-stars can be observed on the right panel.

Table 1.5.2. Preliminary number of species (N) per taxa identified from *in situ* benthic transect on Kelvin Seamount.

Taxa	**N**
Foraminifera	
Xenophyophoroidea	≥ 1
Porifera	≥ 10
Cnidaria	
Anthozoa	3
Octocorallia	≥ 15
Hexacorallia	
Antipatharia	1
Actiniaria	1
Zoantharia	1
Hydrozoa	2
Mollusca	
Scaphopoda	2
Gastropoda	4
Arthropoda	
Crustacea	4
Echinodermata	
Crinoidea	≥ 5
Ophiuroidea	≥ 8
Asteroidea	3
Echinoidea	1
Holothuroidea	2
Others	≥ 3
TOTAL	≥ 66

In 2014 the National Oceanic and Atmospheric Administration (NOAA) completed a 3-leg expedition - Exploring Atlantic Canyons and Seamounts - from August 9 to October 7 on board the R/V Okeanos Explorer. Several seamounts from New England were explored with the ROV *Discoverer 2.* One of the upslope dives carried out on Kelvin Seamount starting at 2052 m depth found a high diversity of corals, including precious corals (Genus *Corallium*), black corals, primnoids, bamboo corals and other octocorals (Fig. 1.5.3). They also found a high diversity of sponges and other VME indicator taxa such as crinoids (http://oceanexplorer.noaa.gov/rss/ex1404_dailyupdates.xml). These results confirm those from 2003 where coral and sponge gardens were observed on Kelvin Seamount (http://oceanexplorer.noaa.gov/explorations/03mountains/logs/summary/summary.html).

Other seamounts belonging to the New England Seamount Chain are entirely (Balanus, Picket) or partially (Gregg) outside of the current NAFO closures (Figure 1.5.4.). These seamounts were explored between 2003 and 2006 by NOAA. Octocorals were observed on all of these seamounts, from the deepest dive on Kelvin (3879 m) to their summits (NOAA 2006). On one upslope dive carried out on Balanus Seamount in 2004, different species of octocorals and black corals were observed and collected between 1556 to 1912 m depth (NOAA, 2006).

In summary, the results of the Joint DFO-Nekton photographic survey on Kelvin Seamount indicate that coral VME indicator species are found shallower than 2000 m depth outside of the current closure boundary within the NRA and the species composition is similar to that found in the southeast portion of the seamount indicating that similar coral concentrations to those found on 2014 by the R/V Okeanos Explorer likely exist.
The work presented includes new evidence to extend the New England Seamount closure boundary to fully encompass Kelvin and other Seamounts, in the New England Seamount chain that are either partially protected (e.g. Gregg Seamount) or not protected at all (e.g. Balanus Seamount) This information should be considered when the boundaries of the closures are reviewed following the advice of the Scientific Council in 2014 (NAFO 2014, p82), who stated that “the polygons of the closures for both the New England and Corner Rise seamounts

be revised to the north, east and west in the NAFO Convention Area to include all the peaks that are shallower than 2000 meters".

The WG-ESA recommends the inclusion of xenophyophorids (Phylum Foraminifera, Superfamily Xenophyophoroidea), in the Annex VI. List of VME Indicator Species of the NAFO Conservation and Enforcement Measures (NAFO, 2016). This VME indicator taxa is unlikely to be caught in the trawl surveys but can be observed *in situ* through video and camera observations.

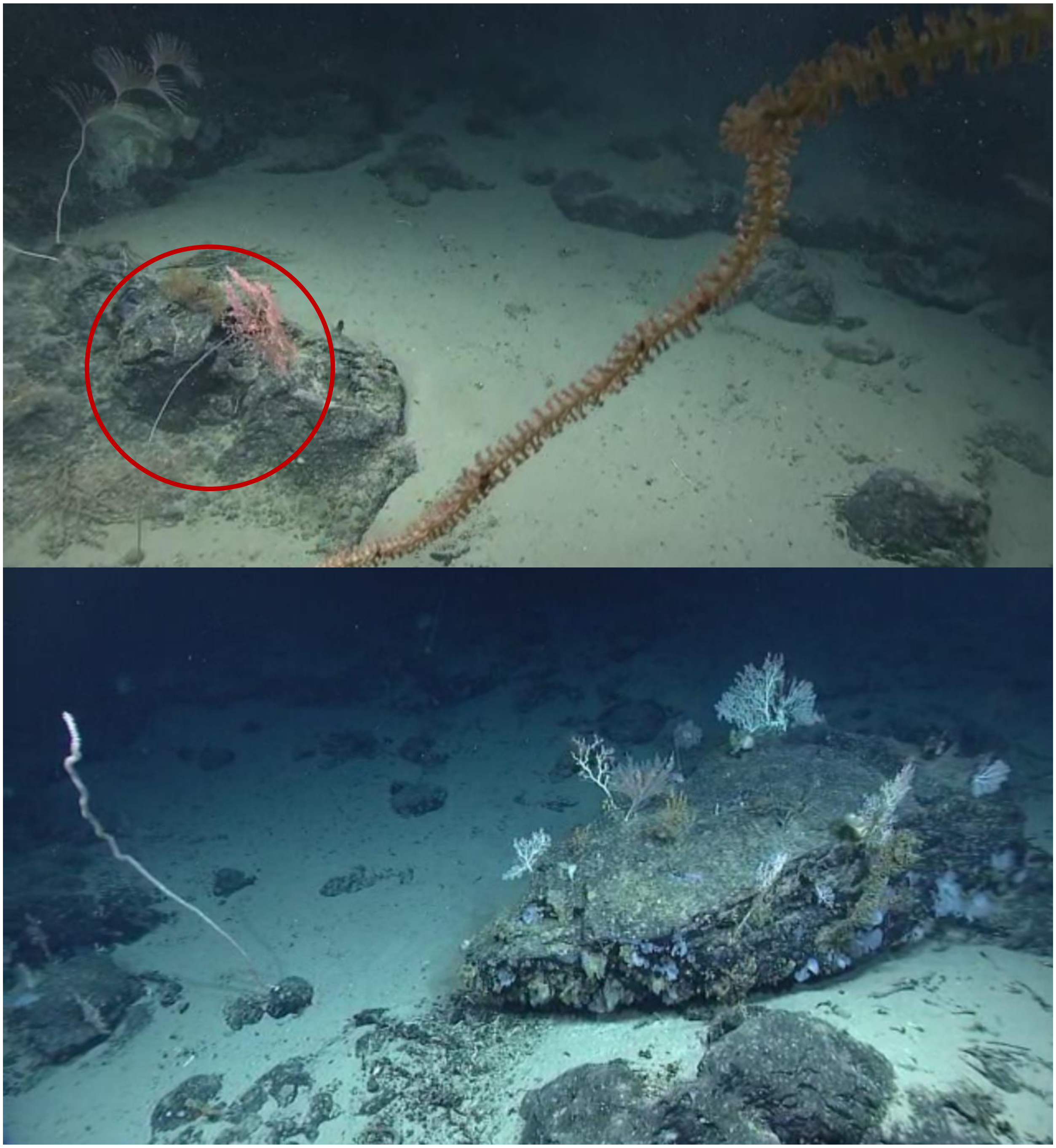

Fig. 1.5.3. Example of bottom type and gorgonians corals found on Kelvin Seamount. Frame grabs obtained from the video Okeanos Explorer EX1404L3: Our Deepwater Backyard: Exploring Atlantic Canyons and Seamounts 2014 Expedition (http://oceanexplorer.noaa.gov/okeanos/explorations/ex1404/logs/leg3-dive09/ex1404-l3-dive9.html). *The gorgonian coral Metallogorgia melanotrichos* is indicated at the upper panel by a red circle. At the lower panel several precious corals (Genus *Corallium*) can the observed attached on a rock. *Video courtesy of NOAA Okeanos Explorer Program.*

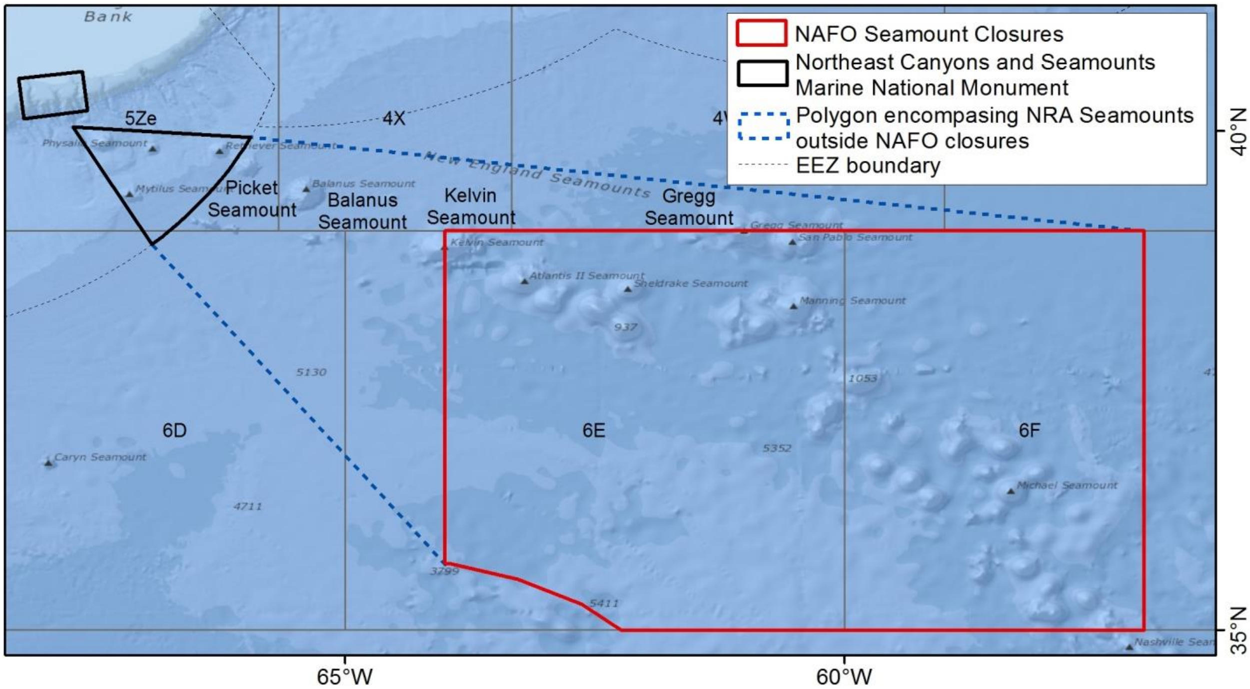

Fig. 1.5.4 NAFO Seamount Closures and Northeast Canyons and Seamounts Marine National Monument approved by the U.S. on September 15, 2016 (http://www.noaa.gov/news/first-marine-national-monument-created-in-atlantic). A polygon encompassing the seamounts of the NRA belonging to the New England complex and outside of the currently NAFO seamount closures is overlaid.

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THEME 2: STATUS, FUNCTIONING AND DYNAMICS OF NAFO MARINE ECOSYSTEMS.

ToR 2.1 Progress of analysis undertaken by EU NEREIDA funded research project [FC Request 6]

Introduction

It was noted following preliminary analysis of data to assess significant adverse impacts on coral and sponge VME in the NAFO footprint (NAFO, 2016) that sea pen appeared to be more resilient than either the sponge (*Ostur*) or large gorgonian VME. Specifically, it was observed that sea pen biomass is found in areas subject to fishing activity at levels proportionately greater than either sponge or large gorgonian VME. This observation raised the possibility that sea pen VME may recover (either partially or fully) following the cessation of fishing activities on a time scale commensurate with implementing dynamic fishery closures to sustain both sea pen VME biomass and fishing opportunities within sea pen VME. At the NAFO annual meeting in 2016 it was agreed to establish a temporary fishery closure to protect sea pen in the eastern part of the Flemish Cap, to be enforced in 2017, with the closure to be reviewed in 2018.

Accordingly, this study aims to provide essential scientific evidence to facilitate the identification of appropriate fisheries management options required to sustain sea pen VME in the NAFO footprint beyond 2018.

This study builds upon and develops the analysis previously undertaken to assess SAI on VME as part of the NAFO review of bottom fisheries in 2016 (NAFO, 2016). The study uses the same sources of biomass and VMS data (NAFO, 2016), but up-dated for the period 2006 to 2016 for sea pen survey trawl biomass, and 2008 – 2015 for fishing vessel VMS data.

The study report comprises three main sections which correspond to the projects principal objectives, namely: **i.**to determine swept area calculations through quantification of the actual direct area of impact derived from VMS data, **ii.** estimate the resilience of VME indicator species (specifically sea pen) to fishing impacts using the information on swept area impacts and VME biomass, specifically to estimate the time it takes for sea pen VME biomass to recover to a certain level post fishing impact, and iii. assess the functional significance of VME through a preliminary review of the literature and an analysis of the spatial/temporal dynamics of fisheries occurring near VME.

Determining swept area impacts

Gear Dimensions

To estimate the potential seabed surface area of impact it is first necessary to understand the size and design of the bottom fishing gears and how they are deployed and operated in NAFO fisheries. There are essentially two types of bottom fishing gear employed for fin-fisheries in the NAFO footprint which have been assessed in this study, namely; i. redfish and cod fishery gears, and ii. Greenland halibut fishery gears. Estimates of gear dimensions was made following consultation with observers on EU fishing vessels working in the NAFO Regulatory Area, and this information is summarised in Table 2.1.1.

Table 2.1.1 Gear dimensions for redfish/cod and Greenland halibut fisheries used in the present study

Redfish and Cod fisheries	Gear Dimensions
Net horizontal opening	59 metres
Net vertical opening	5 metres
Door opening (between otter boards)	140 metres

Greenland halibut fishery	Gear Dimensions
Net horizontal opening	63 metres
Net vertical opening	6 metres
Door opening (between otter boards)	165 metres

In both cases the gears consist of a combination of fishing lines, nets, and otter boards such that the fishing warps from the vessel are attached to otter boards which in turn are attached to bridles which divide the headline (top of the net) from the fishing line (bottom of the net). The point at which the fishing line is designed to have close contact with the seabed is known as the footrope and typically it has several devices attached to it (such as rockhoppers, rubber wheel bobbins and discs) which are designed to prevent it from fouling the seabed. The horizontal net opening is generally measured from the point at which the bridles start, whereas the horizontal opening between the otter boards is associated with a significant unnetted part of the gear that is not designed to have close contact with the seabed. So, in practice, the full extent of fishing line and warps do not have continuous or close contact with the seabed. However, unnetted parts of the fishing lines and warps have the potential to impact benthic organisms that stand erect off the seabed (Eigaard et al., 2016, Buhl-Mortenson et al., 2013), such as the sea pens commonly encountered off the Flemish Cap *Halipteris* sp. (sea whip)(Fig. 2.1.1).

For this study, the worst case average swept area impact was estimated to be 150 metres based upon the gear dimensions employed by the EU fishing fleets.

Fig. 2.1.1. The sea pen Halipteris finmarchica (sea whip) approx. 50 cm – 100 cm in length commonly found around the northern flanks the Flemish Cap.

Simulating the Cumulative Unit Area of Fishing Impact

The rate of accumulation of swept area from repeated passes of a bottom trawl though an area of seabed was simulated using a slightly aggregating random placement of lines across a set area. The lines were buffered to the width of the expected ground impact of fishing gear used in the study area, and the increase in area covered was calculated for each added line. For the purpose of the simulation, width of ground impact from the fishing gear has been fixed at 150m as previously justified. However, the sensitivity of the impact and recovery calculations performed in this study to changes in the swept area dimensions has not been undertaken.

The analysis was done using a 1 km x 1 km polygon. An initial random starting point was created on the edge of the square. Fishing vessels in the study area follow bathymetric contours, making passes through a 1 km square most likely to follow a constant orientation. Therefore, to account for the typical towing behaviour, lines were constrained into passing the square with some variability in orientation introduced through randomly selecting the endpoint for each line from a sample of 1000 values drawn from a normal distribution, with a standard deviation of 50 m, centred around the starting point (excluding points falling outside the square edge – Figure 3.2. Similarly, the next starting point was in turn randomly selected from a sample of 1000 values from a normal distribution with a standard deviation of 500 m (again excluding points that fell outside the square edge). The use of the normal distribution for new lines, instead of a fully random approach accounts for the tendency of fishermen to repeat successful tows. It is unlikely, however, that repeats would be accurate to within less than 500 m. Figure 3.2 illustrates the process of adding lines and calculating areas.

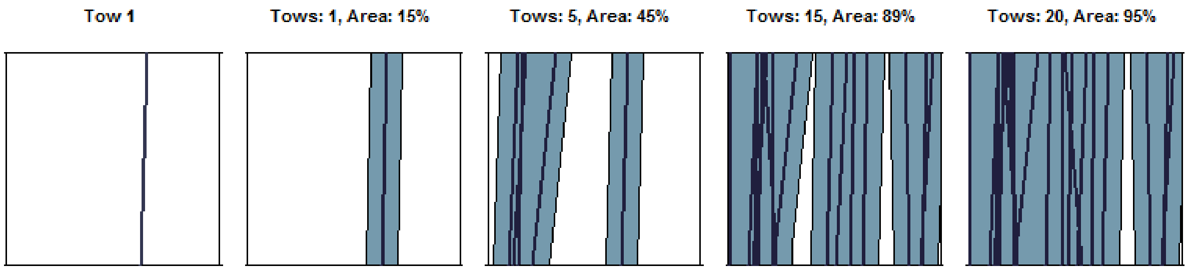

Fig. 2.1.2 Illustration of the simulation of the accumulation of area of ground impact through epeated random tows of 150 metre swath width in 1 km2.

Ten iterations of simulated tow-lines were produced to capture the variability in the spatial distribution and intensity of trawling impact. For each iteration, a series of tow-lines were produced to ensure full coverage of the square. Each line was buffered to 150 m to create a tow-line and added to the existing swept area, recording the number and cumulative length of tow-lines as well as the cumulative area of tow-line impact, until the entire square was fully covered. The buffered lines (tow-lines) were also overlaid to estimate the percentage of the square with various number of accumulating passes (Fig. 2.1.3).

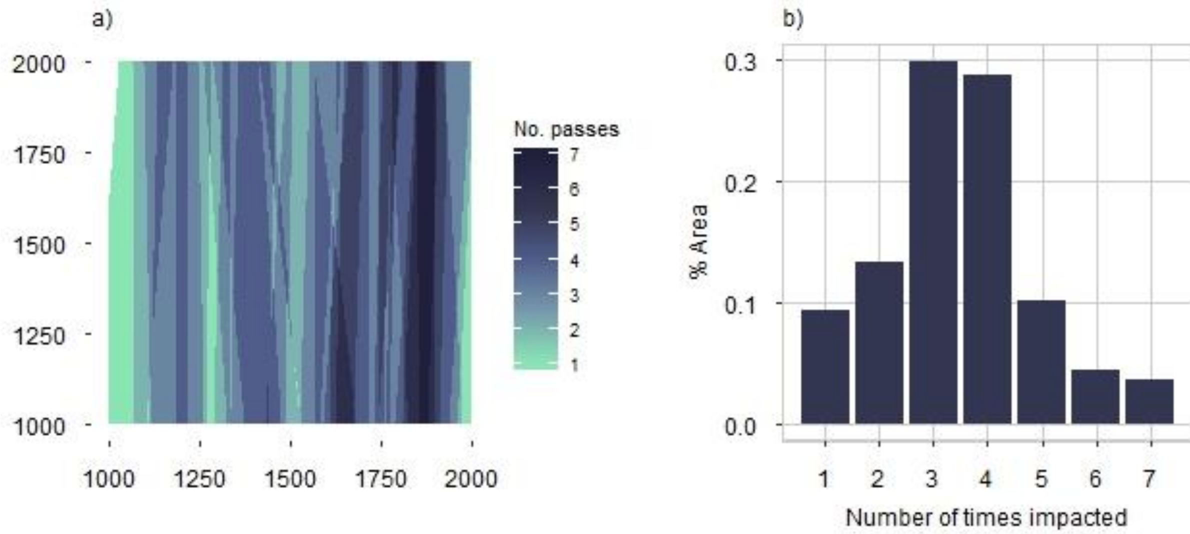

Fig. 2.1.3 Number of cumulative passes associated with random tows impacting the entire area of seabed: a) spatial distribution and intensity of impact, b) average percent of area impacted for a given number of passes (average of 10 iterations).

The analysis shows that on average about 60% of the any given area, subject to 100% trawling impact, will be repeatedly fished between 3 and 4 times. The time-interval over which the impact pattern described above occurs will depend on the amount of fishing effort (e.g. the speed of the vessel) and the dimensions of the gear (e.g. 150 m). The cumulative area of impact for each tow was plotted against the cumulative length of the of random tows (Fig. 2.1.4) which shows that it takes an increasing number tows to impact the last remaining area of seabed in any given area (e.g. it takes on average just under 4 km of trawling to impact 50% of the area, where as it takes over 31 km of trawling to impact 100% of the area). A Generalized Additive Model (GAM) was fitted to the data to find the best fit for a smooth curve between the cumulative length of tows and the cumulative percent of area covered. The best model was chosen based on visual fit on plotted points and the most even distribution of residuals. The final model was fitted on log-transformed cumulative line length using a Gaussian family and a logit link function, with 4.8 degrees of freedom. Deviance explained by the model was 93.1%.

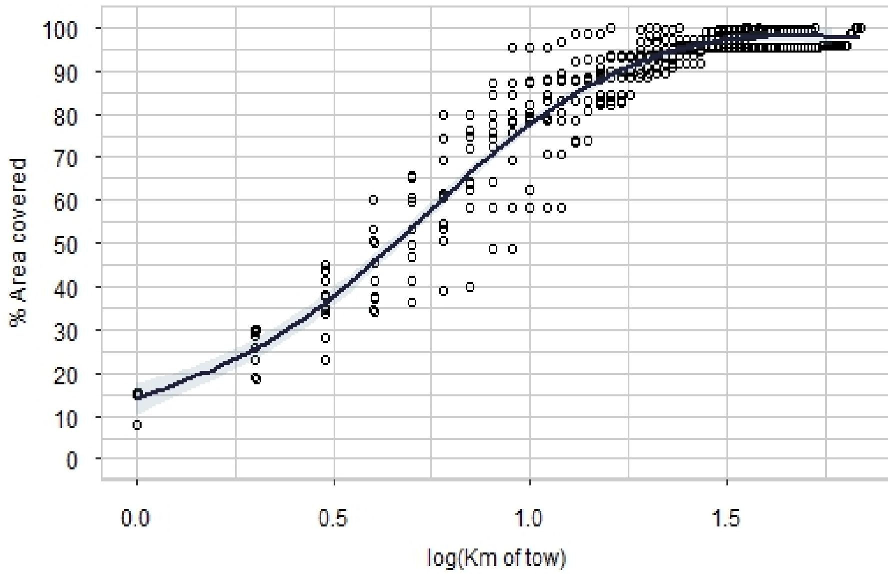

Fig. 2.1.4. Cumulative % area covered by successive simulated tows in a 1 km2 box plotted against the log of cumulative line length in kilometers. The line shows a GAM fitted with 4.8 degrees of freedom.

Resilience of Sea Pen VME

Testing Assumption of Sea Pen Biomass Equilibrium

An equilibrium in overall sea pen biomass implies that the relationship between loss of biomass caused by fishing (and other sources of loss) remains in balance over time with the recovery of biomass in unfished areas. However, two factors are important in determining whether such an equilibrium state exists or not, namely; **i.** the extent of sea pen VME habitat and the proportion of that habitat subject to fishing activity at any one time and **ii.** how the fished area changes over time. For example, if fishing effort in sea pen habitat remains relatively stable over time, but the distribution of that effort shifts from one year to the next, then areas once fished may shows signs of biomass recovery, whilst previously unfished areas now fished would be expected to experience a decline in biomass. Therefore, as stated, an equilibrium is achieved if the overall loss of biomass (caused by fishing) is equal to the overall gain in biomass (by recolonization and growth) associated with sea pen VME habitat. To test if biomass is in equilibrium, the biomass and VMS data were first divided into two equal parts (of 4 years duration each), e.g., 2009 – 2012 and 2013 – 2016, and the cumulative biomass curves against fishing pressure for these two periods was then compared. If the cumulative biomass curves for these two periods are the same, then it is indicative of an equilibrium state.

Sea pen biomass layer

As part of the NAFO review of VME (coral and sponge) fishery closures undertaken in 2014, the spatial extent of VME was determined using species kernel density analysis (KDA) (Kenchington *et al.* 2014). The analysis conducted for the review utilised VME indicator biomass data from Canadian and European trawl surveys sampled between 2003 and 2013 which resulted in a sea pen VME polygon (Fig. 2.1.5)

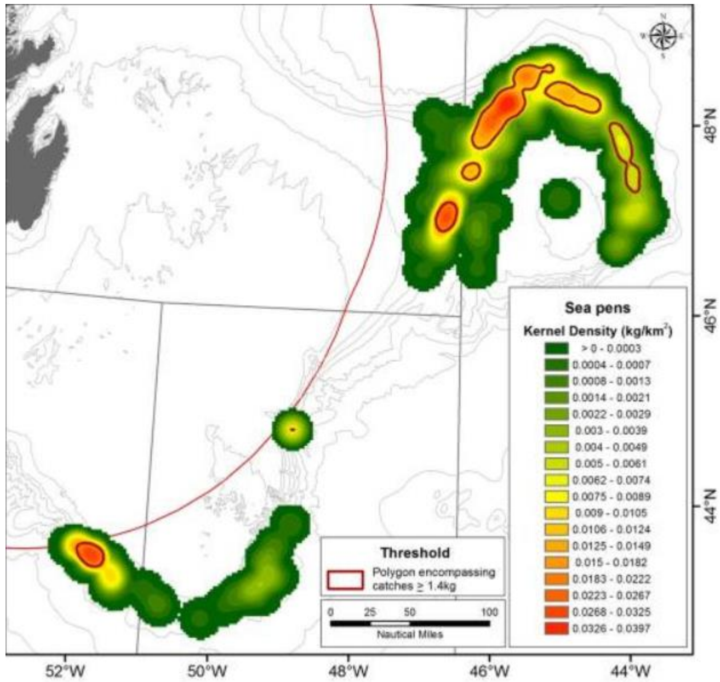

Fig. 2.1.5. The modelled distribution of sea pen showing the VME polygon (red outline) using a threshold biomass of 1.4kg from survey data (2003 – 2013), from Kenchington et al., (2014).

This KDA approach was re-applied to data incorporating the latest biomass trawl survey sample records, 2006 to 2016 (following the same methods given in Kenchington et al., 2014) (Fig. 2.1.6). The up-dated sea pen VME polygon forms a continuous 'horse-shoe' area around the North of the Flemish Cap which is consistent with habitat suitability model predictions (WGESA, 2013; Cefas, 2015) shown in Fig. 2.1.7.

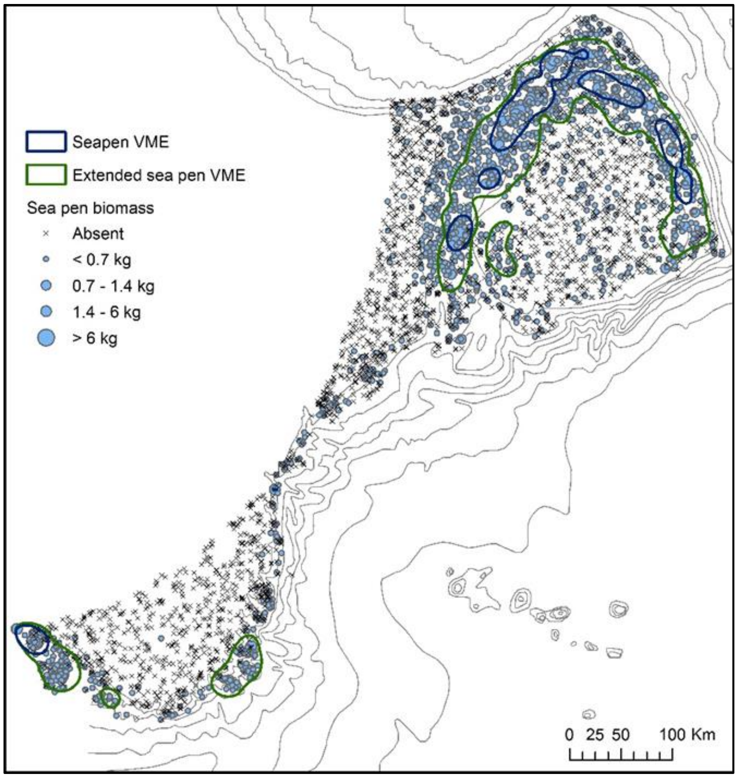

Fig.2.1.6. Sea pen biomass in 1 km long scientific trawls collected between 2006-2016, with the core sea pen VME area identified using kernel density analysis with threshold values by Kenchington *et al.* (2014) and extended sea pen study area based on a simple kernel density analysis of updated dataset, encompassing all tows above the threshold identified in Kenchington *et al*. (2014). Bathymetric contours are shown at 500 m depth intervals.

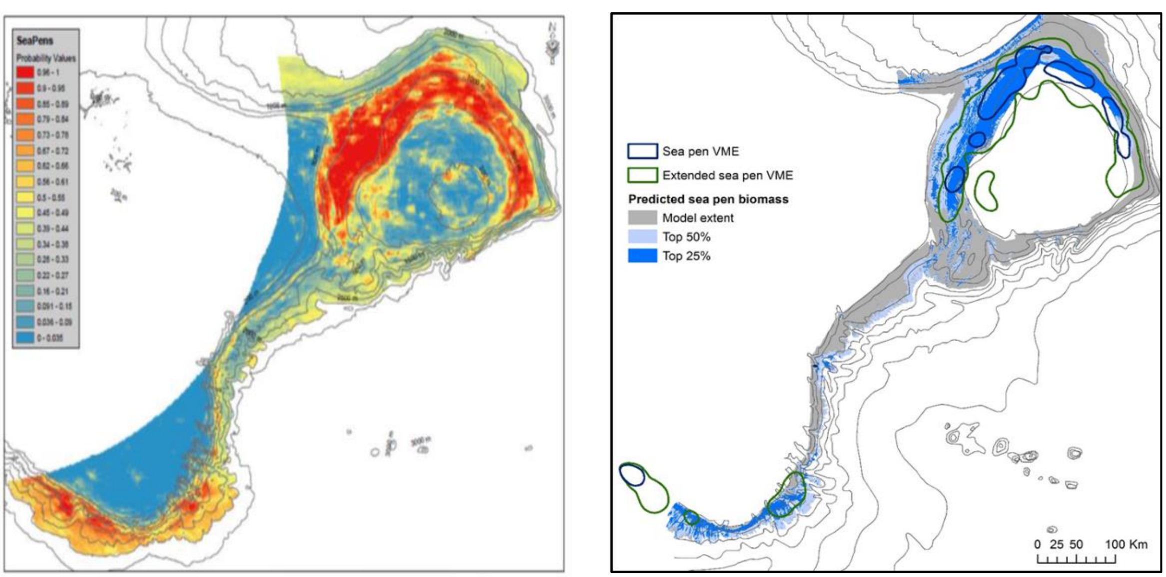

Fig. 2.1.7. Left panel shows the predicted extent of suitable sea pen VME habitat using sea pen presence/absence data (1.4 kg.km^{-2}), following methods described in WG-ESA (2013). Right panel shows the predicted extent of suitable sea pen VME habitat using all sea pen biomass data excluding areas subject to high levels of fishing activity, but restricted to depths between 400 and 2000 m, following methods reported by Cefas (2015).

The subsequent analysis and results (below) describing cumulative sea pen biomass against fishing pressure and the testing of biomass equilibrium was therefore performed on two biomass/VMS data sets corresponding to two different spatial extents, namely; **i.** data covering the original 2014 VME polygon area, and **ii.** data covering the revised sea pen VME polygon area which encompasses the original 2014 area.

Fishing Effort (VMS) data layer

Raw VMS data was supplied by NAFO for the period 2008 to 2015. From this a histogram of vessel speed was plotted (Fig. 2.1.8) and a filter then applied to the data to select only the VMS records most likely to be associated with fishing effort (e.g. between 1 and 5 knots).

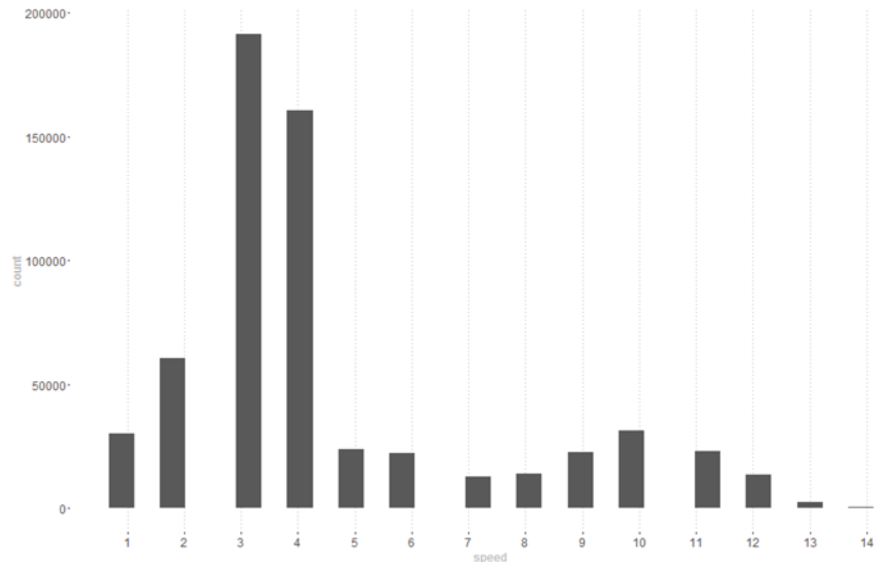

Fig. 2.1.8. Speed frequency distribution histogram for NAFO VMS data 2008 – 2015.

Fishing intensity, as hours of fishing per square kilometre per year (hrs.km^{-2}.yr^{-1}) was calculated in a 211 m cell size grid individually for each year 2008 – 2015 for which VMS data is available. Fishing effort corresponding to each scientific trawl was extracted individually for each year in the time series. The point locations for trawls are coordinates of the start of a kilometre-long tow, with direction of tow unknown. Consequently, effort was calculated as the mean of cells falling inside a 1 km buffer of the trawl start point. To account for the cumulative nature of fishing effort, the effort corresponding to each scientific trawl was averaged across years preceding the trawl. This way effort occurring after a scientific trawl had been collected does not interfere with the result. It must be noted, however, that effort recorded for the earlier years in the data set does not allow for the effects of the shifting nature of effort from year to year, with fewer years of effort included. It is also not possible to account for any shifts in effort that have happened in the preceding decades, before the beginning of the VMS time series.

A map showing cumulative fishing effort and how this has changed over time between 2008 and 2015 is shown in Fig. 2.1.9.

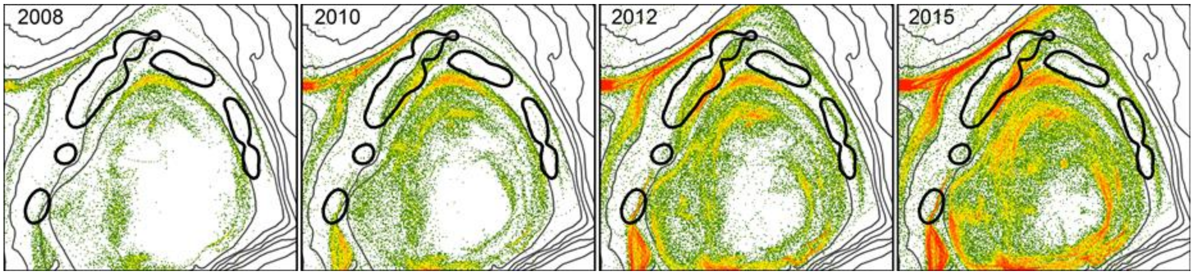

Fig. 2.1.9. Accumulation of fishing effort from 2008 to 2015 around the Flemish Cap.

Cumulative sea pen biomass (Original 2014 VME polygon area)

Cumulative biomass (expressed as a percentage and absolute biomass) against fishing pressure was analysed for the original sea pen VME polygon area, for the two periods, to generate two separate biomass response curves, e.g. 2009 – 2012 and 2013 – 2016 (Fig). The biomass and VMS data are offset by 1 year such that the 2009 biomass data was analysed against 2008 VMS data, the 2010 biomass data was analysed against the average of 2008 and 2009 VMS data, and so on. It should be noted that the number of samples between the two time-periods are substantially different, e.g. between 2009 – 2012 there are 45 samples, whereas between 2013 – 2016 there are 70 samples. Therefore, to generate plots of cumulative 'absolute' biomass for comparison between the two time-periods it was first necessary to randomly re-sample the samples associated with the 2013 – 2016 period to ensure that the number of samples between the two periods were the same. The re-sampling was done several times before fitting a GAM to all the re-sampled data (Fig. 2.1.10 – right panel). There is considerable variability in the re-sampled plots which reduces the significance of the apparent difference in the curves.

The fitted curves for cumulative % biomass show in part a small, but significant, difference (based upon two standard errors), suggesting that an equilibrium state in sea pen biomass is not apparent at levels between 75 % and 95 % of the cumulative biomass. Indeed, the difference observed, suggests that the high VME biomass areas are being depleted over time. Furthermore, this assertion is supported by an examination of the spatial pattern of cumulative fishing effort between 2008 and 2015 (Fig. 2.1.9), which appears to show a recent spatial shift in effort (from 2010 onwards) towards deeper water to the Northwest of the Flemish Cap where higher biomass of sea pen is known to occur. By contrast, relatively low effort is observed in recent years to the east of the Flemish Cap over the same period (see section).

Cumulative sea pen biomass (Up-dated, most recent, VME polygon area)

Cumulative biomass (expressed as a percentage and absolute biomass) against fishing pressure was analysed for the up-dated (extended) sea pen VME polygon area, for the two periods (e.g. 2009 – 2012 and 2013 – 2016), to generate two separate biomass response curves, (Fig. 2.1.11). It should be noted that the number of samples between the two time-periods are substantially different, e.g. between 2009 – 2012 there are 187 samples, whereas between 2013 – 2016 there are 309 samples. Therefore, to generate plots of cumulative 'absolute' biomass for comparison between the two time-periods it was first necessary to randomly re-sample the samples associated with the 2013 – 2016 period to ensure that the number of samples between the two periods were the same. The re-sampling was done several times before fitting a GAM to all the re-sampled data (Fig. 2.1.11– right panel). The response curves for cumulative % biomass show no significant difference indicating that an equilibrium state in sea pen biomass is likely apparent when assessed at the scale of the extended sea pen VME polygon. However, the absolute cumulative biomass response curves for the two periods do show a significant difference, with the more recent years exhibiting a greater total cumulative sample biomass compared to the earlier years. An explanation for this observed difference is not fully understood, but more cumulative sea pen biomass in recent years is clearly a more favourable outcome than having less biomass. However, this may be an artefact of sample design not sufficiently well representing either the cumulative pattern of fishing effort or distribution of sea pen biomass at the scale of the larger VME polygon (e.g. there may be a larger number of samples associated with low fishing effort when using the extended polygon when compared to the smaller 2014 VME polygon), this apparent difference was not investigated further in the present study.

In conclusion, it appears (especially for the extended VME polygon area) that sea pen biomass is at or close to an equilibrium state based upon the assessed fishing activity over the last 8 years. Therefore, it should be possible to estimate the recovery time to achieve a given level of biomass using a combination of the known fishing pressure as swept area impact over a given time and the associated biomass of sea pen sustained at the corresponding level of fishing pressure.

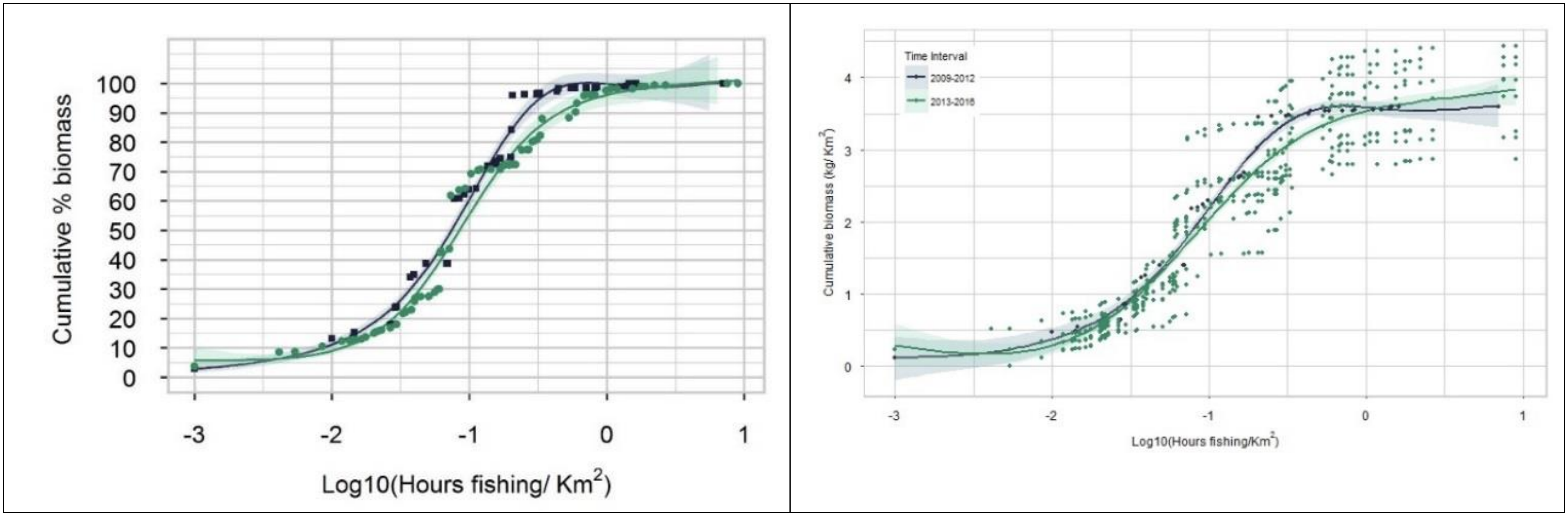

Fig. 2.1.10 Left panel. Cumulative % biomass for the 2014 sea pen VME over the gradient of increasing fishing intensity for the two periods 2009-2012 (blue) and 2013-2016 (green) in the 2014 sea pen VME polygon area. Right panel. Cumulative absolute biomass for the same set of data

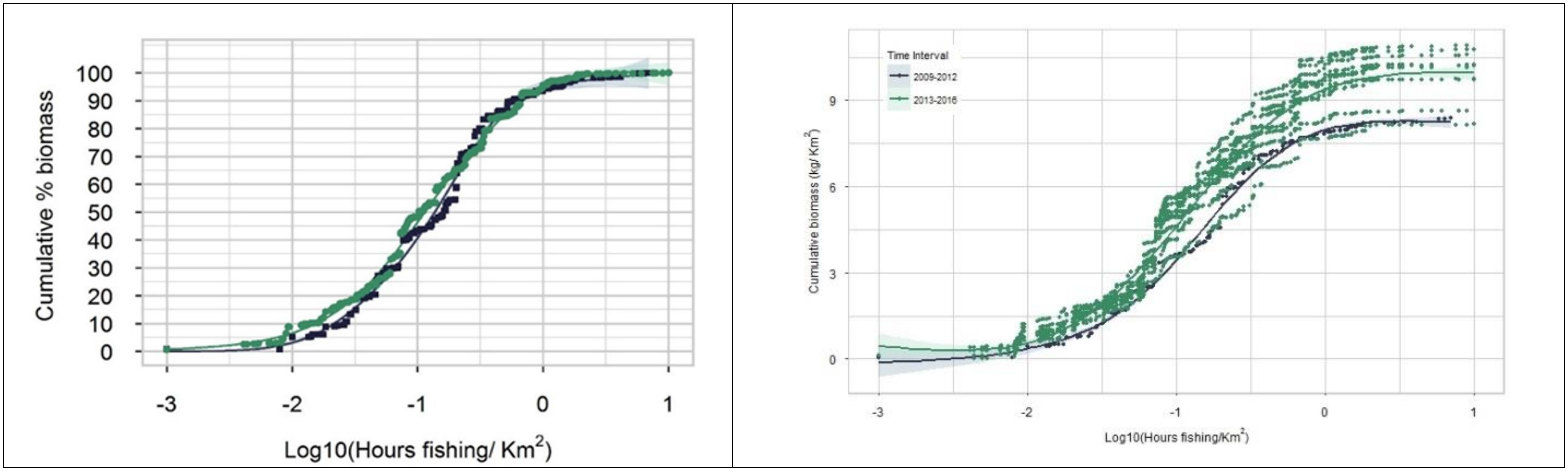

Fig. 2.1.11 Left panel. Cumulative % biomass for the extended sea pen VME area over the gradient of increasing fishing intensity for the two periods 2009-2012 (blue) and 2013-2016 (green) in the 2014 sea pen VME polygon area. Right panel. Cumulative absolute biomass for the same set of data

Estimating the Recovery Time of Sea Pen Biomass

The analysis presented above provides an estimate of the amount of sea pen biomass sustained at a given level of fishing effort (or swept area impact pressure) assuming an equilibrium state exists. The fishing effort, expressed as $hrs.km^{-2}.yr^{-1}$, was converted to total distance travelled and swept area using the previously defined gear dimensions at an estimated fishing speed of four knots. The total swept area was then equated to the total length of tow required to cover 99% of a 1 km x 1 km square, as estimated in section 0. The relationship, therefore, between fishing effort and the time it takes to impact 99% of seabed (and hence sea pen biomass) can be determined, and this is shown in Fig. 2.1.12. By knowing how much time (t) it takes to impact 99% of the seabed area (or sea pen biomass) for a given level of fishing effort, and the proportion of seabed area impacted once (f_1), twice(f_2) etc., (see Fig. 2.1.13), it is then possible to estimate the recovery time to sustain a given level of sea pen biomass by applying the following equation:

Eq.1 $$\frac{tf_1 + \frac{tf_2}{2} + \frac{tf_3}{3} \ldots\ldots \frac{tfn}{n}}{f_1 + f_2 + f_3 \ldots f_n} = Ave.\, t_{recovery}$$

Where t is the time to impact 99% of the seabed area, f is the area of seabed impacted associated with either once (f_1), twice (f_2) etc., whose upper limit is determined by the corresponding level of biomass to be sustained, e.g. *area = biomass*. This is because the biomass sustained is most likely to be associated with the area of seabed least impacted by trawling – as defined in Fig. 2.1.13.

For example, from Fig. 2.1.11, the fishing effort which corresponds to 50% of the sustained cumulative biomass is seen to be about 0.16 $hrs.km^{-2}.yr^{-1}$. The total time to impact 99% of the seabed at 0.16 $hrs.km^{-2}.yr^{-1}$ is estimated, from Fig. 2.1.12, to be about 20 years. We know that 50% of the biomass is sustained at this level of fishing pressure (assuming an equilibrium state) so [$f1$ + $f2$ + fn] = 50 (Fig. 2.1.13).

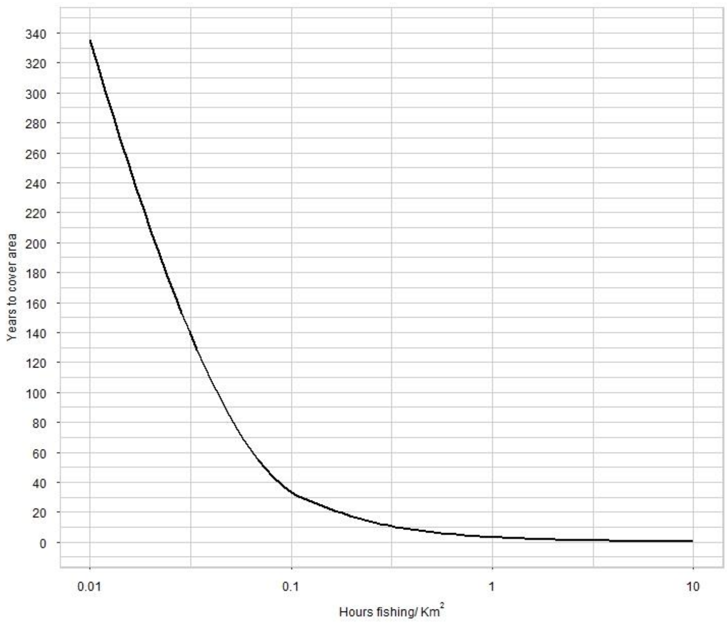

Fig. 2.1.12. Years taken to impact 99% of the sea floor at different levels of fishing effort.

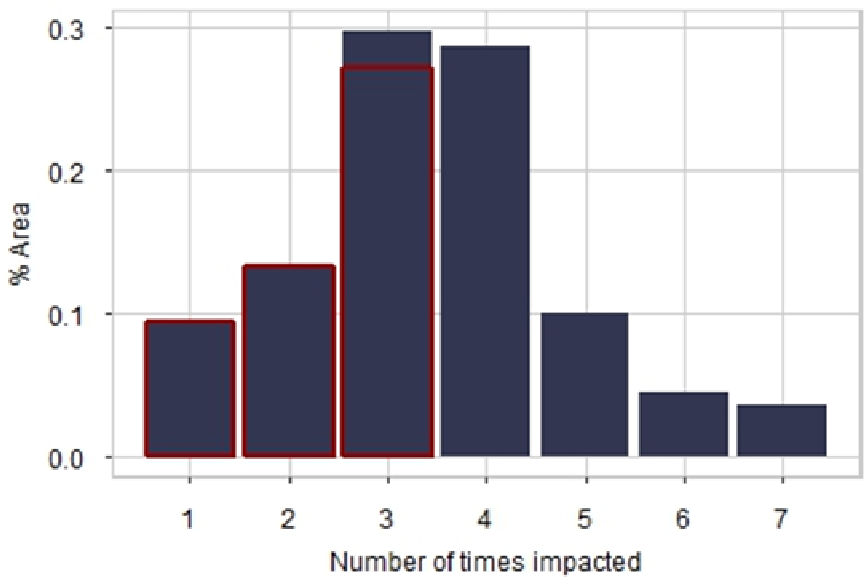

Fig. 2.1.13. Histogram showing the seabed area impacted a set number of times (over 20 years in the worked example) with the proportion amounting to 50% of total area highlighted in red.

So, from equation 1, the average recovery time in years to sustain 50% sea pen biomass is calculated to be:

$$\frac{20\times 0.095 + \frac{20\times 0.13}{2} + \frac{20\times 0.275}{3}}{0.095 + 0.13 + 0.275} = 10.1\ years$$

Repeating this calculation for different levels of sea pen biomass as determined by the two separate curves in Fig. 2.1.11 reveals differences in the recovery times of sea pen (Table 2.1.2).

Table 2.1.2. Number of years required for recovery to maintain the sea pen population at a set percentage of highest possible biomass

Sea pen biomass	**Number of years to recover from fishing**	
	2009-2012	2013-1016
40%	7.5	8.2
50%	9.4	11.26
60%	11.7	14.0

Clearly there are many assumptions behind this calculation, most notably that the sea pen biomass is near or close to equilibrium. However other factors will also either tend to increase or decrease the recovery times. Some of the sources or error and their expected impact on recovery times are noted in (Table 2.1.3), along with an indication of which of these errors is likely to be more applicable in the present assessmen. Table 2.1.3 indicates three sources of error applicable in the present study which tend to underestimate recovery times, whereas there are only two sources of error which tend to overestimate recovery times. Therefore, there is possibly a slight bias in the present analysis towards underestimating the recovery times, although the actual effect of each source of error is not known in the absence of more detailed analysis.

Table 2.1.3. Sources of error likely to impact estimates of recovery time either positively or negatively and what the tendency of the error is likely to be in the present assessment.

Potential sources of error in calculating recovery times	**Impact on estimated recovery times**	**Likely error tendency in the present assessment**
Swept area over estimated (direct and indirect loss of biomass)	↓	✓
Swept area under estimated (direct and indirect loss of biomass)	↑	-
Speed of vessel whilst trawling is over estimated	↓	✓
Speed of vessel whilst trawling is under estimated	↑	✓
Sea pen biomass is spatially clumped within suitable habitat	↑	-
Sea pen biomass is evenly distributed within suitable habitat	↓	✓
Trawl swept area is clumped	↑	✓
Trawl swept area is randomly distributed	↓	-

Nevertheless, the recovery times estimated in Table 2.1.2 are in line with reported recovery times in the literature for selected species of sea pen which are commonly found in the NAFO Flemish Cap area. For example, Neves *et al.*, (2015) conducted studies on the longevity of *Halipteris finmarchica* and reported that it is a "slow-growing, relatively long-lived organism whose recovery from damage can take over 20 years". The current study calculates that 50% of the sea pen biomass (as a composite of several commonly occurring species) can recover over a period of about 10 years. However, uncertainty remains as to the functional significance of sustaining sea pen biomass at 50% of its unimpacted state, and whether such a level of biomass would indeed represent an optimal level in terms of any functional attributes supporting commercially targeted fish stock biomass. To recover higher levels of biomass, e.g. 80%, would take considerably longer than 10 years as even 60% would take up to 14 years by current study estimates.

Functional Role of Sea Pen VME

It is now widely appreciated (e.g. Elliot and Quintino, 2007) that observing changes in structural attributes of benthic assemblages provides only a limited capacity to understand ecosystem function which is at the heart of more recent EU policy drivers, such as the reform of the Common Fisheries Policy (CFP) and the Marine Strategy Framework Directive (MSFD). Recent studies show that, following both natural and anthropogenic stressors, functional impacts and functional recovery trajectories are not always matched by their structural counterparts (Cooper et al., 2008; Grilo et al., 2011; Bolam, 2012; Wan Hussin et al., 2012). Marine benthic habitats and their communities provide a wide range of goods (e.g. fish stock biomass, minerals, energy) and services (e.g. nutrient and carbon recycling, life support, atmospheric regulation) and changes in biological indicators, based on structural attributes, may not necessarily result in significant changes in the overall functioning of the ecosystem, or their associated provisions of goods and services. Consequently, the conservation of marine systems requires knowledge of not only the species present, but also of how the system works and the effects of multiple and potentially co-interacting threats (Bremner, 2008). To fully determine how an ecosystem is affected by anthropogenic pressures, emphasis has to be placed on its functioning (Elliott and Quintino, 2007; Duarte et al., 2013).

Sustaining a balance between marine resource exploitation and biodiversity so as to protect ecosystem functioning is the *raison d'être* of the ecosystem approach (CEC, 2008). It aims to safeguard function as well as biodiversity. Therefore, an ecosystem approach to fishing impacts means that benthic function needs to be understood before it can be managed. While directly measuring ecological function (e.g., food availability for higher trophic levels, nutrient flux with overlying water) remains time-consuming and methodologically and logistically difficult, the recent development of several numerical analytical approaches has allowed alterations to functioning to be estimated and functional recovery compared with that of structural recovery (Cooper et al., 2008; Barrio Froján et al., 2011; Wan Hussin et al., 2012). The relatively recent application of Biological Traits Analysis (BTA) has provided an enhanced understanding of the responses of the benthic functioning resulting from several anthropogenic pressures (e.g. Bremner et al., 2003; Tillin et al., 2006; Papageorgiou et al., 2009; Frid, 2011; Wan Hussin et al., 2012; Oug et al., 2012; Munari, 2013; Borja and Elliott, 2013; Bolam et al., 2014) and along environmental gradients (Dimitriadis et al., 2012; Van Son et al., 2013). Utilising assemblage information to determine what the organisms do within the ecosystem (i.e., their 'traits') as opposed to merely their taxonomic identity (i.e. what they are) offers great advances into our understanding of the functional capabilities of assemblages (Bremner, 2008). Currently, little is known about how these approaches can be useful in marine ecological assessments and management, although they have been successfully and widely applied in both freshwater and terrestrial ecosystems (Guilpart et al., 2012; Colas et al., 2014). Functional diversity, i.e., the diversity and range of functional traits possessed by the biota of an ecosystem (Wright et al., 2006), is likely to be the component of an ecosystem most relevant to the functioning of ecosystems (Hooper et al., 2004). Nonetheless, there is neither an accepted suitable method for the measurement of functional diversity, nor adequate information regarding the actual traits to be used for its derivation (Petchey and Gaston, 2006).

Most research on the functional role performed by corals in benthic ecosystems has been conducted in tropical regions (Glynn, 2012), however in recent years, there has been more research in cold-temperate regions (Buhl-Mortensen *et al.* 2010) following the increase in deep water marine resource development in these areas.

A review of the evidence of the functional role that sea pens (*Pennatulacea*) highlights the potential importance of; bioturbation and baffling of sediment flows, providing a food source for higher trophic levels, creating unique habitats, acting as nurseries for fish and invertebrates and refugia for predator avoidance. Sea pens occur in "fields or patches" in areas of soft sediment on the sea floor. Unlike many benthic invertebrates, sea pen morphology is rather simple with a single stem called 'rachis' populated with feeding polyps and a bulbous base called 'peduncle' which anchors the colony (Williams, 1995). However, what they lack in individual size and structure they more than make-up for by typically occurring in large densities over wide areas of suitable seabed habitat in the form of massive sea pen "fields" (Kenchington et al., 2010; Kenchington et al., 2011; Baker et al., 2012)

There are few observations of sea pens providing suitable hard substrate for attachment by other organisms, with the exception of the Northwest Atlantic, *Halipteris finmarchia*, which has been observed with commensal sea anemones *Stephanauge nexilis* firmly attached to the rachis (cf. Miner, 1950; Wareham and Edinger, 2007), which may increase food availability located higher in the water column.

Many invertebrates (e.g. crustaceans, nudibranch) have been observed feeding on sea pens as a primary food source (Birkeland, 1974; Moore & Rainbow, 1984; Krieger and Wing, 2002). Brodeur also observed hundreds of *Sebastes alutus* inside dense aggregations of *Halipteris willemoes* in the Bering Sea (Brodeur, 2001), suggesting sea pens provide an important habitat as a source of food for red fish. Furthermore, Baillon *et al.,* (2012) has also shown that sea pens can act as important nurseries for two at least two species of *Sebastes* sp. on the Grand Banks of Newfoundland, where the larvae were observed lodged between the polyp leaf and the main rachis with yolk sac still visible.

In conclusion, there is growing evidence that sea pen fields most likely provide an important functional role in relation to commercial fish species, most notably *Sebastes* sp. The most important functions being the indirect provision of food and substrate for *Sebastes sp*.

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ToR 2.2 Approaches for analysing VMS data to determine actual fishing effort and swept area impacts [FC Request 6]

Swept Area Canadian Fisheries (FC Request 6)

Highlights

1. Vessel monitoring system (VMS) data can be aggregated over a grid to represent the fishing footprints and fishing intensities, or it can be used to create tracks and determine swept area and trawling frequency

2. Appropriate speed thresholds for fishing behaviours in VMS data can be selected through visual examination of speed histograms or through statistical mixture models

3. Logbook data can be integrated with VMS to provide opportunity for data verification

4. Emerging research provides pathways to examine impacts and extent of fixed gears on benthos

Accurate representations of fishing effort are essential to estimate potential impacts of fishing on vulnerable marine ecosystems (VMEs). Last year, WGESA created spatially explicit layers of fishing effort with point data from the vessel monitoring system (VMS) aggregated over a spatial grid (NAFO 2015). While aggregation of point-based fishing locations over a grid is a common way to represent fishing effort (Lee et al. 2010), it can inflate estimates of the fishing footprint if cell resolution is too low (Piet et al. 2007) and this approach may not reflect the trajectories of vessels during fishing.

Fisheries and Oceans Canada (DFO) staff have mapped Canadian fishing effort with a VMS point-in-grid approach (DFO 2017). However, upon project completion, their research continued to further refine delineation of fishing effort using track-based approaches for otter bottom trawl fisheries in Newfoundland and Labrador waters. DFO staff shared experiences with WGESA in order to promote the development of track-based footprints in the NAFO Regulatory Area.

The selection of appropriate fishing speed thresholds for VMS data is an important first step that can influence final results (Piet et al. 2007). In the simplest approaches, thresholds can be selected with expert knowledge or by visually examining the frequency distributions of speeds associated with VMS points assuming that speeds will belong to different "peaks" that represent vessel behaviours such as floating, fishing, or steaming. An alternative approach is to use mixture models to fit normal distribution curves to the speed histograms and assign speeds to a given distribution representing different behaviour states (Hintzen et al. 2012). DFO staff used the mixture model approach and developed different fishing speed thresholds based on the size class of the vessel, the gear type and the directed species groups. Technical details of the mixture model method used can be found in the *vmstools* and *mixtools* R packages (Hintzen et al. 2012; Benaglia et al. 2009).

Once VMS points are filtered for fishing speeds, the simplest way to create vessel tracks is to connect points with straight lines (e.g. Eastwood et al. 2007). However, this method has been shown to underestimate fishing effort because vessels do not always travel in straight lines (Hintzen et al. 2010). An alternative is to use a spline method which incorporates speed and heading recorded at individual VMS points to create a smoothed track. These curved tracks approximate the "true" track more accurately in terms of the trajectory and the distance travelled (Hintzen et al. 2010).

DFO staff applied the cubic hermite spline interpolation method to consecutive VMS fishing points according to the methods in Hintzen et al. 2010. Points that were separated by a non-fishing VMS point were considered to be from different sets and assigned a different set identifier. On the occasions where there was a single VMS fishing point surrounded by two non-fishing points, there was no track created and the number of single-point fishing instances was noted.

The time intervals (ping-time) of VMS points associated with tracks were added up and compared to the tow durations reported in logbooks. Overall, on a year-by-year basis the median estimate of fishing time from VMS was lower than reported in logbooks by at least one hour. If we assume that logbooks are accurate, it is possible that the tracks may have been underestimating effort. In an attempt to compensate for this discrepancy, DFO staff extended the tracks in a straight line on either end by approximately 30 minutes' worth of fishing. The length of the extension was based on the distance a vessel would travel in 30 minutes at an average fishing speed for the given fishery (2.2 – 2.9 km on each end, depending on the fishery).

The linear tracks can be further processed in two different ways to represent intensities. The first method overlays tracks on a grid, similar to the point-in-cell method and calculates the number of times a track crosses into a cell. The number of interactions in a given cell can be used as a proxy for trawling frequency. The advantage of this method over the point-in-cell method is that cells are not "skipped" when a vessel crosses over multiple grid cells in between VMS point transmissions.

The second method involves estimating swept area. Tracks are buffered with the trawl door spread distance as an indicator of the potential extent of impact from the track. The door spread is used, rather than the width of the net, because the different components of the gear between the doors can interact with bottom substrate (Eigaard et al. 2016). For example, the doors themselves can penetrate as deep as 35 cm depending on the substrate type (Lucchetti and Sala 2012), and sweeps and bridles may intersect with vertically structured organisms. Using the door spread as the buffer distance for tracks ensures the full extent of potential interaction between gear and benthos is considered.

Because door spreads vary across fisheries and vessels, different buffer sizes were used accordingly. DFO staff collected estimates of door spread from net manufacturers and fishing technicians in Newfoundland (Table 2.2.1), and supplied half the door spread distance as the buffer value for each side of the track.

Table 2.2.1. Estimates of door spread distance for various fisheries in Newfoundland and Labrador waters. In the instances where the values are given as a range, the midpoint was used.

Gear	**Vessel size class**	**Target species**	**Door spread (m)**
Shrimp trawl	all	Shrimp	50
Otter trawl	>=100 ft	Yellowtail flounder	250 – 300
Otter trawl	>=100 ft	Greenland halibut	250 – 300
Otter trawl	all	Redfish, cod	60 – 65
Otter trawl	65 – 99 ft	Yellowtail flounder	80 – 100
Otter trawl	65 – 99 ft	Greenland halibut	80 – 100
Otter trawl	35 – 64 ft	Other	40

Upon creation of buffered tracks, the total swept area can be calculated after "dissolving" the individual track polygons. An indicator of total trawling frequency for a given fishery can be calculated by summing the area of each individual track and expressing it as a ratio of total fished area : dissolved swept area (lower numbers approaching "1" indicate dispersed fishing activity, higher numbers indicate more aggregated activity). Alternatively, this ratio can be calculated for portions of tracks on a grid to create a proxy of trawling frequency across space.

An important consideration for future WGESA work is that the VMS time intervals can influence the ability to create accurate tracks (Hintzen et al. 2010). For point-intervals greater than 1-2 hours on average the accuracy of resultant tracks should be verified through alternative data sources such as observer data.

While bottom mobile gears are well known to have bottom impacts during normal operation, the physical impact of bottom fixed gears such as longlines is less clear. A recent report developed in Australia (FRDC 2014), examined the interactions of bottom longlines with substrates via a longline-mounted camera apparatus. The video analysis revealed that longlines can move laterally, either through or above the substratum for a mean movement of 6.2 m (standard deviation = 8.2 m, maximum > 30 m) during longline retrieval (FRDC 2014). Given that longlines can be 5000 m or longer, the "swept area" of a longline can be in the same order of magnitude of a bottom trawl deployment (FRDC 2014). For the NAFO Regulatory Area, the only non-trawling gear used is bottom longline for cod fishing in 3M, and preliminary examinations of fishery-specific effort indicate low likelihood of interacting with VME polygons at this time (ToR 3.3); however potential co-occurrence of longlines and VME polygons should be monitored.

Additionally, as fisheries-specific effort layers are in development for the NAFO Regulatory Area (ToR 3.3), fixed gear effort should receive special consideration. The use of VMS data for analysing fixed gear fishing effort can be challenging because the typical speed frequency profiles demonstrated by mobile gears do not apply (de Souza and Boerder et al. 2016). That is, similar speeds can be used for different vessel behaviours. However, for vessels using fixed gears such as longlines and gillnets, sharp turning angles indicate locations of deployment and retrieval. New research has identified methods to detect the turns and create refined methods of estimating fishing locations (Queiroz et al. 2016; de Souza and Boerder et al. 2016).

In summary, VMS data is a powerful data source that can be linked to logbooks and processed into highly resolved spatially explicit fishing effort layers. The selection of appropriate fishing speed thresholds is a key step to reduce biased estimates. Then filtered "fishing" data points can be aggregated in a point-in-cell approach. For other analyses that require more refined estimates, such as studies with a small spatial extent, data for mobile gears be processed into linear tracks with a straight line interpolation, or a spline interpolation (such as the cubic Hermite spline). These tracks can then be either overlaid onto a grid or can be buffered with trawl door spread distance to create individual polygons representing the swept area for the trawl. Although traditional speed-based filtering methods do not perform well for fixed gears, new methods have recently been developed that involve selecting areas where vessels demonstrate sharp turning angles to indicate fishing activity. The availability of many sophisticated methods and peer-reviewed literature and tools increase the opportunities for working with VMS data.

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Fishing stability in proximity to VME

Spatial dynamics of the fisheries operating in sea pen VME

A sub-set of the VMS effort data, selected from the extended sea pen VME polygon area including the 2014 VME polygon area, was created. A high spatial resolution hexagonal regular grid was created (0.025 degrees) which captures better the effort at VME boundaries) compared to a square or rectangular regular grid (Birch *et al.,* 2007). To visualise how fishing activity has changed over-time in the VME the effort data is presented in 10th percentile intervals (Fig. 2.2.1 & Fig. 2.2.2) and each hexagonal cell has a number which corresponds to the number of unique vessels fshing in that cell. For most years, the highest fishing effort is concentrated in the VME area at a depth <900 m. However, in 2012 it appears that some vessels are moving into deeper water areas, between 1,000 and 1,100 metres.

It is apparent that a significant decline in effort is observed to the east of the Flemish cap from 2009 onwards which coincides with a significant increase in effort located to the south west of the Flemish cap from 2010 – 2014, located in deeper water. What is driving this significant large scale spatial trend within the extended sea pen VME polygon is presently unknown. Some further interrogation of fisheries log-book (daily catch) data may help to explain this observed variation, especially if some fisheries were either opened or closed during this period. Nevertheless, it appears that the overall pattern of change observed in the spatial distribution of the fishery operating in the sea pen VME over the last 8 years (2008 – 2015) is of about the same duration as the time required to recover 50% of sea pen biomass (10yrs). If this is the case, then the fishing effort observed in 2008 and 2009 to the east of the Flemish Cap may represent the tail-end of several years of higher fishing activity in this area, before the fishery moved onto new areas to the west and north of the Flemish cap. However, this assertion requires further investigation before any direct and conclusive relationship between the broad scale spatial dynamics of the fishery and sea pen biomass can be made.

It should also be noted that the countries with greatest fleet presence in the extended sea pen VME are Portugal and Spain, with a yearly average of 1185 days and 823 days, respectively. The Spanish fleet operate with an average of 12 vessels per year, whilst Portugal typically operate with 10 vessels. Each vessel has on average 98 days fishing in the area.

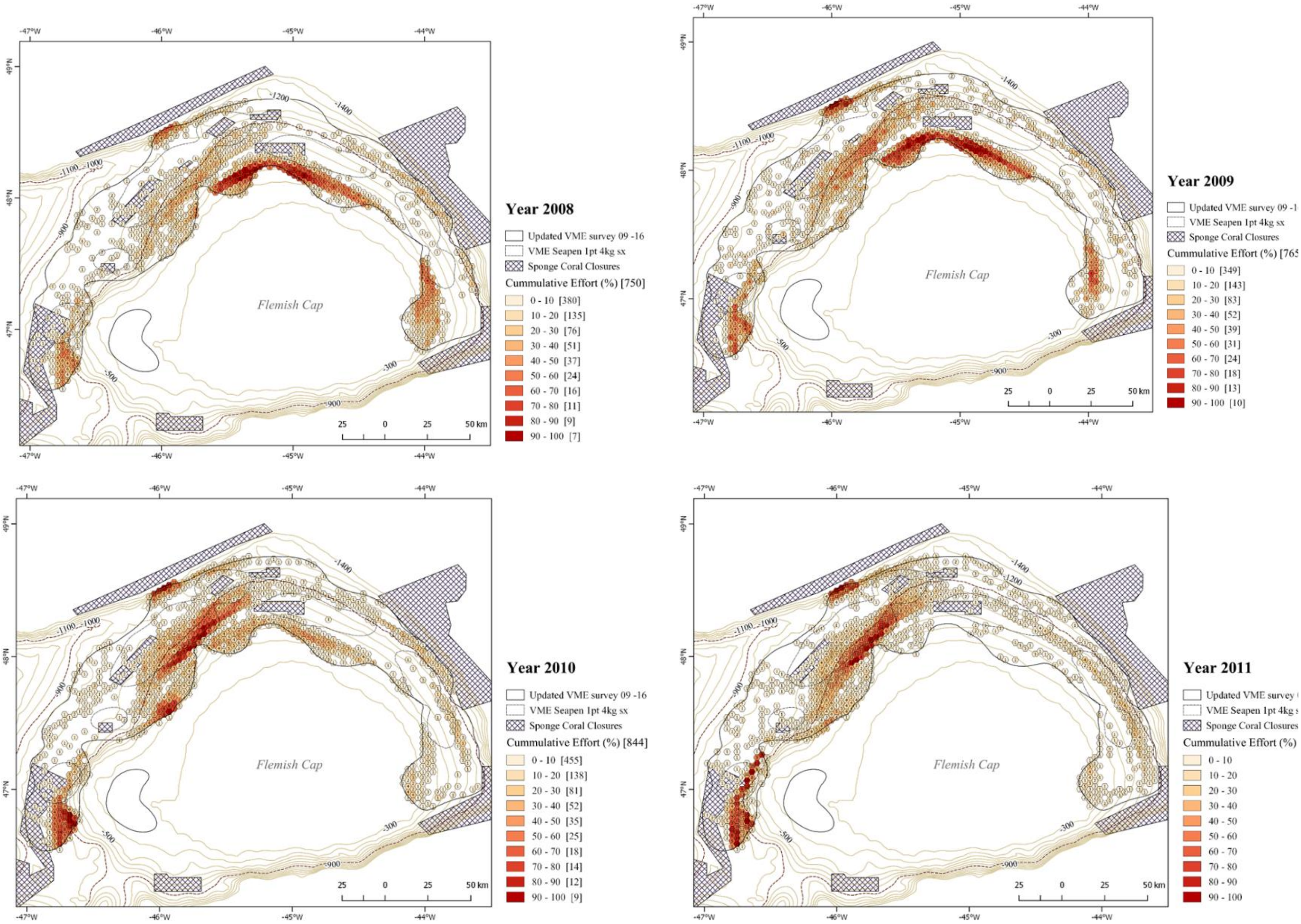


Fig. 2.2.1. Fishing effort as percentiles of effort with the top 10% of effort shown in dark red for 2008 – 2011.

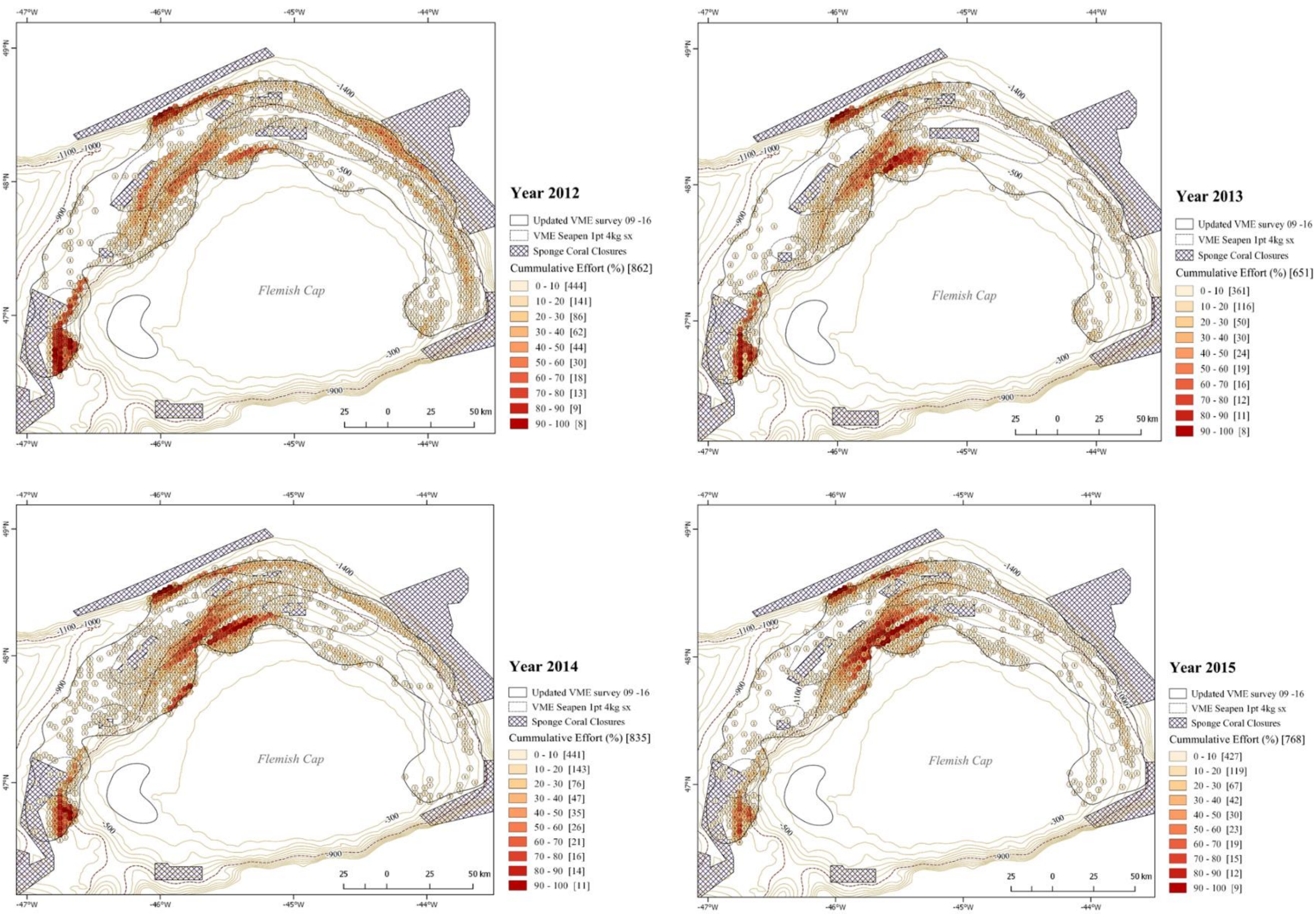


Fig. 2.2.2. Fishing effort as percentiles of effort with the top 10% of effort shown in dark red for 2009 – 2015.

ToR 2.3 Updated analysis on Guidelines for Total Catch Ceilings (TCC) in NAFO Ecosystem Production Units (EPUs)

NAFO is committed to apply an ecosystem approach to fisheries management in the Northwest Atlantic that includes safeguarding the marine environment, conserving its marine biodiversity, minimizing the risk of long term or irreversible adverse effects of fishing activities, and taking account of the relationship between all components of the ecosystem. The process and guiding principles that NAFO is following to achieve this goal is summarized in the organization's "Roadmap for developing an Ecosystem Approach to Fisheries for NAFO" (Roadmap). The current representation of the Roadmap (Fig. 2.3.1) provides an operational perspective of how the Ecosystem Approach to Fisheries (EAF) is being conceived in a work-flow process that suits NAFO structure and practices. This schematic incorporates the hierarchical approach to define exploitation rates, and integrates the impacts on benthic communities (e.g. Vulnerable Marine Ecosystems –VMEs-) associated with the different fisheries that take place within the ecosystem. The Roadmap is not a fixed plan; as its name indicates, it is a guiding set of ideas whose details evolve as it is developed and implemented.

In terms of setting sustainable exploitation levels, the Roadmap follows a 3-tier, hierarchical process (Fig. 2.3.1). The first tier defines fishery production potential at the ecosystem level, taking into account environmental conditions and ecosystem state. This allows a first order consideration for the potential influence of large scale climate/ecological forcing on fishery production, as well as explicitly considering the basic limitation imposed by primary production on ecosystem productivity. The second tier utilizes multispecies assessments to allocate fisheries production among a set of commercial species, taking into account species interactions as well as considerations on the resilience and stability of the exploited assemblage. This tier explicitly considers the trade-off among fisheries, and allows identifying exploitation rates which are consistent with multispecies sustainability. The third tier involves single-species stock assessment, where the exploitation rates derived from tiers 1 and 2 can be further examined to ensure single-species sustainability. This hierarchical sequence allows considering the sustainability of the exploitation at the ecosystem, multispecies assemblage, and single stock level.

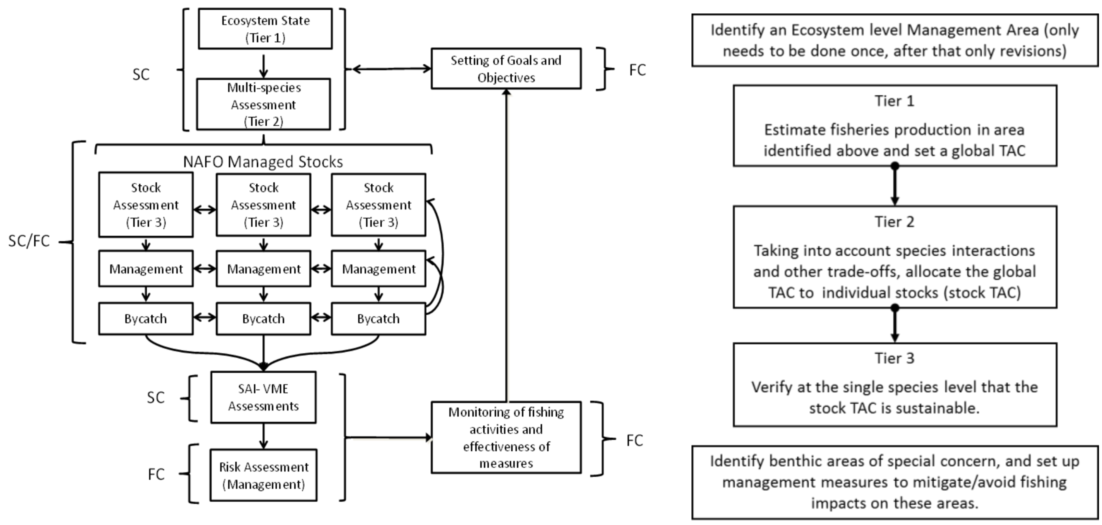


Fig. 2.3.1 Current working template of the NAFO "Roadmap" (left), with a synoptic overview of the key steps required for using it (right). SC: Scientific Council, FC: Fisheries Commission, SAI: Significant Adverse Impact, VME: Vulnerable Marine Ecosystem

As part of the work towards implementing Tier 1 of the Roadmap, WGESA and SC have been developing Ecosystem Production Potential (EPP) models for the three Ecosystem Production Units (EPUs) that SC has targeted for pilot exercises on Roadmap implementation. These EPUs are the Flemish Cap (3M), The Grand Bank (3LNO), and the Newfoundland Shelf (2J3K) (Fig. 2.3.2). These EPP models have been used to derive Total Catch Ceilings (TCCs) for these ecosystem units.

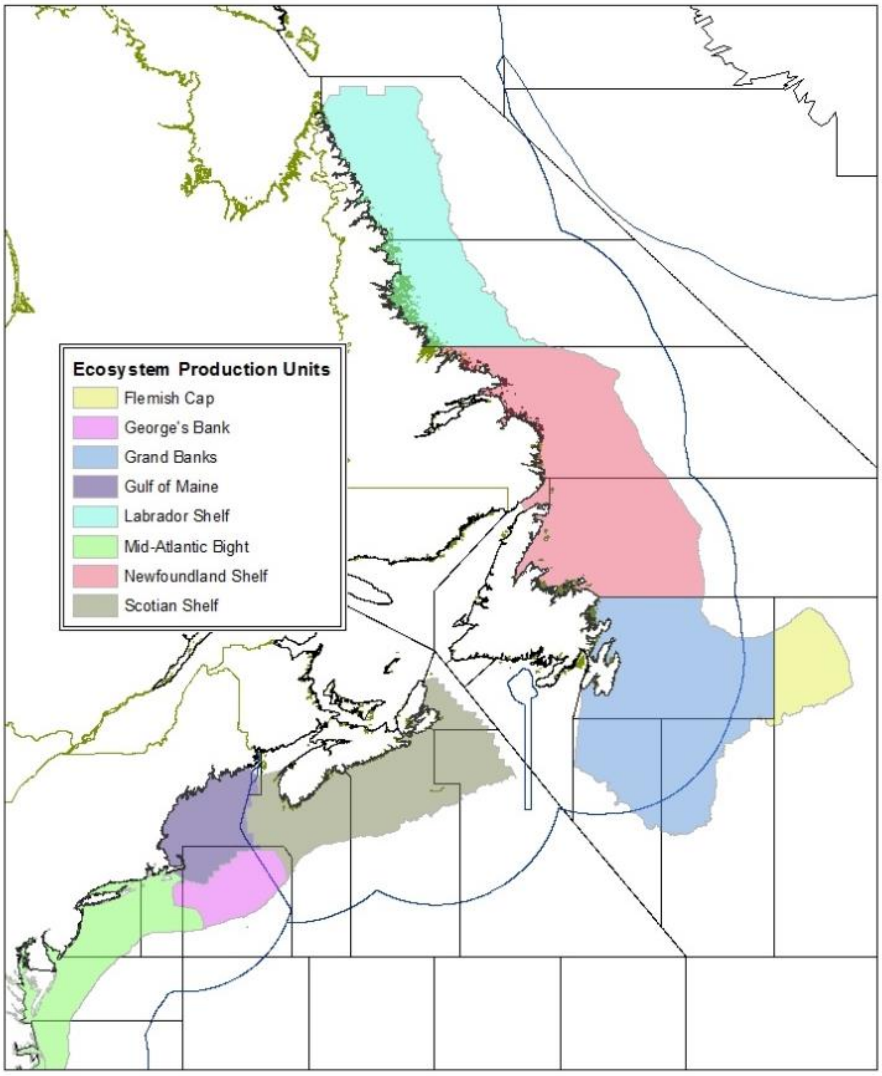


Fig. 2.3.2. Ecosystem Production Units (EPUs) identified across the shelf ecosystems in the NAFO Convention Area. These EPUs have been proposed as candidate Ecosystem-level Management Areas, and pilot exercises on the Roadmap implementation are been conducted by SC on the Flemish Cap (3M), the Grand Bank (3LNO), and the Newfoundland Shelf (2J3K) EPUs.

The process for deriving the TCCs is schematically depicted in Figure 3.20. Following this process, the TCCs and associated median values for each one of the three targeted EPUs were calculated (Table 2.3.1). These values were updated from the ones presented in 2015 after an error in data processing was corrected. Current TCC guidelines group the Fisheries Production Potential (FPP) estimated from the EPP models into "Standard Demersal Components" (SDC), which aggregates all traditional groundfish and shellfish commercial species, and "Other Components" (OC), which captures pelagic and benthos species. Catches in the three pilot areas fall almost exclusively within the SDC aggregate.

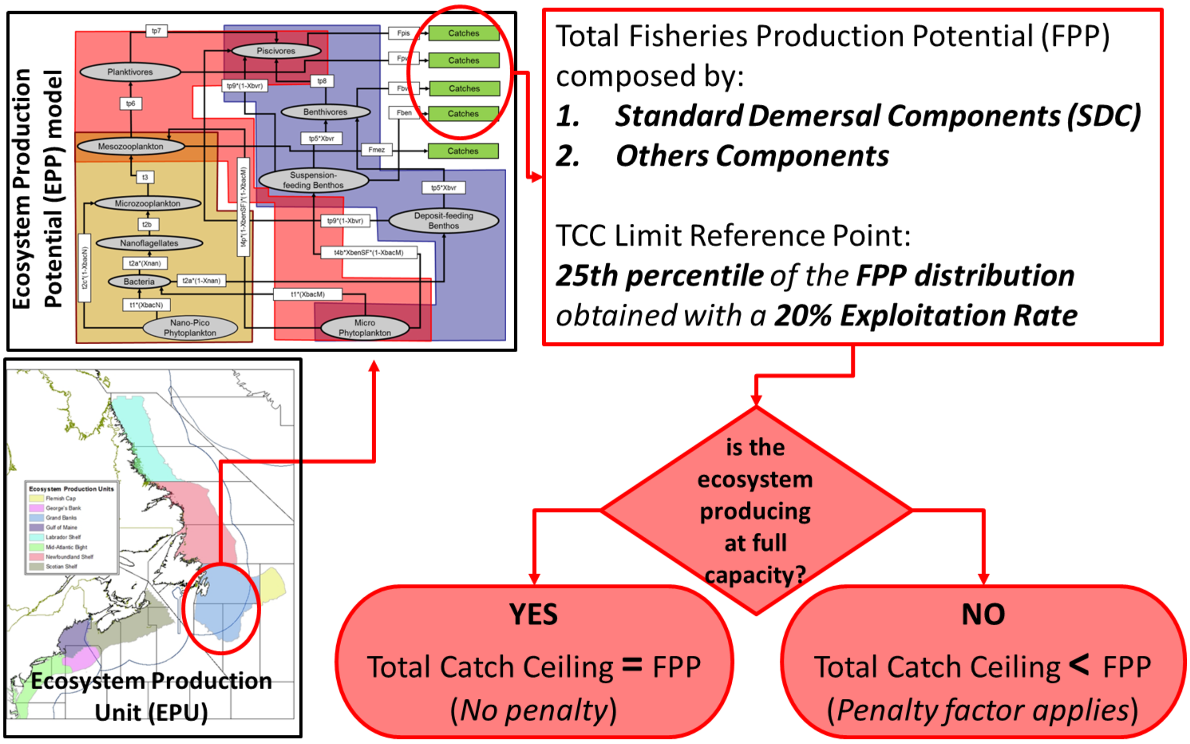


Fig. 2.3.3. Schematic depiction of the process to derive TCC LRPs from the FPP estimated using the EPP model, including the discrimination between SDC and Other FPP.

Table 2.3.1 Updated guidelines for Total Catch Ceilings (TCC) for the Flemish Cap (3M), Grand Bank (3LNO), and Newfoundland Shelf (2J3K) Ecosystem Production Units (EPUs) based on the estimated distributions of the Fisheries Production Potential (FPP) for these areas, and the application of penalty factors when required. TCCs are provided for the Standard Demersal Components (SDC) and Other Components (OC) aggregates of species. SDC includes traditional groundfish stocks as well as shellfish species (e.g. Atlantic cod, Greenland halibut, American Plaice, Redfish, Yellowtail flounder, Witch flounder, Northern Shrimp, snow crab), while the OC includes pelagic and benthic species (e.g. capelin, herring, scallops, sea cucumbers).

	Standard Demersal Components (SDC)		Other Components (OC)	
	TCC LRP Guideline (25th percentile of FPP distribution)	Median (50th percentile of FPP distribution)	TCC LRP Guideline (25th percentile of FPP distribution)	Median (50th percentile of FPP distribution)
Flemish Cap EPU (3M)	52,000 tonnes	83,000 tonnes	57,000 tonnes	82,000 tonnes
Grand Bank EPU (3LNO) (penalty factor: 50%)	116,000 tonnes	186,000 tonnes	128,000 tonnes	185,000 tonnes
Newfoundland Shelf EPU (2J3K) (penalty factor: 50%)	87,000 tonnes	140,000 tonnes	96,000 tonnes	140,000 tonnes

Although most targeted species can be coarsely assigned to the different nodes in the EPP models, reality is that many species actually spend stages/periods of their life history in different nodes. This is the rationale behind combining the piscivore and benthivore nodes within a single SDC aggregate for the purpose of advising on TCC values. However, aggregating nodes has the potential drawback of hiding imbalances in the distribution of catches within an aggregate. For example, if all catches within SDC are directed to a single benthivore stock, the total catch level would appear as sustainable, even though the benthivore node itself and the specific stock being targeted would likely be overfished.

WG-ESA and SC explored this issue in 2015 and 2016, and concluded that catches in the Flemish Cap EPU were severely biased towards piscivores, which suggested that the sustainability at the ecosystem levels could be in jeopardy. To prevent impacts on this ecosystem unit, it was advised to moderate catches on cod, redfish or both, and it was indicated that Tier 2 level analyses (e.g. multispecies models) were required to further explore this situation.

In 2016, WG-ESA continue developing the multispecies model for the Flemish Cap (see section 2.4), but it also further refined the analysis at the Tier 1 level. This refinement involved a closer examination and partition of the catches by EPP node.

As indicated above, a key argument for presenting TCC advice at the SDC and OC aggregate levels is the fact that the production of different stages of a target species are associated with different EPP nodes. For example, early life history stages of species typically associated with the piscivores node are likely contained in the planktivores and/or benthivore nodes. This implies that assigning all catches to a single node may overestimate the actual fishing pressure that node is receiving. In order to refine current catch allocations against the estimated TCC levels in the Flemish Cap, the changes in diet of key target species with size were used to estimate fractions of the catch that could be allocated to different nodes in the EPP model.

This analysis involved two main components; the first one was the examination of the diet by predator size and assigning the different prey types to a corresponding node within the EPP model architecture. This allowed estimating how the diet of the target species was dependent on different EPP nodes. The second component of the analysis was to estimate the size distribution of the catches, and determine which fraction of the total catch in biomass was associated with different size ranges. Finally these two components were integrated to estimate the fraction of the catch of the target species that was dependent on different nodes within the EPP model. This analysis was directed to the three key target species in the Flemish Cap: cod, redfish (taken as a multispecies aggregate), and Greenland halibut. The results of this analysis are summarized in Table 2.3.2

Table 2.3.2. Revised assignation of the catches of key species in the Flemish Cap (3M) to different nodes of the Ecosystem Production Potential (EPP) model. This revision is intended to improve the allocation of catches to the different EPP model nodes, and hence, provide a more accurate representation of catches for comparison with TCC levels.

	Initial assignation (no split among nodes)		Revised assignation (split among nodes based on diet composition and size)	
Target species	Piscivore EPP Node	Planktivore EPP Node	Piscivore EPP Node	Planktivore EPP Node
Atlantic cod	100.0%	0.0%	84.7%	15.3%
Redfish	100.0%	0.0%	59.4%	40.6%
Greenland halibut	100.0%	0.0%	100.0%	0.0%

This revised allocation of catches allowed a re-examination of the catch levels in the Flemish Cap in relation to the estimated TCCs (Fig. 2.3.4). These results indicated that, although the fraction of piscivores represented in the catch is lower than previously estimated, the total catch for piscivores is still clearly above the sustainable level for that component. This refinement also increased the catch associated with the planktivore node, and consequently to the OC aggregate.

In addition to the revised allocation of catches, this revision also considered the catches for transient pelagic species (e.g. tunas, oceanic sharks) reported to NAFO. These catches were excluded from the nominal catch series under the premise that the production associated with these species is largely derived from resources outside the Flemish Cap EPU. Given their relative magnitude keeping or excluding these catches had no impact on the results.

On the basis of this examination, similar revisions will be entertained for the other targeted EPUs (2J3K and 3LNO). At the present time, and taking into account the available diet data, the current level of catches, and the estimated TCCs, it is expected that this examination will have minimal impacts on the current Tier 1-level advice for the Newfoundland Shelf and the Grand Bank EPUs.

In summary, the refinement and re-examination of the catch assignations in the Flemish Cap EPU rendered a reduced piscivores catch levels, but still showed a severe biased towards piscivores catches in this ecosystem, reinforcing the original WGESA conclusion that current catch levels and their distribution among target stocks could be jeopardizing the sustainability of the fisheries. These results indicate the need for considering the interactions between cod and redfish when defining Total Allowable Catches (TACs) for these stocks, and further highlight the importance of implementing both Tier 1 and Tier 2 of the Roadmap to ensure ecosystem-level sustainability in the Flemish Cap fisheries.

Finally, these revisions and closer examinations of catch levels in relation to the estimated TCC levels, clearly shows that, in addition to the originally reported aggregates, comparisons with TCCs at the EPP node level are also useful. Implementing Tier 1 and Tier 2 of the Roadmap is expected to be an iterative process between scientists and managers, and the TCC estimates from the EPP models may potentially be used in different contexts. Therefore, it could be useful to report, in addition to the SDC and OC aggregates, the equivalent FPP values at the EPP node level that feed into these aggregates. These values, together with the SDC and OC ones, are summarized in Table 2.3.3.

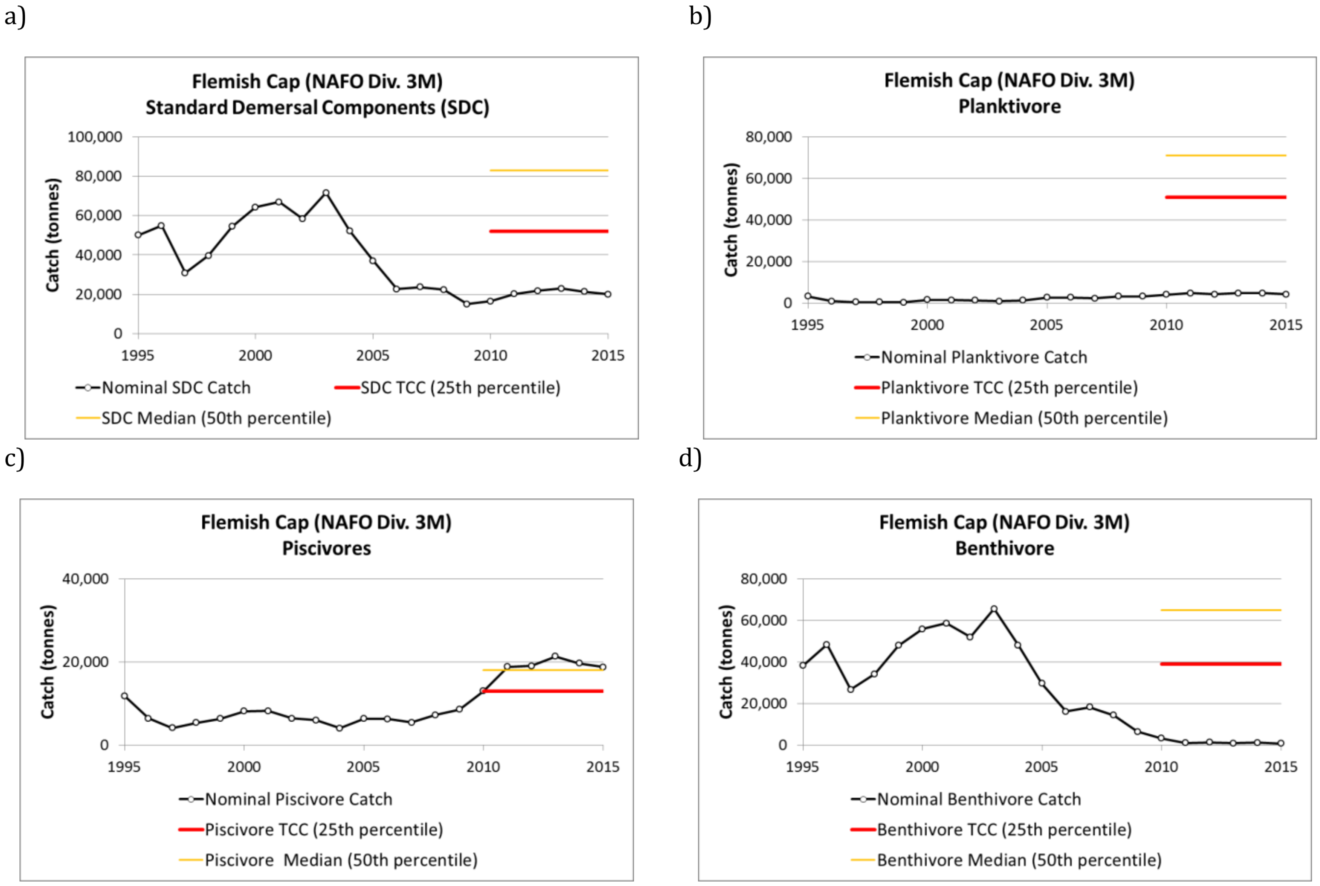


Fig. 2.3.4. Updated comparison between nominal catch levels and the estimated TCC levels in the Flemish Cap (3M) EPU. a) Standard Demersal Components (SDC) correspond to the aggregate of Piscivores and Benthivores; b) Planktivores is one on the nodes in the Other Components (OC) aggregate; catches of this node increased because early stages of cod and redfish were re-assigned to this node; c) Piscivores; although revised assignations indicated a reduction in the catches on this node, the revised values still indicate a fishing pressure well above the TCC level; d) Benthivores; catches on this node did not change after the revised assignation of nominal catches.

Table 2.3.3 Summary of Total Catch Ceilings (TCCs) (25th percentile of the Fisheries Production Potential –FPP- distributions), and medians (50th percentile of theFPP distributions) for the original aggregates (Standard Demersal Components –SDC-, and Other Components –OC-), as well as for the individual Ecosystem Production Potential (EPP) model nodes. All values in this table are in thousand tonnes.

	Ecosystem Production Units (EPUs)		
	2J3K	3LNO	3M
EPP Aggregates			
SDC Total Catch Ceiling (TCC) (25th percentile)	87.13	116.21	52.06
SDC Median FPP (50th percentile)	139.83	185.93	83.50
OC Total Catch Ceiling (TCC) (25th percentile)	95.70	128.42	57.19
OC Median FPP (50th percentile)	139.71	185.31	82.40
EPP Individual Nodes			
Piscivores Total Catch Ceiling (TCC) (25th percentile)	22.31	29.94	13.32
Piscivores Median FPP (50th percentile)	30.78	41.35	18.44
Benthivores Total Catch Ceiling (TCC) (25th percentile)	64.83	86.26	38.73
Benthivores Median FPP (50th percentile)	109.04	144.57	65.06
Planktivores Total Catch Ceiling (TCC) (25th percentile)	84.30	114.55	51.16
Planktivores Median FPP (50th percentile)	118.95	160.66	71.50
Suspension Feeding Benthos Total Catch Ceiling (TCC) (25th percentile)	11.41	13.87	6.03
Suspension Feeding Benthos Median FPP (50th percentile)	20.76	24.65	10.90

ToR 2.4 Flemish Cap multi-species model

Introduction

The way we can influence in the state and dynamic of exploited stocks is by changing quantitatively and qualitatively the fishing activity: fishing effort, exploitation pattern by age/size, protected areas and biological states, seasonal fishing closure, etc. However, it is important to consider not only the direct effect of a given management strategy, but also the indirect effects mediated by trophic interactions, both in the population for which the management is being designed but also for other species in the ecosystem (some of them of commercial value as well). In addition, other than trophic interactions, different fishing patterns could affect in different way on the Spawning Stock Biomass (SSB) and the reproductive potential of the stock, and hence in the expected recruitment.

Single species stock assessment models indicate that the Flemish Cap cod and redfish stocks experienced extreme fishing mortality during the late 1980's and early–mid 1990's, which in conjunction with bad recruitments produced the declines of both stocks, and the collapse of cod by mid 1990s. For shrimp, catch and survey index analysis have been used to support that the strong fishing mortality was the main reason for the collapse of this stock by 2010. However, the outcomes of the project GadCap (EU Marie Curie project to develop a Gadget multispecies model for cod, redfish and shrimp in the Flemish Cap) supports that not only fishing mortality has been important but: *"Fishing , recruitment and predation mortality changed strongly since 1988 in their relative influence by species, age, and length over time, and worked in a synergic way producing a transition from a traditional redfish-cod dominated system in the early 1990s, to an intermediate shrimp-other fish species state by late 1990s, and turn back to something close to the initial state by late 2000s."* (Pérez-Rodríguez et al, 2016).

Ecosystem and multispecies model allow performing simulations in which different attributes of fishing activity are changed and the consequences of those changes can be evaluated at different levels in the exploited system. In this work the multispecies model GadCap was used to examine how different fishing strategies over the period 1988-2012 could have affected the three exploited stocks producing different configurations of the Flemish Cap. Special attention was focused on exploring if different fishing strategies could have avoided the collapse of cod and shrimp and the declines of redfish, leading to higher and/or more stable yields over time. The importance of fishing in the dynamic of all the three stocks affecting and interacting with predation and recruitment processes were analyzed.

Material and methods

To perform these simulations the structure of the multispecies model GadCap has been maintained as presented in Pérez-Rodríguez et al, 2016 (Fig. 2.4.1) with cod, redfish and shrimp split in different sub-stocks based in sex, maturity state and diet composition. Immature and mature cod preyed on immature cod, redfish, shrimp, whereas redfish preyed on immature redfish and shrimp. Two fleets fished on cod (gillnetters and trawlers), one trawl fleet fished on redfish, and one trawl fleet on shrimp, which also caught redfish as by-catch especially in years 1993 and 1994.

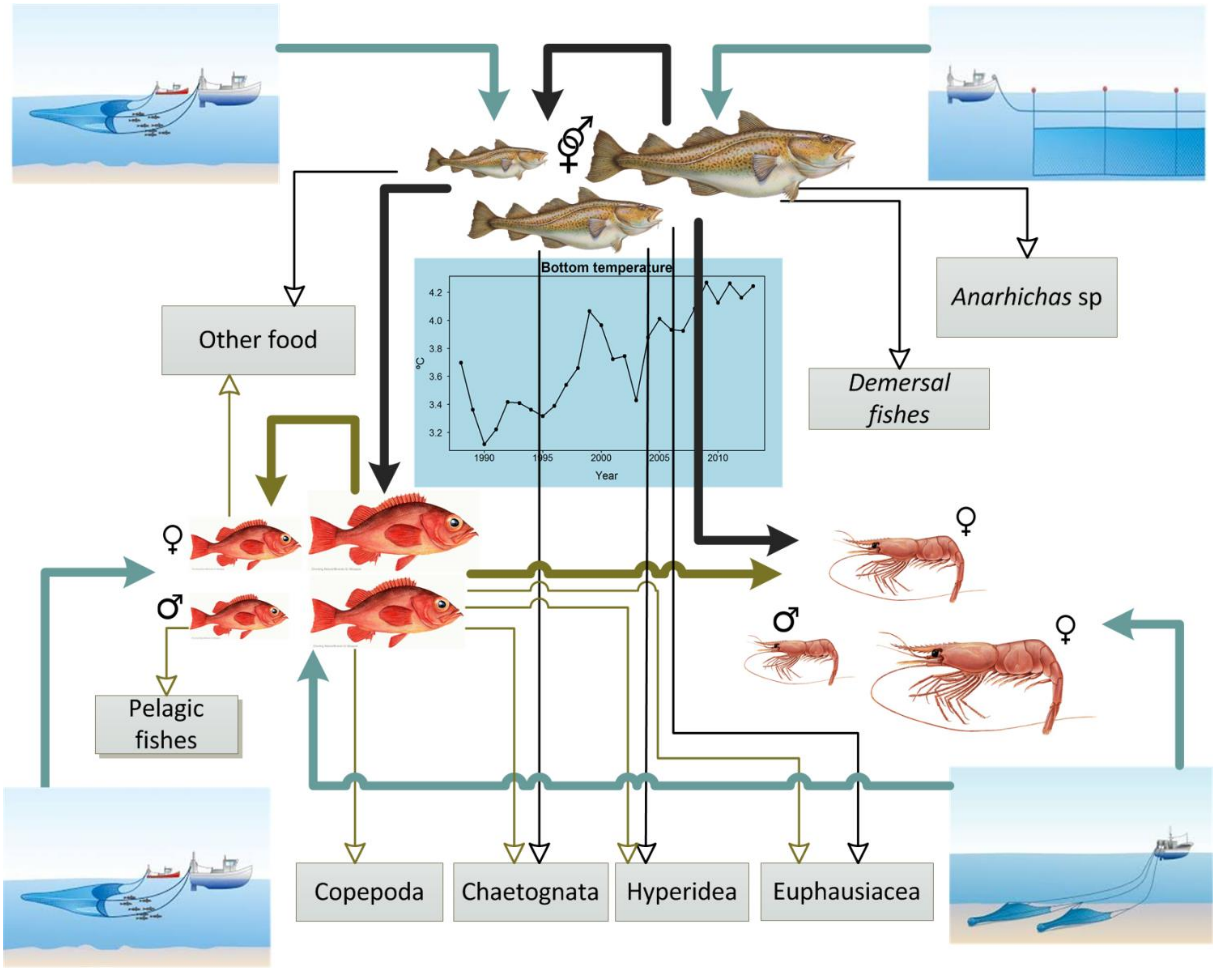


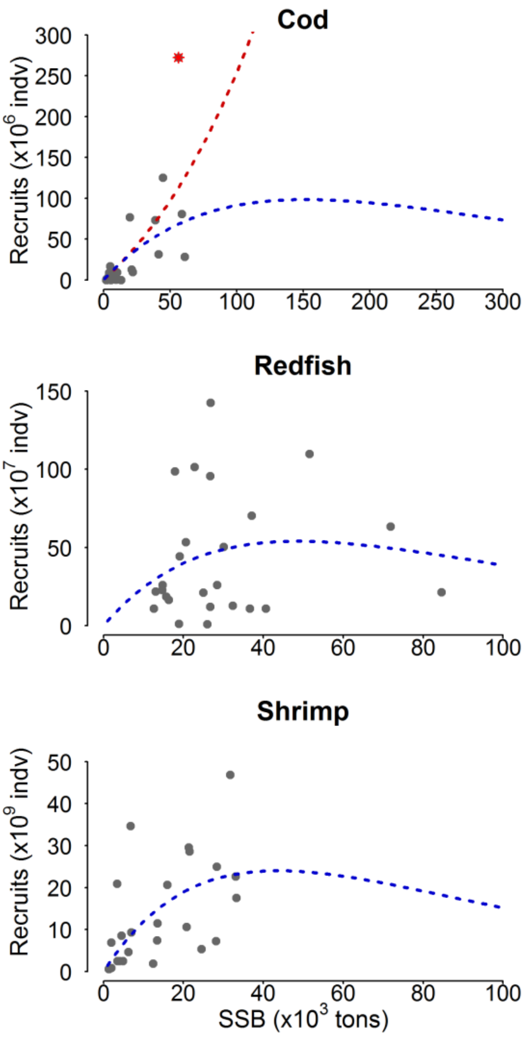
Fig. 2.4.1. Structure of model GadCap, with the three stocks cod, redfish and shrimp split in sub-stocks based in sex, maturity state and/or diet composition. The trophic interactions between these three stocks, the commercial fleets as well as alternative prey species are shown. The bottom water temperature was utilized to model cod consumption.

However, two elements have been changed in GadCap to arrange the model to perform more sounded simulations.

- The first component is the introduction of annually varying SSB-Recruitment relationships. To do so for each stock a Ricker SSB-Recruitment model was fit using the SSB and recruitment estimates presented in Pérez-Rodríguez et al, 2016 (Fig. 2.4.2). Next, a "year factor" was calculated dividing the observed recruitment (those presented in Pérez-Rodríguez et al, 2016, grey points in Fig. 2.4.2) by the estimated with the fitted Ricker model (blue dotted line in Fig. 2.4.2). Finally, the parameter α of the Ricker model was multiplied by these annual factors resulting in SSB-curves similar in shape, but with different maximum values depending on the year.

- The second element changed in GadCap in comparison to the model presented in Pérez-Rodríguez et al (2016) was the introduction of a Harvest Control Rule for each stock. These HCRs consisted in the total cancellation of the directed fishing activity when the SSB was below:

  - Cod: 16000 tonnes (González-Troncoso, 2012).
  - Shrimp: 2564 tonnes (NIPAG. Mikel Casas, pers.comm).
  - Redfish: 20000 tonnes (SSB value when recruitment declines remarkably, Fig. 2.4.2).



$$Recr = \alpha SSB e^{-\mu SSB}$$

Species	α	μ
Cod	1.761586	6.58E-09
Redfish	30.05803	2.05E-08
Shrimp	1494.783	2.29E-08

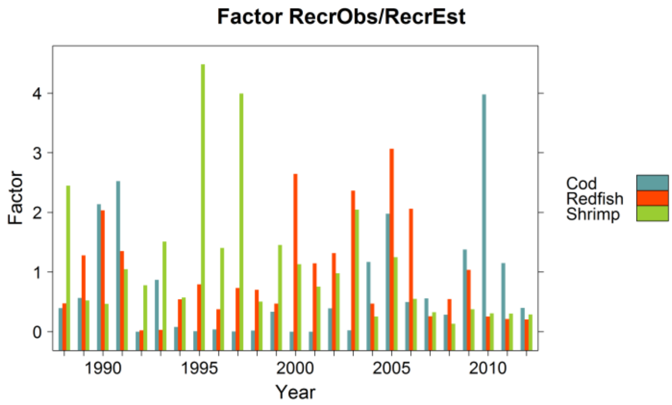


Fig. 2.4.2. Left column figures: SSB-Recruitment estimates from GadCap (Pérez-Rodríguez et al, 2016) for cod, redfish and shrimp (dark grey points). The blue dotted lines represent the fitted SSB-Recruitment Ricker model. For cod, 2010 data point (red coloured point) was considered an outlier, as it influenced strongly in the resulting Ricker model (red dotted line). Right column from top to bottom: Ricker model equation; table with the fit α and μ parameters for each stock; figure with the estimated “year factor” for each stock.

Once these changes were introduced in GadCap the model structure was prepared to run different simulations. The next fishing scenarios were tested:

- Hindcast_0: simulation with the original optimized parameters of GadCap (Pérez-Rodríguez et al, 2016). Includes Ricker SSB-Recruitment relationships with year effect.
- Hindcast_1: like Hindcast_0 but including the specified HCRs. Directed fishing on one stock is cancelled when SSB is lower than the specified B_{lim}.
- Hindcast_2: like Hindcast_1 but cod trawl effort over the whole time period 1988-2012 was fixed to the average level during 2010-2012, when fishing pressure has been relatively low. For the gillnet fishery the average effort of 1988-1996 was applied instead.
- Hindcast_3: like Hindcast_1 but with the effort of the redfish trawl fishery averaged to the levels of 2010-2012.

- Hindcast_4: like Hindcast_1 but with the effort of the shrimp trawl fishery fixed to half of the average value over the period 1993-2010.

- Hindcast_5: like Hindcast_1 but cod and redfish fisheries with effort like Hindcast_2 and Hindcast_3.

- Hindcast_6: like Hindcast_1 but cod, redfish and shrimp fisheries with effort like Hindcast_2, Hindcast_3 and Hindcast_4.

- Hindcast_7: like Hindcast_6 but with an extra trawl fleet for large cod those years of high cod recruitment.

From hindcast 0 to 6 the goal was testing how different levels of fishing pressure would have affected the three exploited stocks, while in hindcast 7 the goal was, in addition, exploring how different patterns of selectivity would have impacted the exploited community.

Results and discussion

The different simulations showed substantial differences in the dynamics of all the three stocks as result of the combined effect of fishing, predation and reproductive potential (Fig. 2.4.3). In relation to the status quo scenario (Hindcast_0), the introduction of a HCR for all three stocks at once (Hindcast_1) ensured the SSB being above B_{lim} for all the three stocks. Accordingly, a higher biomass was obtained at least during the first half of the study period, especially for cod and redfish. Since 2000, the higher abundance of cod and large redfish individuals implied higher levels of predation mortality in redfish and shrimp (Fig. 2.4.4 and Fig. 2.4.5) decreasing the survivorship and biomass of the stocks in later years (Fig. 2.4.3). Despite the higher cod predation mortality on shrimp, the good environmental conditions (reflected in the year effect in the SSB-Recruitment relationship, Fig. 2.4.2) made possible the excellent recruitment events in the mid-late 1990s, producing the increase of shrimp to very high levels of biomass by early 2000s.

These levels of complex interactions of fishing, predation, reproductive potential (SSB), environmental conditions (year effects) and recruitment occurred in all the different scenarios and can be observed by analysing Figs. 2.4.2 to 2.4.4. Those scenarios that consisted in a lower fishing mortality on cod (3, 6 and 7) showed a much higher biomass for this species in the early-mid 1990s, in parallel with a decline in biomass of redfish and shrimp. In simulations 5 and 6 cod biomass reached the highest values due to the lowest fishing pressure (like in hindcast 2), but also to the higher biomass of redfish and shrimp as response to the lower fishing pressure on these stocks as well. GadCap is not design yet to account for the effect of prey availability in the growth and survivorship of predators, but it can still simulate some positive effect: the higher availability of prey reduces the cannibalism in predators. Accordingly, the low fishing pressure on cod and the lower cannibalism due to higher prey availability raised cod to values above the status quo until early 2000s. However, when the individuals of the successful cohorts of early-mid 1990s reached large sizes, the decline in redfish and shrimp availability (as result of predation/fishing) enhanced cannibalism in cod (Fig. 2.4.4 andFig. 2.4.5), which in parallel to low recruitments (adverse environmental conditions; low year factor, Fig. 2.4.2) led inevitably to the collapse of cod (SSB lower than B_{lim} and hence cancellation of fishing). Still, cod biomass was higher most years in comparison with the status quo scenario. Hindcast 7 (a fleet with a selectivity curve with L_{50}=70 cm fished intensely on large individuals those periods of high recruitment) produced the highest catches

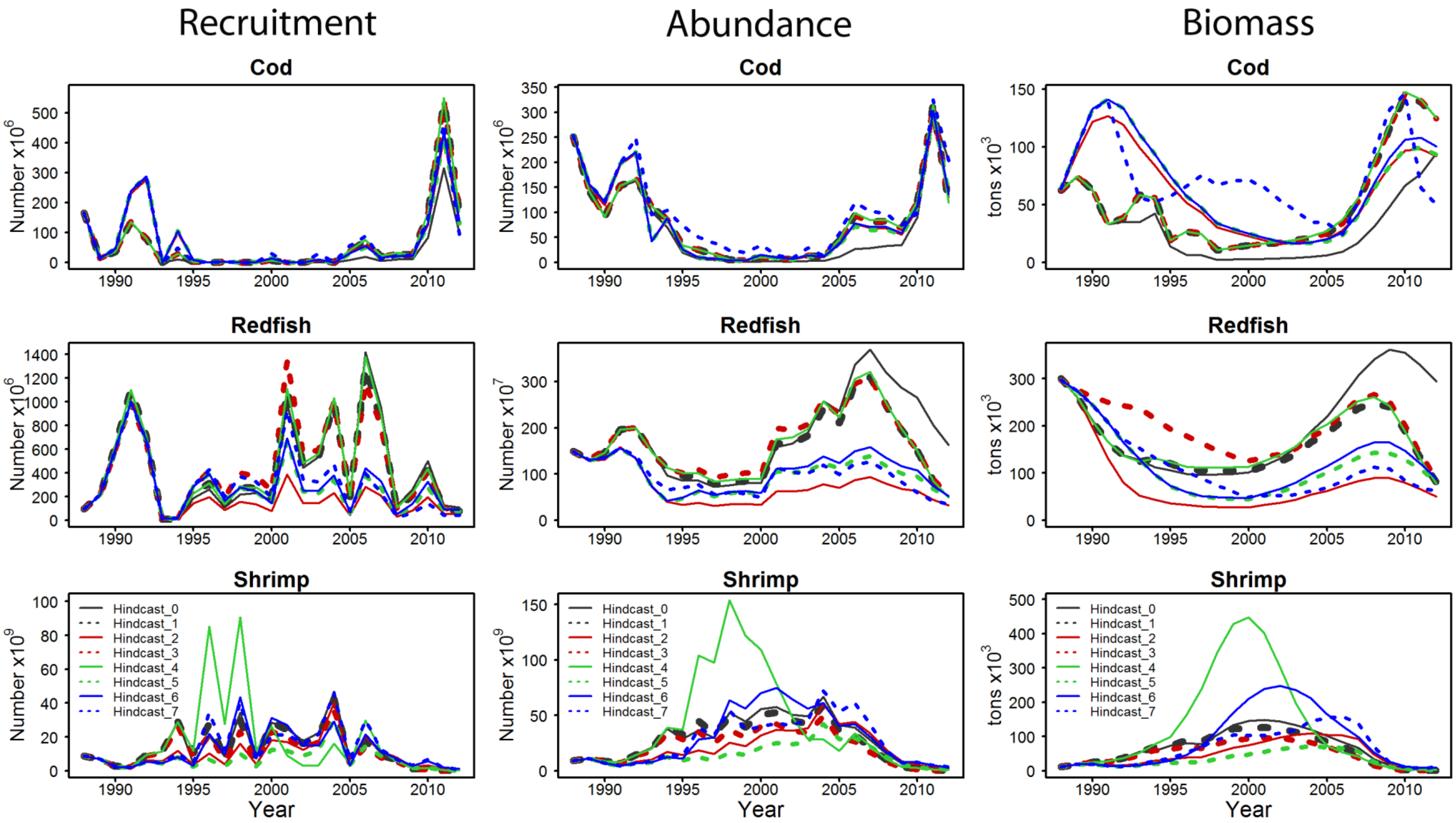


Fig. 2.4.3. Recruitment, abundance and biomass estimated annually for all the three species as result of the 7 different scenarios simulated.

and was the only fishing scenario that maintained the biomass of cod above B_{lim} (except for 1999 and 2006). Due to the extremely good year effect on recruitment, in the last years all fishing scenarios raised the biomass of cod above the levels of the hindcast 0, which had a negative effect specially on redfish.

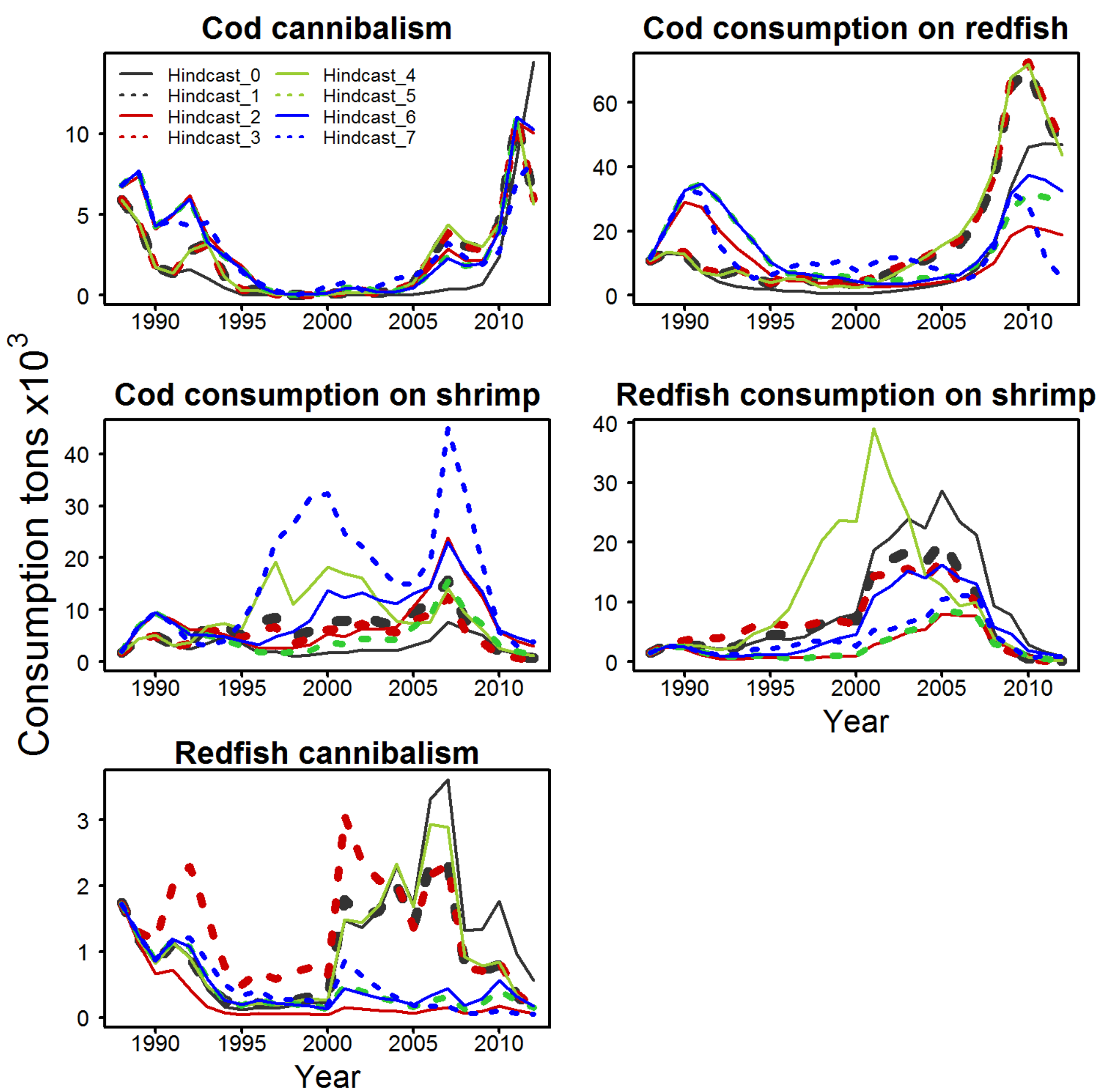


Fig. 2.4.4. Cod and redfish consumption over the different prey species, including cannibalism.

The hindcast 7 (with a fleet fishing to the larger portion of cod stock those years of good recruitments) is not presented here as a real candidate management strategy, since it would be probably very hard to implement due to technical, economic and biological reasons. However, these results can be considered as an indication that, in order of reducing cannibalism and increasing productivity, those years with higher abundance of large individuals and successful recruitments the selectivity of the fishery should be changed somehow towards larger sizes. The lower abundance of large and piscivorous cod would also produce benefits on redfish by allowing a higher survivorship of young individuals (Fig. 2.4.4 and Fig. 2.4.5).

The hindcast 3, where fishing mortality was high for cod but low for redfish, was the only scenario which the biomass of this stock was substantially above of that estimated in the status quo scenario (Fig. 2.4.3). However, since early 2000s, the higher abundance of large redfish led to a situation with more cannibalism (Fig. 2.4.4 and

Fig. 2.4.5) and a decline of total biomass in later years. These results suggest that, as observed in cod, the fishery on redfish should target more intensively on larger individuals by changing the selectivity of the fleet those years of high abundance of large individuals and successful recruitments. This scenario will need to be consider in further simulations.

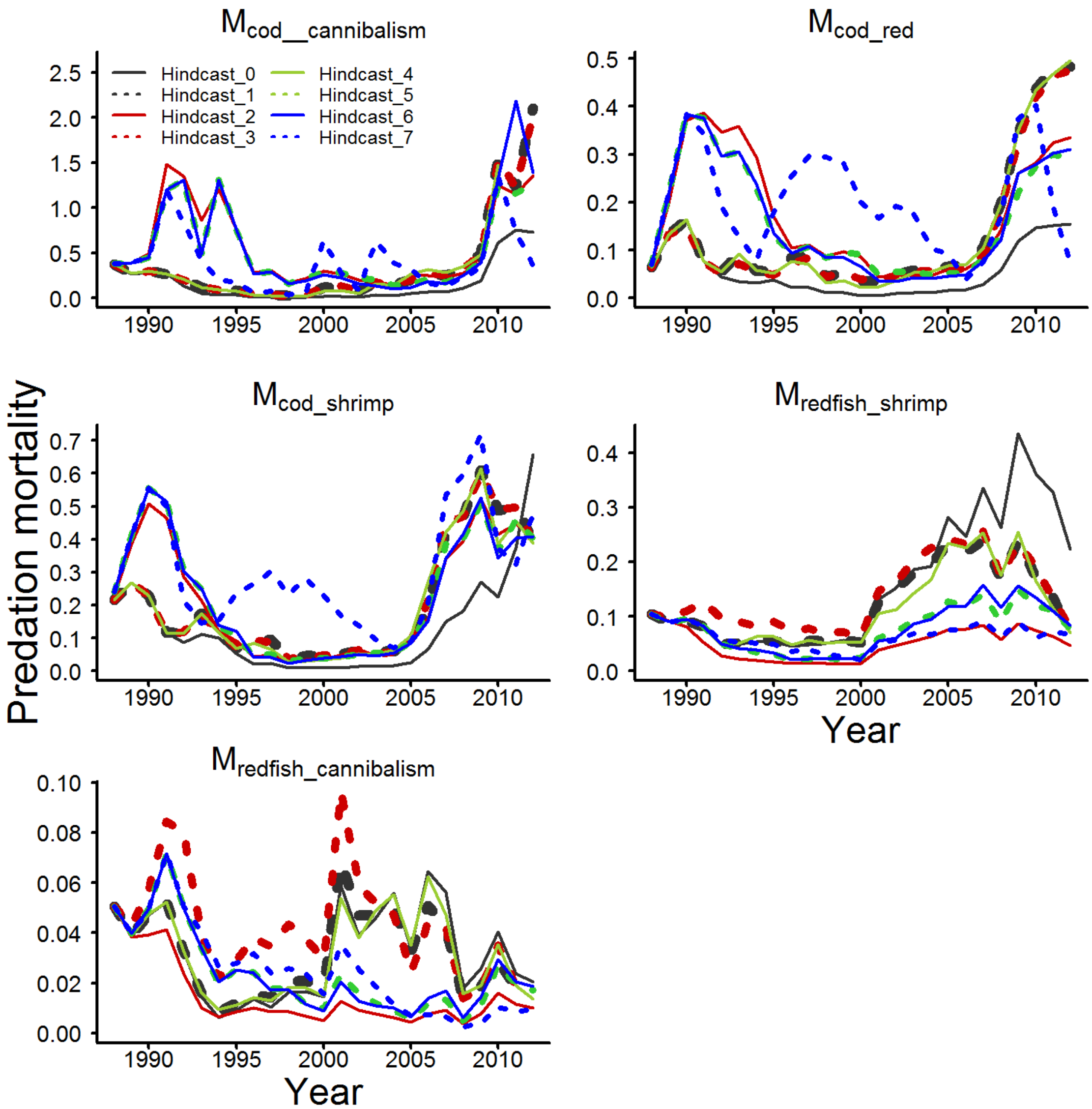


Fig. 2.4.5.- Predation mortality over the different prey induced by

For shrimp, the reduction of fishing mortality in hindcast 4, implied a very high survivorship of individuals from late 1980s cohorts. This fact in parallel with the very good environmental conditions (year effect, Fig. 2.4.2) in the late 1990s produced the explosive increase in this stock. It has been argued that cold periods benefit recruitment in shrimp (Apollonio et al, 1986; Koeller, 2000), which suites well with the estimated year factor (Fig. 2.4.2) and the oceanographic conditions in the Flemish Cap during this period (Colbourne et al, 2016). However, in this model the effect of environmental limiting food availability in the dynamic of the shrimp stock has not been included. It is very probable that this extreme high levels are above the carrying capacity of the ecosystem for this stock. Accordingly, the results of hindcast 4 need to be considered more as an indication of trends result of lower fishing mortality than as a reliable value. Although in hindcast 6 it is also possible that the biomass of shrimp is above the carrying capacity, the lower fishing pressure on cod and redfish allowing higher biomass of these stocks and predation on shrimp make more reliable the simulated dynamic for shrimp in this scenario.

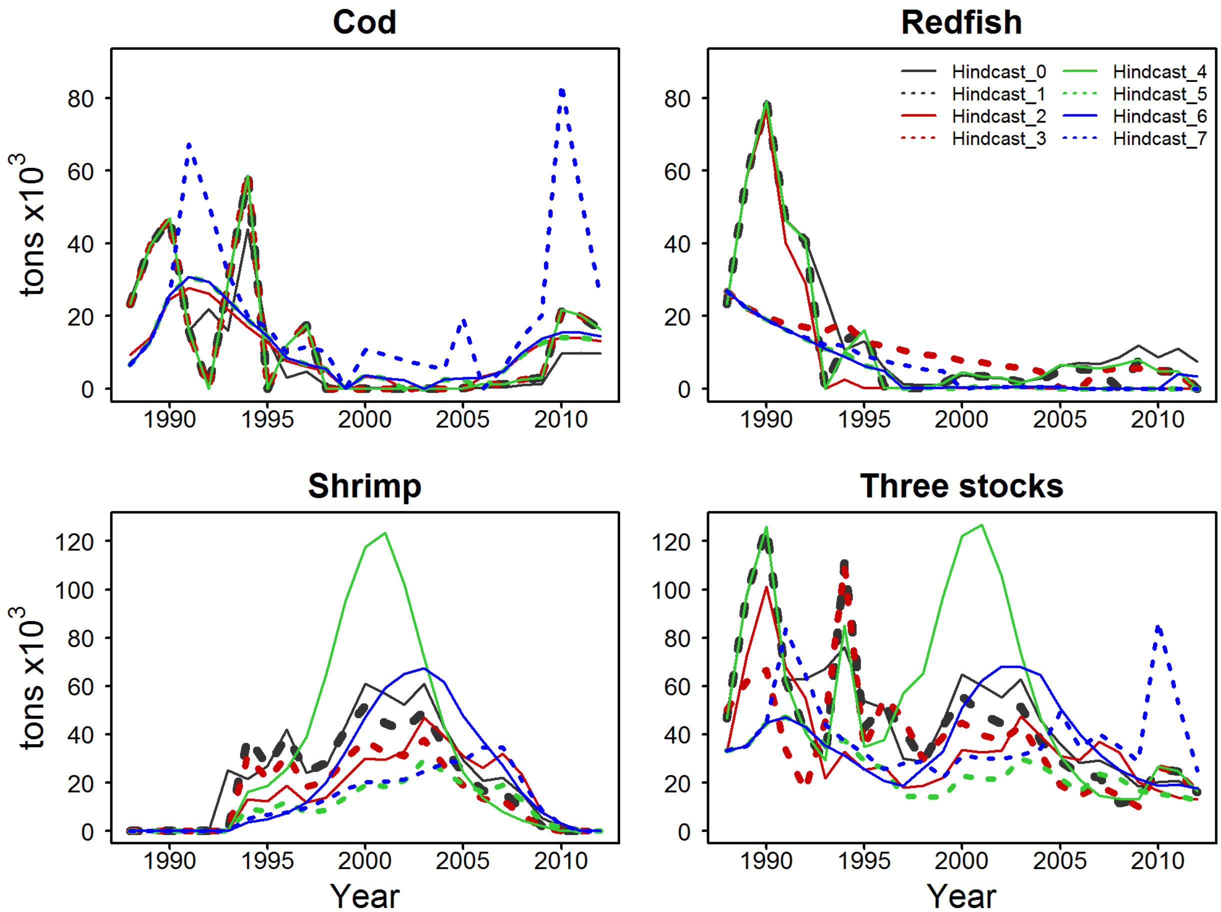
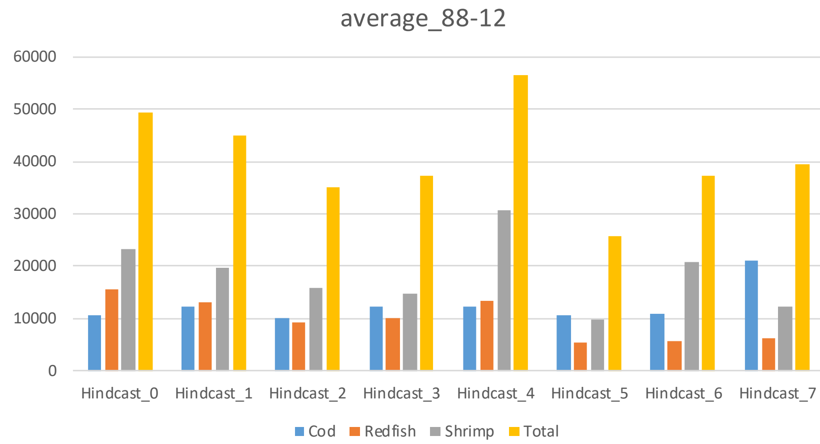


Fig. 2.4.6. Total catches of cod, redfish and shrimp over the period 1988-2012.

The results of all those different scenarios when fishing mortality on prey stocks (mainly shrimp but also redfish) was lower (Hindcasts 3, 4, 6) in contrast to those where fishing was reduced to the predators (Hindcasts 2 and 5) support that reducing fishing pressure on prey stocks increases total net catches (Fig. 2.4.6 and Fig. 2.4.7). Hence, despite the effect of prey in the dynamic of the predator is a pending task in the model GadCap, in this study the benefits from a higher availability of the prey in the dynamic of the predator is already detected through the reduction on cannibalism. This is especially clear in hindcast 6, the reduction of fishing pressure on all three stocks led to relative high catches and low inter-annual variability (Fig. 2.4.5 and Fig. 2.4.6). The analysis of the interconnected productivity of these stocks would contribute to shed light about the level of fishing pressure that would have to be applied to each stock in order of producing the most equilibrated exploitation rate under varying environmental conditions, i.e. multispecies MSY with environmental considerations. This approach has been already explored (Pérez-Rodríguez et al, 2016 SCR), although a more in depth analysis is still required.



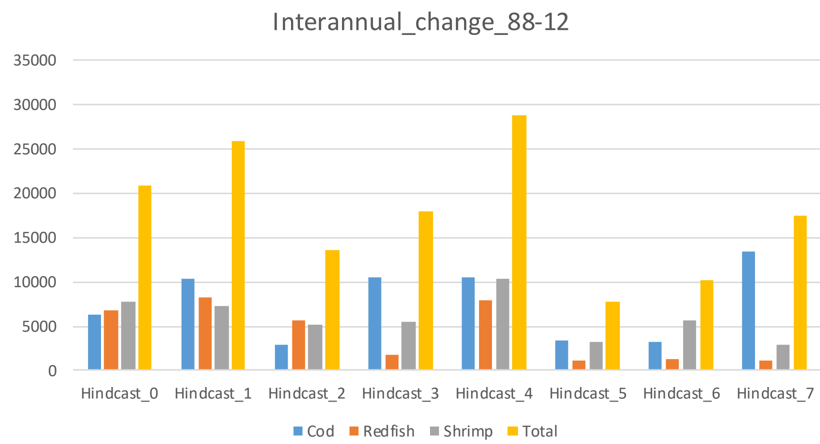


Fig. 2.4.7. For each simulation scenario the average annual over the period 1988-2012 and interanual differences in catch for each of the three stocks is presented.

The results presented in this work show the possibilities of multispecies models in NAFO area as tools to evaluate different management strategies and HCRs, allowing the estimation of reference points like the F_{msy} and B_{msy}. However, some important improvements need still to be implemented in GadCap, among them:

- Spliting the three redfish species: there are reasons to think that cod preys more intensely on Sebastes fasciatus and S. norvegicus, while S. mentella, the main redfish stock, overlaps in a lower degree with cod. Implementing this in the model would probably improve the modelled state of the redfish stock, reducing the impact of cod that at this moment seems excessive.

- The implementation of a functional response relation of type III. This type of functional response would avoid predation (including cannibalism) when the density of the prey is low. This would reduce cannibalism to those years of especially good recruitments, and would reduce excessive predation of redfish and shrimp at low densities of this prey population.

- Introduction of more information related with the reproductive potential of the stock in relation with the recruitment and the environmental conditions.

Conclusions

- The collapse of cod was not avoided by reducing only the fishing pressure due to the relative low recruitments since 1992 to 2005 and the increased cannibalism. The introduction of a functional response III in the model would probably reduce the importance of cannibalism in years of low recruitments.
- Fishing on large individuals to avoid cannibalism is the only strategy avoiding catch zero for cod most years. Other simulated scenarios with new HCRs and less drastic changes in the length selectivity of the fleet, including the redfish fishery will need to be tested.
- All the management scenarios would have produced a lower redfish biomass at the end of the time period in comparison with the status quo scenario due to increased predation by cod and/or cannibalism, which produced lower reproductive capacity since 2000. The separation of redfish species would probably improve the estimated impact of cod on the redfish stock.
- Despite the timing of the increase in the shrimp stock was earlier or later depending on the state of cod stock on each management strategy, the shrimp stock always increased to very high levels. This was due to the exceptional environmental conditions (year effect) leading to very high recruitments in the mid-late 1990s and the low abundance of redfish as result of cod predation.
- Similarly, the collapse of shrimp would not have been avoided reducing fishing pressure to half of average value. Increased predation by cod, and redfish, together with low recruitments after 2000 would have still led the collapse.
- The strategy that presented the best trade off in between average and inter-annual variability in catches were those were fishing mortality on preys was reduced to lower levels. The higher availability of prey stocks would produce higher survivorship and productivity in predators.

References:

Apollonio, S., Stevenson, D., Dunton, E. 1986. Effects of Temperature on the Biology of the Northern Shrimp, Panda/us borealis, in the Gulf of Maine. NOAA Technical Report NMFS 42.

Colbourne, E., Pérez-Rodríguez, A., Cabrero, A., González-Nuevo, G. 2016. Ocean Climate Variability on the Flemish Cap in NAFO Subdivision 3M during 2015. NAFO SCR Doc. 16/019.

Koeller, P.A. 2000. Relative. Relative importance of abiotic and biotic factors to the management of the northern shrimp fishery on the scotian shelf. J. Northw. Atl. Fish. Sci. Vol 27: 21-33.

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A. Pérez-Rodríguez, D. Howell, M. Casas, F. Saborido-Rey, Antonio Ávila-de Melo, F. González-Costas, D. González-Troncoso. 2016. GadCap: A GADGET multispecies model for the Flemish Cap cod, redfish and shrimp. NAFO SCR Doc. 16/35.

THEME 3: PRACTICAL APPLICATION OF EAFM

ToR 3.1 Develop draft summary sheets at ecosystem level.

Design of ecosystem summaries is based on NAFO's revised convention objective which aims "to ensure the long term conservation and sustainable use of the fishery resources in the Convention Area and, in so doing, to safeguard the marine ecosystems in which these resources are found". In part, this will be achieved through NAFO's commitment to apply an ecosystem approach to fisheries management that includes safeguarding the marine environment, conserving marine biodiversity, minimizing the risk of long term or irreversible adverse effects of fishing activities, and taking account of the relationship between key components of the ecosystem. Summaries are to consist of two element groups: one based on measures of state (i.e. oceanographic, production, ecological features) and species interactions within each of the major Ecosystem Production Units that have been the focus of WGESA activities (i.e. Flemish Cap, Grand Banks, and Newfoundland Shelf); the second based on the relationship of the state variables relative to management framework and objectives.

The design aims to mirror the basic objectives that underlie the structure of the stock summary sheets but in a manner that recognizes how environmental conditions and ecosystem structure affect NAFO's ability to report on the objectives of the Convention. Ecosystem summary assessments should be carried at medium-term intervals (3-5 years).

Elements of the summary sheets (a-e).

(a) Assess state and trends of ecosystem elements (environment, lower trophic levels, ecosystem productivity) that play fundamental roles in promoting/ensuring the long-term sustainability and optimum utilization of renewable resources;

Long-term sustainability of fisheries resources (state: long term prospects based on current state of ecosystem, environmental conditions and trends and/or regime shifts)

- Environmental conditions – state and medium-term trends in thermal environment and standing stock/composition of lower trophic levels (from STACFEN); state of conditions relative to historical range or reference period (e.g. 1981-2010; meteorological standard 30 year frame of reference)
- Productivity regime – total standing stock and production of ecosystem critical renewable resources based on multispecies surveys contrasted with a defined reference period and/or state
- **Label for table**: Environmental conditions and ecosystem state.
- **Rationale**: Evaluation of status and trends of environmental conditions, and the productivity regime required to sustain/promote abundance and production of key fisheries resources in the Ecosystem Production Unit.
- Traffic light rationale:
- **Green (good)**: Current ecosystem state and expected environmental conditions and trends within a 5 year horizon are likely to be conducive to high productivity of key/traditional fisheries resources in the Ecosystem Production Unit.
- **Yellow (concern)**: Current ecosystem state and expected environmental conditions and trends within a 5 year horizon show unclear and/or contradictory signals that could hinder or limit productivity of key/traditional fisheries resources in the Ecosystem Production Unit.

- **Red (bad)**: Current ecosystem state and expected environmental conditions and trends within a 5 year horizon indicate conditions that are expected to result in low productivity of key/traditional fisheries resources in the Ecosystem Production Unit.

- Note: Some conditions may favour some resources while hindering others. If this is the case, the comments column within the table could be used to indicate which stocks may do well under “red” conditions.

(b) Adopt measures based on the best scientific advice available that integrates knowledge across trophic levels to ensure that fishery resources are maintained at or restored to levels capable of producing maximum ecosystem yield;

Ecosystem at or above ecosystem-level B_{msy} (state: current level of the system)

- FPP level – Quantify the standing stock (what about productivity?) and relative composition of key functional feeding groups contrasted with a defined reference period and/or state (e.g. 1981-1985; pre-collapse)

- Species interactions (where available) – Quantify shifts in diet composition of key EPU components (e.g. cod, redfish) contrasted with prior data/knowledge

- **Label for table**: State and composition of renewable resources.

- **Rationale**: Provide ecosystem-level assessment of status and trends in total biomass/abundance and the relative community composition of key fisheries resources in the Ecosystem Production Unit to identify/avoid shifts away from “desired/optimal” state.

- Traffic light rationale:

- **Green (good)**: Current conditions and expected trends in total standing stock, relative species composition and availability of key prey within a 5 year horizon are indicative of a productive state of key/traditional fisheries resources in the Ecosystem Production Unit.

- **Yellow (concern)**: Current conditions and expected trends in total standing stock, relative species composition and availability of key prey within a 5 year horizon show unclear and/or contradictory signals (e.g. imbalance in composition of functional groups, decline in forage species) that could result in hindered/limited productivity of key/traditional fisheries resources in the Ecosystem Production Unit.

- **Red (bad)**: Current conditions and expected trends in total standing stock, relative species composition and/or availability of key prey within a 5 year horizon indicate a high likelihood of a decline in productivity of key/traditional fisheries resources in the Ecosystem Production Unit.

- Note: Some changes in community composition may favour some resources while hindering others. If this is the case, the comments column within the table could be used to indicate which stocks may do well under “red” conditions.

(c) Take due account of the need to preserve marine biological diversity;

Protect marine biodiversity (state)

- SAI-VME (state/assessment side) – Quantify the abundance, biomass and extent of all VMEs throughout the NRA from surveys and commercial catches (if they're ever reported)

- Species at Risk – Quantify trends in abundance of some/all depleted species/stocks or taxa at risk of extinction.

- **Label for table**: Preserve marine biodiversity.

- **Rationale**: Provide assessment of changes in the distribution, status and trends in total biomass/abundance of VMEs and species or stocks of special concern in the Ecosystem Production Unit.

- Traffic light rationale:

- **Green (good)**: The distribution and abundance of VME taxa (and/or species of special concern) has not changed substantially or has improved within the Ecosystem Production Unit.

- **Yellow (concern)**: The distribution and abundance of VME taxa (and/or species of special concern) show unclear and/or contradictory signals that could result in hindered/limited productivity or declines in abundance in the Ecosystem Production Unit.

- **Red (bad)**: The distribution and abundance of VME taxa (and/or species of special concern) indicate there has been a decline in productivity of within the Ecosystem Production Unit.

(d) Apply the precautionary approach in accordance with Article 6 of the 1995 Agreement;

Implementation of the Roadmap tiers (management framework: sustainability of exploitation)

- Assessment of Tier 1 (TCC) – quantify total catches and expected trends of key species/functional groups relative to expected total expected productivity of ecosystem components within the Ecosystem Production Unit.

- Assessment of Tier 2 (multispecies interactions; where available) – quantify the effects of stock dynamics (reproduction/recruitment potential?), species interactions and fishing pressure on recent changes in conditions (abundance?) and expected trends within a 5 year horizon of key/traditional fisheries resources within the Ecosystem Production Unit.

- **Label for table**: Apply precautionary approach.

- **Rationale**: Evaluation of status and trends total catches of functional groups and/or key/traditional fisheries resources, and the productivity regime that may sustain/promote in relation to fisheries production potential in the Ecosystem Production Unit. Estimates of FPP should be considered as equivalent to Limit Reference Points, with the 25% percentile of the distribution of FPP serving to define a Total Catch Ceiling (TCC) under current conditions.

- Traffic light rationale:

- **Green (good)**: current catches have not exceeded or do not have a high likelihood of exceeding the fishery production potential of any of the key functional groups (or species?) within a 5 year horizon and are likely to continue to allow high productivity of key/traditional fisheries resources in the Ecosystem Production Unit.

- **Yellow (concern)**: current catches exceed or have a high likelihood of exceeding the fishery production potential of one (or several?) of the key functional groups within a 5 year horizon or show unclear and/or contradictory signals that could result in hindered/limited productivity of key/traditional fisheries resources in the Ecosystem Production Unit. This is indicative of the need for an assessment of the effects of stock dynamics, species interactions and fishing pressure on recent changes in conditions on the potential productivity of key/traditional fisheries resources within the Ecosystem Production Unit.

- **Red (bad)**: current catches exceed or are highly likely of exceeding the fishery production potential of several the key functional groups within a 5 year horizon that will hinder/limit productivity of key/traditional fisheries resources in the Ecosystem Production Unit. This is indicative of the need for an assessment of the effects of stock dynamics, species interactions and fishing pressure on recent changes in conditions on the potential productivity of key/traditional fisheries resources within the Ecosystem Production Unit.

- Note: Some conditions may favour some resources while hindering others. If this is the case, the comments column within the table could be used to indicate which stocks may do well under “red” conditions.

(e) Take due account of the impact of fishing activities on other species and marine ecosystems and in doing so, adopt measures to minimize harmful impact on living resources and marine ecosystems;

Minimize harmful impacts on ecosystems (management framework: protection of VMEs, benthic ecosystems)

- SAI-VME (management side), closures, encounter protocols

- Species at risk Bycatch and other sources of loss

- **Label for table**: Minimize harmful impacts on ecosystems.

- **Rationale**: Evaluation of the risk of impact on total biomass/abundance of VMEs (and species or stocks of special concern?) in the Ecosystem Production Unit.

- Traffic light rationale:

- **Green (good)**: Incursions into fishery closures have been limited (<x% of fishing sets during 5 year review period?) and there is a low proportion of the area or biomass of VME outside the fishery closures (<25% limit to be informed by functional considerations) which is currently at low risk of impact within the ecosystem Production Unit.

- **Yellow (concern)**: Incursions into fishery closures have been infrequent (>x% and <y% of fishing sets during 5 year review period?) and/or there is a high proportion of the area or biomass of VME outside the fishery closures (>25% based on PA principles) which is currently at high risk of impact because it falls in an area within the fishing footprint but most of the area falls below the defined cut-off point of fishing effort (within any one year?) the Ecosystem Production Unit.

- **Red (bad)**: Incursions into fishery closures have been frequent (>y% of fishing sets during 5 year review period?) and/or there is a high proportion of the area or biomass of VME outside the fishery closures (>25% based on PA principles) which has been exposed to a level of fishing effort above the defined cut-off point (within any one year?) the Ecosystem Production Unit.

(f) Take due account of the need to minimize pollution and waste originating from fishing vessels as well as minimize discards, catch by lost or abandoned gear, catch of species not subject to a directed fishery and impacts on associated or dependent species, in particular endangered species.

- `Note: There is concern about putting effort into an area where WGESA has not undertaken substantial analyses, other than suggesting that there is a host of topics or issues which may require some form of quantitative assessment based on synthesis of existing knowledge or new research. This section could serve to highlight emerging concerns of issues that could be addressed through management or regulations following substantive analysis of new data.

ToR 3.2 Continue progression on the review of the NAFO PA Framework, [FC Request 7]

In 2015, a joint FC-SC Working Group on Risk-Based Management Strategies (WG-RBMS), convened a technical working group to explore the revision of the precautionary approach. This technical working group (informally named "WG-PAF" by WG-RBMS) held a number of informal discussions by Webex in early 2016 to discuss ideas. This led to the decision to jointly develop a multi-authored document (which could possibly become a SCR or SCS Doc following review and revision by SC) reviewing the NAFO PAF.

Among the terms of reference of this review is; *NAFO PAF in the context of an ecosystem approach*. Text addressing this ToR was drafted by then WG-ESA co-chair, Mariano Koen-Alonso, demonstrating how the the PAF could be integrated with the NAFO roadmap. The 2016 meeting of WG-ESA reviewed and discussed this text: WG members were broadly in agreement with the approach taken, however, due to time constraints, the WG was not able to reach a conclusion or to make any revision to the current draft. WG members will continue to work within WG-PAF and WG-RBMS to develop the revision of the PAF within the context of an ecosystem approach.

ToR 3.3 Assess the overlap of NAFO fisheries with VME to evaluate fishery specific impacts in addition to the cumulative impacts, [FC Request 6]

Highlights

1. Preliminary work was carried out to assess the overlaps of individual fisheries with VMEs
2. Preliminary results showed that Greenland halibut otter trawl fishery appeared to occur over the largest area of VME polygons, while cod longline and shrimp fisheries had no co-occurrence with VME polygons, and other fisheries had intermediate degrees of co-occurrence.
3. This analysis will be repeated in more depth and with revised fishing effort layers for the next WGESA meeting.

In 2015 WGESA assessed the risk of significant adverse impacts (SAI) for VME taxa by examining areas that overlapped between the full fishing footprint and VME polygons and closures (NAFO 2015). However, the contributions of individual fisheries to the risk of SAI were not assessed.

Building on the NAFO 2015 analysis, we conducted a simple preliminary analysis of fisheries-specific overlaps between eight fisheries (Table 3.3.1) and the 2014 NAFO VME polygons. We measured the area (km^2) of: a) polygons for each of the VME taxa and a layer with all VMEs combined; b) area that coincides for all combinations of VMEs and individual fishing footprints, and expressed it as the percent VME overlapped by a given fishery. The areas of VME polygons (km^2) are as follows: 27557 for all VMEs combined, 3505 for large gorgonians, 6983 for sea pens, and 19824 for sponges.

Table 3.3.1 Description of fisheries-specific footprint layers examined. An “all fisheries” layer was also created by merging together each of the below fisheries; it had a total footprint of 78460 km^2.

Directed species or taxa	Gear	Main NAFO Division	Years	Code	Footprint area (km^2)
Cod	Longline	3M	2012/13, 2014-2015	COD_LL	6472
Cod	Otter trawl	3M	2012-2015	COD_OTB	24998
Greenland halibut	Otter trawl	3LNM	2012-2015	GHL_3LNM	48794
Redfish	Otter trawl	3LNO	2012-2015	RED_3LNO	20960
Redfish	Otter trawl	3M	2012-2015	RED_3M	17739
Shrimp	Otter trawl	3LMNO	2013-2014	PRA_3LMNO	2968
Skate	Otter trawl	3LNO	2012-2015	SKA_3LNO	15148
Flounders	Otter trawl	3LNO	2012-2015	WYP_3LNO	6482

Preliminary results (Fig. 3.3.1) showed that there was no fishing in VME polygons for the cod longline and shrimp fisheries. The Greenland halibut fishery overlapped the largest amount of VME area compared to the other fisheries (more than double the area for the next largest fishery). The sponge VME had the largest absolute area overlapped by Greenland halibut fishing footprint (5059 km^2) representing 26% of the VME area. While sea pen VMEs had 3027 km^2 overlapped, this represented a greater proportion (43%) of their area. The other fisheries showed lower values of overlapping VME-fishery area than Greenland halibut. Each of the fisheries (except for WYP_3LNO) had some portion of its fishing footprint in each of the three VME types. For WYP_3LNO, the fishing footprint occurred over sponge VME and large gorgonian VME but not over sea pens.

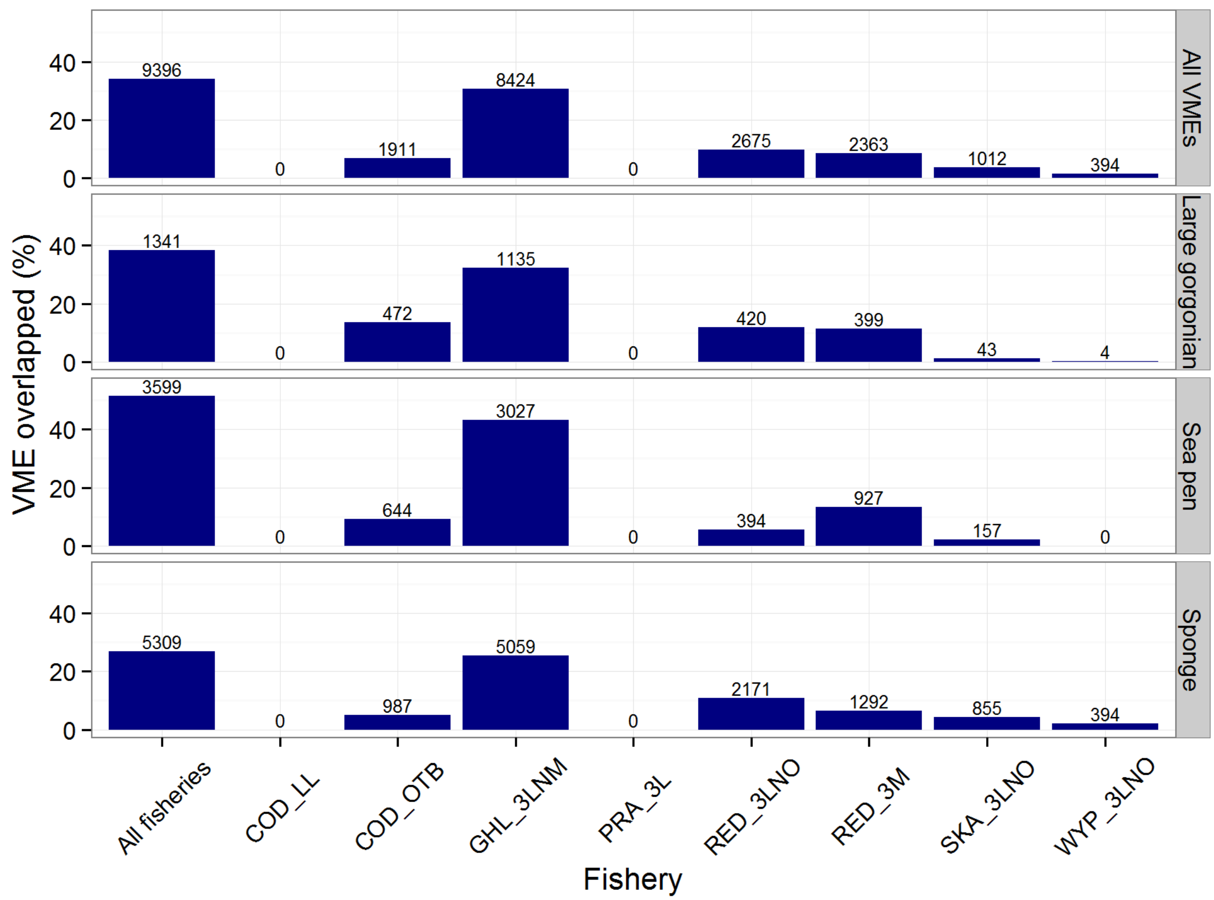

Fig. 3.3.1. The proportion of a given VME area overlapped by all fisheries combined and by fisheries-specific footprints. Panels represent specific VMEs with the top panel showing data for all VMEs combined. The size of the overlapping area (km²) used to calculate the percentage is provided above each of the bars. Note that some VMEs for different taxa overlap, therefore the areas for the bottom three panels do not add up to the areas in the top panels. Codes for fisheries are provided in Table 3.3.1.

The WG-ESA participants noted that the results of the preliminary analysis for the "all fisheries" layer should support the results in the 2015 SAI analysis. That is, the percentage of VME area overlapped by the "all fisheries" layer shown here should be less than the sum of the percentages of area at "high risk" and "impacted" from SAI analysis (see Table 4.2.5.3.4 in NAFO SCS Doc. 15/19). The summed "high risk" and "impacted" values yield 84%, 43% and 35% of VME area overlapped for sea pen, large gorgonian and sponge, respectively. Indeed, the results from this year's overlap analysis indicated that the "all fisheries" layer overlaps 52%, 38% and 27% of sea pen, large gorgonian and sponge VME respectively, less than the above-noted values, as expected. This exercise confirms that the two different methods yield similar conclusions—sea pens are at highest risk of impacts.

Based on these preliminary analyses and the ensuing discussions of WG-ESA participants, some recommendations for the full re-analysis were made. First of all, participants noted that the speed thresholds for the VMS data were likely too wide and could be further refined through more careful examination of speed histograms or through empirical methods such as the mixture models described in ToR 2.1. Second, some of the fisheries groupings were not sufficiently refined (e.g. WYP_3LNO) which could be parsed into footprints for individual directed species. Third, the large grid cell size (on the order of ~36 km²) inflates the size of the fishery-specific footprint and could be decreased to 1nm or 1km. Finally, the use track-based approaches for creating the fishing footprints was explored as a means to create the most refined possible estimate.

There will be two changes in data inputs to note for the upcoming analysis of VME-fishery overlaps. First, new VME polygons will be created in 2017, and these new layers should be used in the analysis (ToR 1.2). Second, as of 2016, commercial logbooks record haul-by-haul catch records. This new data will be used to refine the estimates of fishing pressure by providing a means to verify estimates of fishing pressure in the VME. It can also be used to assess the accuracy of the past efforts used to derive estimates of fishing pressure from VMS.

Reference

NAFO. 2015. Report of the 8th Meeting of the NAFO Scientific Council (SC) Working Group on Ecosystem Science and Assessment (WG-ESA) [Formerly SC WG-EAFM]. NAFO SCS Doc. 15/19, Serial No. N6549, 176 pp.

ToR 3.4 Consider clearer objective ranking processes and options for objective weighting criteria for the overall assessment of risk, [FC Request 6]

This ToR will be addressed once a review of the functional significance of VMEs has been completed (see ToR 2).

ToR 3.5 Maintain efforts to assess all of the six FAO criteria including the three FAO functional SAI criteria, [FC Request 6]

It was agreed that work on this ToR, specifically to define assessment approaches to evaluate the FAO criteria which relate to the functions of VME can only realistically be achieved once research quantifying the functions of VME has been completed. This ToR will theffroe be addressed at a later date.

ToR 3.6 Continue to work on non-sponge and coral VMEs (for example bryozoan and sea squirts) to prepare for the next assessment, [FC Request 6]

Work on this ToR is ongoing and will be presented in subsequent reports of WG-ESA

ToR 3.7 Develop and compile identification guides for fishes (e.g. sharks and skates) that could be provided to observers, [FC Request 6]

Work on this ToR is ongoing and will be presented in subsequent reports of WG-ESA

ToR 3.8 Plan to continue work on the risk assessment of scientific trawl surveys impact on VME in closed areas, and the effect of excluding surveys from these areas on stock assessments, [FC Request 3].

The WG was informed of the work presented at SC in June 2016 relevant to the FC request #3. In summary, a partial analysis was conducted to evaluate the impact of removing the closed areas on the indices of biomass derived from the EU survey in Div. 3M. The results indicated minimal impact on estimates of survey biomass and trends for all the assessed species with the exception of roughhead grenadier and Greenland halibut. Further investigation is required for abundance indices by length or age used in the assessments. The WG also noted that although a comparable analysis has not yet been conducted for various Canadian RV surveys in Div. 3LMNO, sampling has ceased in Div. 3M since 2007, in Div. 3NO beyond 732m since 2010, and has been sporadic in Div. 3L beyond 732m since 2010. These are areas where most of the closed areas reside and therefore it is unlikely there would be any impact on stock assessments being conducted for species inhabiting these areas. Nevertheless, the WG recommended the analysis be conducted and presented to SC in June 2017.

WG-ESA undertook a spatial analysis and assessment of research vessel (RV) catches of vulnerable marine ecosystem (VME) indicator species to evaluate the impact of the RV surveys on VME. Three VME indicator species were evaluated; sponge, sea pens, and large gorgonians using data that had been collected since 2002, 2005 and 2007 respectively. Because of the varied lengths of the time series the number of sets used in the analysis varied between VME with sponge at 4384, sea pens at 4298 and large gorgonians at 3560.

This first part of this analysis involved spatially classifying the RV catch data for each of the VME (Large Gorgonians, Sea Pens and Sponge) into three analytical regions (Fig.3.8.1) and evaluating the frequency distributions of the RV catches (kg.) in each of these regions. The first region represents the RV catches that are within the fishery footprint but are outside any identified VME polygons and closure areas. The second region is comprised of those catches that fall within the identified VME polygons but are outside of the closures. The third region is comprised of the catches that fall within the closed areas.

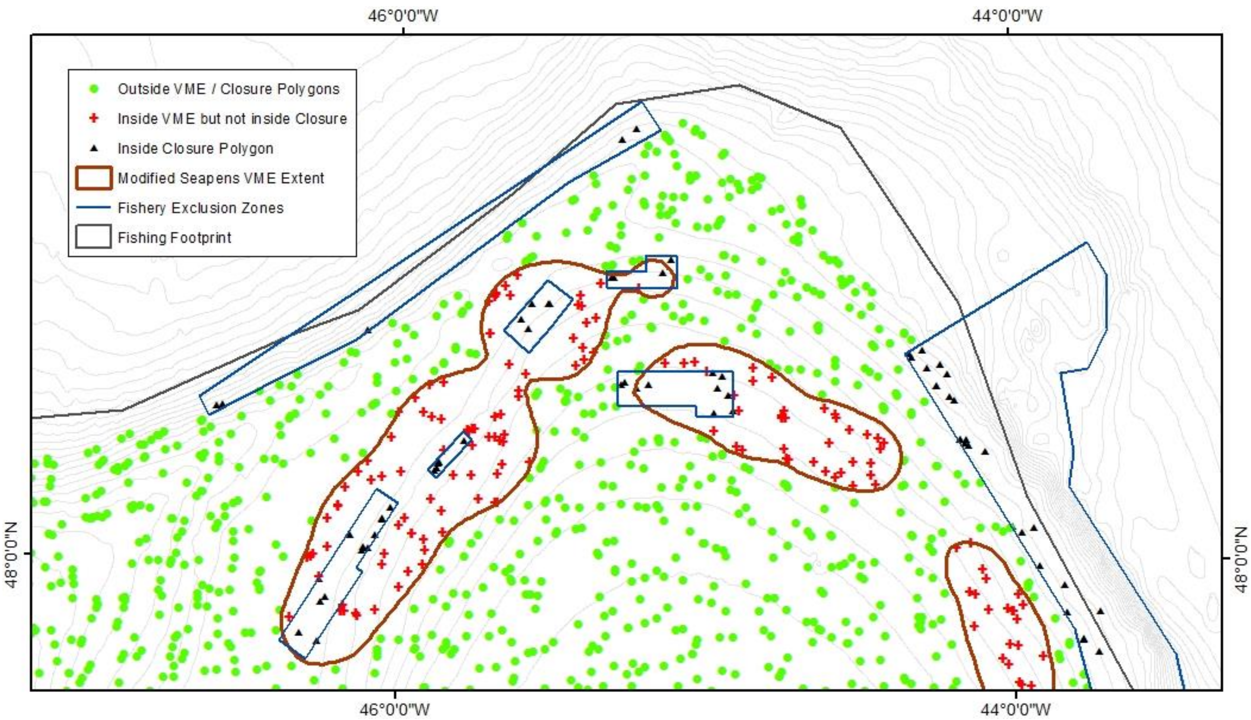

Fig. 3.8.1. Sample partitioning of RV survey catches, sea pens.

RV survey catch weight frequency distributions were created for each VME and for each of the analytical regions described above. The distributions illustrated in each region illustrate exactly how the RV surveys are impacting that specific portion of the habitat. All of the catch weight histograms below have the catch weight in kilograms on the x-axis and the frequency on the y-axis. Both axes are shown using a log10 scale to help accentuate the trends in the data.

Large Gorgonians

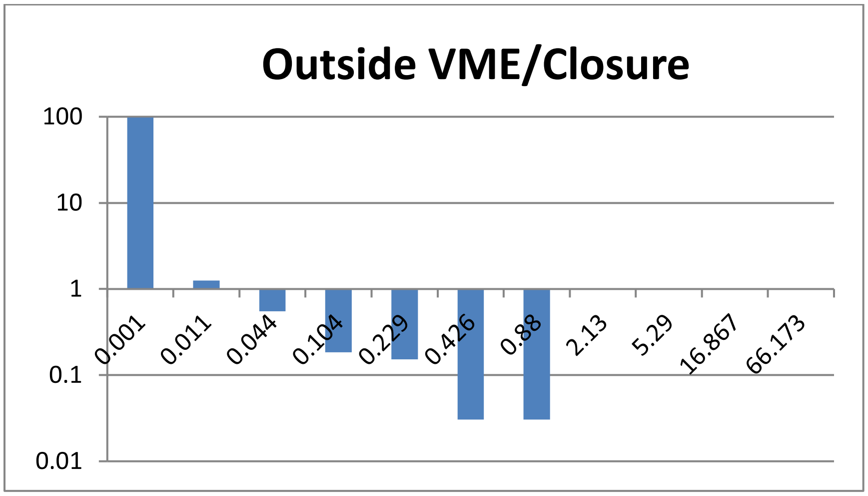

Fig. 3.8.2. Histogram of RV catches of Large Gorgonians outside VME polygon and closure areas. X-axis in kilograms, Y-axis is frequency of occurence on a log-scale.

For Large Gorgonians in Region 1 (within the fishery footprint and outside the VME and closure areas, Fig. 3.8.2.) there are a large number of zero catches in the RV survey data and only a few smaller catches all less than 1 kg. were observed.

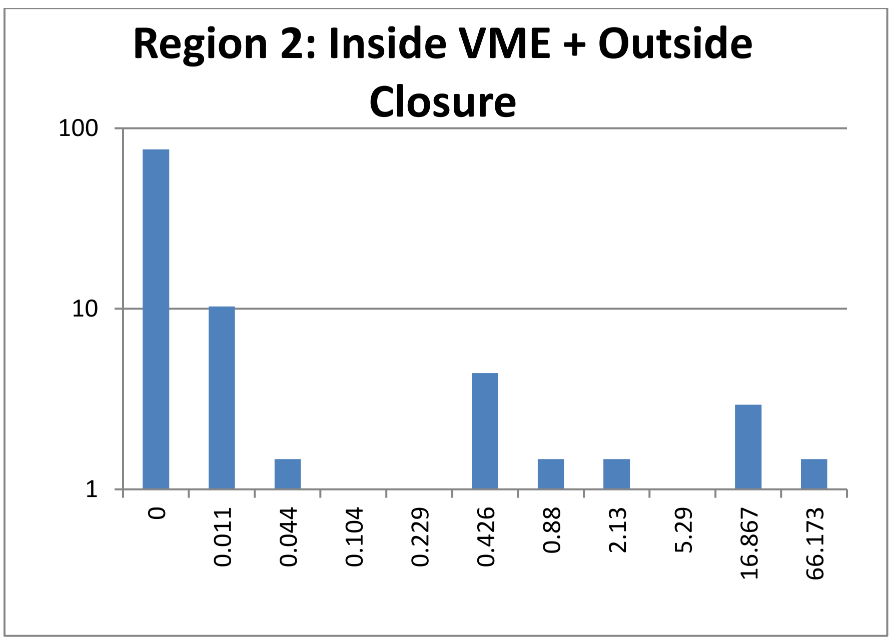

Fig. 3.8.3. Histogram of RV catches of Large Gorgonians inside the VME polygons but outside closure areas. X-axis in kilograms, Y-axis is frequency of occurence on a log-scale .

In region 2 (inside the VME polygons and outside the closure area, Fig. 3.8.3), there are still a large number of zero Large Gorgonian catches but an increase in the number of moderate to larger catches

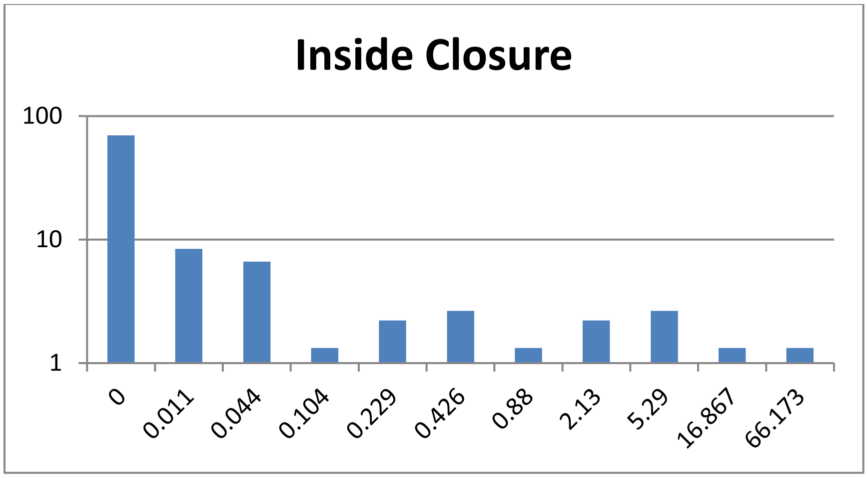

Fig. 3.8.4. Histogram of RV catches of Large Gorgonians inside the closure areas. X-axis in kilograms, Y-axis is frequency of occurence on a log-scale .

Inside the closure (Region 3, Fig. 3.8.4), there is a marginal increase in the frequency of the small, moderate and larger catches compared with the remaining area of the VME polygon (Region 2).

<u>Sea pens</u>

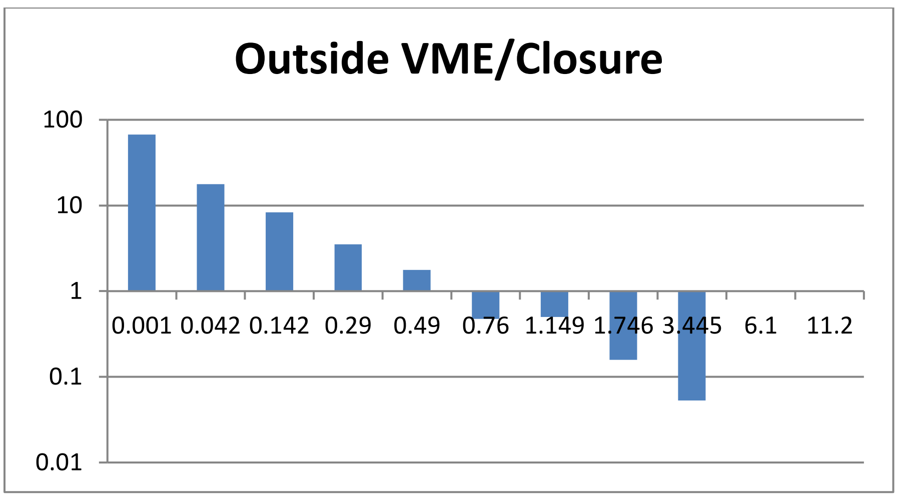

Fig. 3.8.5. Histogram of RV catches of Sea Pens in the Outside VME polygon and closure areas. X-axis in kilograms, Y-axis is frequency of occurence on a log-scale

The Sea Pen catch weight distributions within the fishery footprint, and, outside the VME polygons and closure areas (Region 1) show the largest number of sets were zero , with very few moderate to larger catches (Fig. 3.8.5).

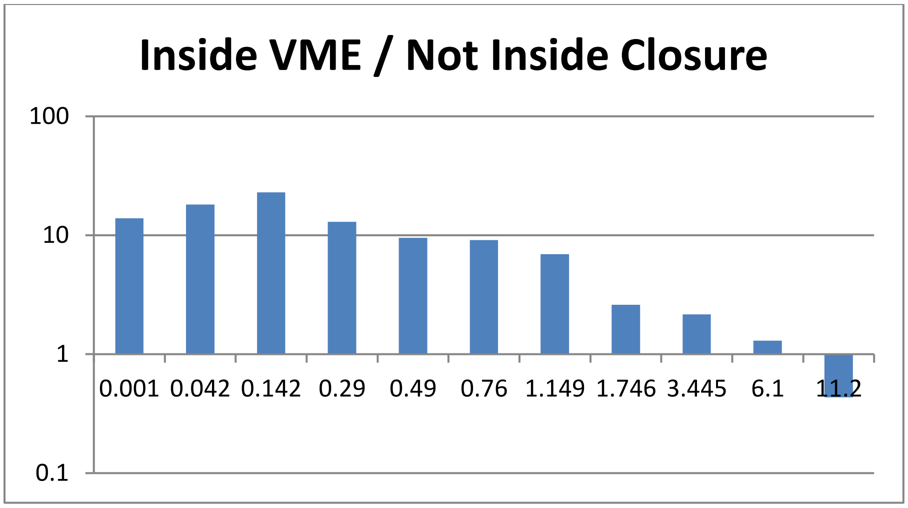

Fig. 3.8.6. Histogram of RV catches of Sea Pens inside the VME polygon but outside closure areas. X-axis in kilograms, Y-axis is frequency of occurence on a log-scale .

In Region 2 (Fig. 3.8.6) there are fewer sets with zero catches of Sea Pens indicting that there are more sets within the VME but outside the closure that catch sea pens compared to the fishery footprint

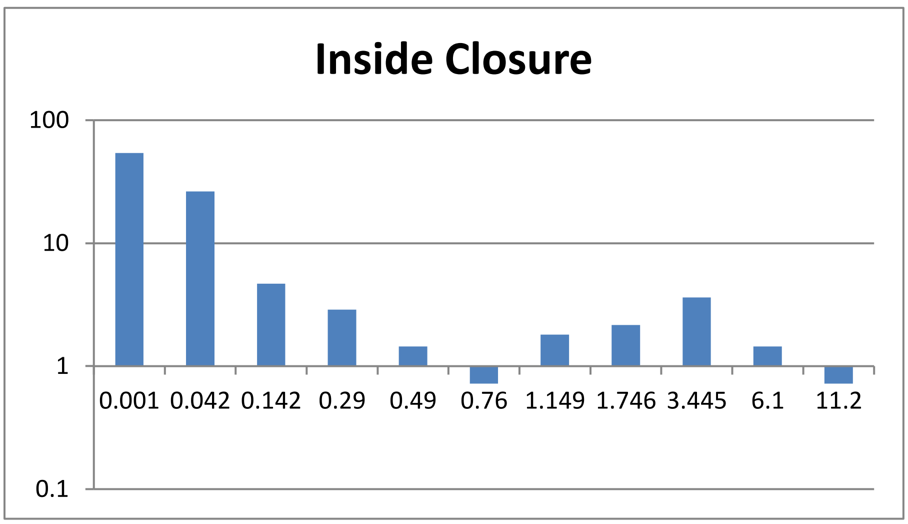

Fig. 3.8.7. Histogram of RV catches of Sea Pens inside the closure areas. X-axis in kilograms, Y-axis is frequency of occurence on a log-scale .

In Region 3, (inside the closure, Figure 3.8.7) there are a smaller number of moderate Sea Pen catches but an increased frequency in largest catches when compared to the remaining VME area outside the closure. It is also observed that the zero sets occur most frequently.

Sponges

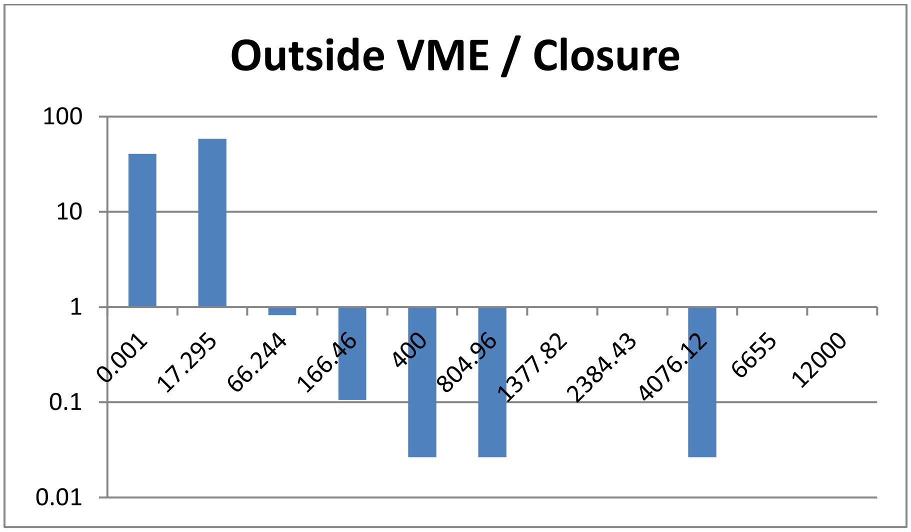

Fig. 3.8.8. Histogram of RV catches of Sponge in the Outside VME polygon and closure areas. X-axis in kilograms, Y-axis is frequency of occurence on a log-scale

Within the fishery footprint (Region 1, Fig. 3.8.8) there are more RV sets that catch sponges than not but there are very few moderate and larger catches.

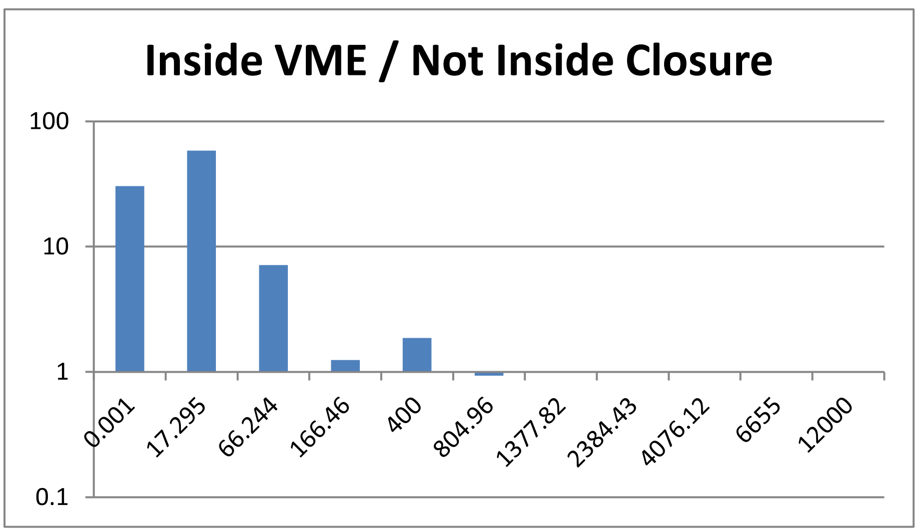

Fig. 3.8.9. Histogram of RV catches of Sponge inside the VME polygon but outside closure areas. X-axis in kilograms, Y-axis is frequency of occurence on a log-scale .

In Region 2 (within the VME polygon and outside the closure, Fig. 3.8.9) there is a higher overall frequency of non-zero catches and a small increase in the frequency of small to moderate catch values compared to the footprint area. Additionally, no large catches are observed inside the VME and outside the closure polygon.

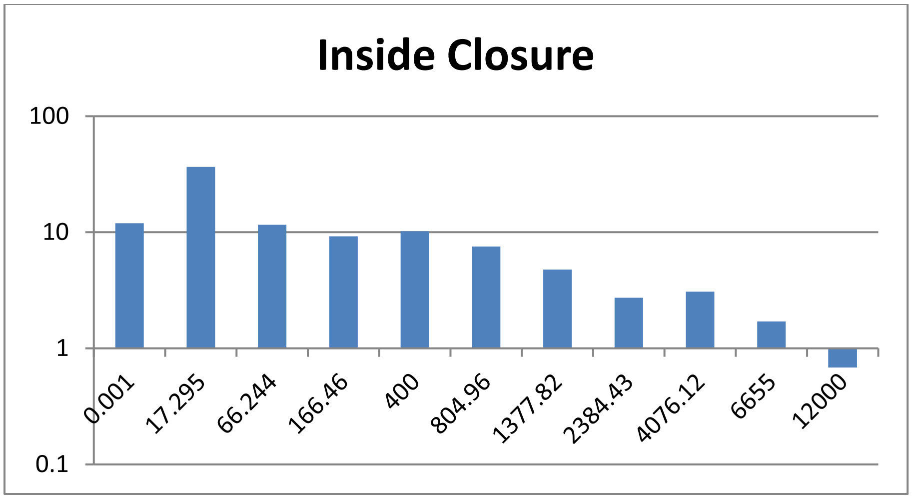

Fig. 3.8.10 Histogram of RV catches of Sponge inside the closure areas. X-axis in kilograms, Y-axis is frequency of occurence on a log-scale .

Within the closed area (Region 3, Fig. 3.8.10) non-zero sets once again dominate and there is a marked increase in small, moderate and large catch weight classes compared to all other regions.

In summary, it is observed that catches by the RV survey have typically caught the least amount of VME biomass and usually have the largest number of zero sets in the fishery footprint (outside VME and Closed areas, Region 1). The areas inside the VME but outside the closure (Region 2) typically show an increased frequency of moderate to high catches and a lower frequency of zero sets. Within the closure polygons (Region 3) the highest frequency of the largest catches typically occur. This analysis at the raw data level is consistent with the kernel density models.

Analysis of 'Significant Catches'

In addition to the catch weight frequency distributions the same region-based analysis as above was performed to examine the proportion of 'significant' RV catches, defined as those exceeding the VME-specific thresholds based on the kernel density analysis (WG-ESA 2015). The thresholds for sea pens, large gorgonians and sponge are 1.4kg, 0.6kg and 75kg respectively.

For each VME indicator species (Table 3.8.1), the percentage of the total number of sets occurring within each of the analytical regions that exceeded the significant catch threshold was enumerated. Most notably, it is observed that 40% of the catches that occurred within the sponge closure area were above the 75kg threshold catch value.

Table 3.8.1. Proportion of total number of catches within each analytical region (kg = total weight of the significant catches).

	Sea pens	Large Gorgonians	Sponge
Outside VME and Outside Closure	0% (n=3 of 3790) 6 kg	0% (n = 0 of 3470) 0 kg	0% (n=4 of 3769) 4320 kg
Inside VME and Outside Closure	6% (n=14 of 231) 42 kg	7% (n=5 of 68) 53 kg	4% (n=13 of 322) 3772 kg
Inside Closure	7% (n=20 of 277) 71 kg	8% (n=19 of 225) 167 kg	40% (n=116 of 293) 126,714 kg

Additionally, calculations were performed to determine the proportion of 'significant' catches that fell into each of the analytical regions. In all VME the largest portion of the significant catches occur in the closure area (Table 3.8.2, Figs. 3.8.12 to 3.8.14). This is consistent with the results of the kernel density analysis Most notable is the 87% (n=116) of all significant sponge catches are found inside the closure polygon..

Table 3.8.2. Proportion of significant catches within each analytical region.

	Sea pens	Large Gorgonians	Sponge
Outside VME and Outside Closure (Region 1)	8% (n=3)	0%	3% (n=4)
Inside VME and Outside Closure (Region 2)	38% (n=14)	21% (n=5)	10% (n=13)
Inside Closure (Region 3)	54% (n=20)	79% (n=19)	87% (n=116)

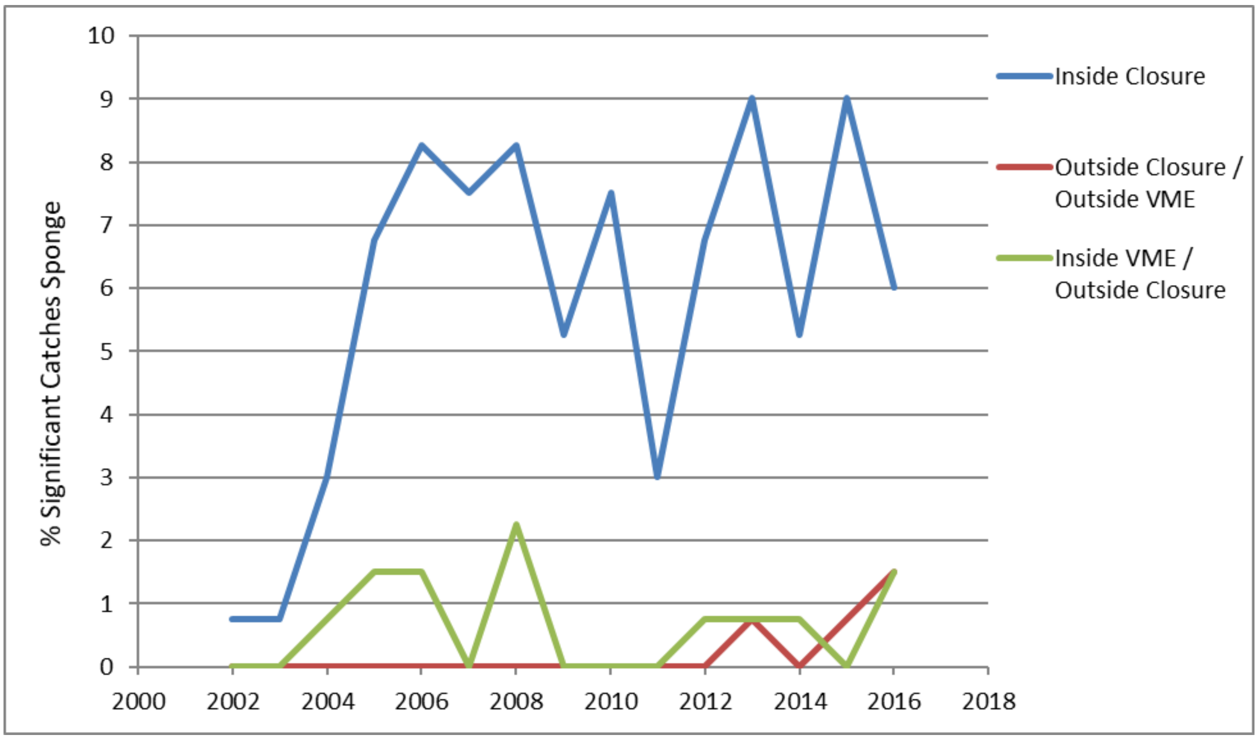

Fig. 3.8.11 Percentages by year of significant sets found in each of the analytical regions for the sponge VME. Similar plots were not generated for large gorgonians and Sea Pens due to insufficient data.

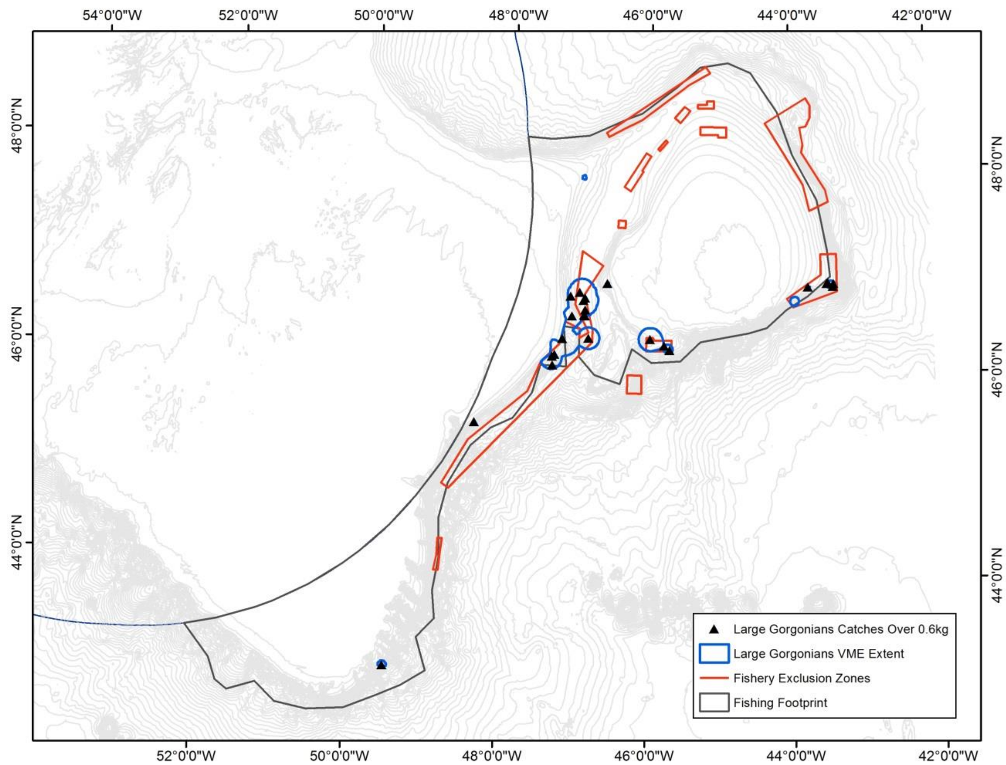

Fig. 3.8.12 Locations of the significant catches of large gorgonians.

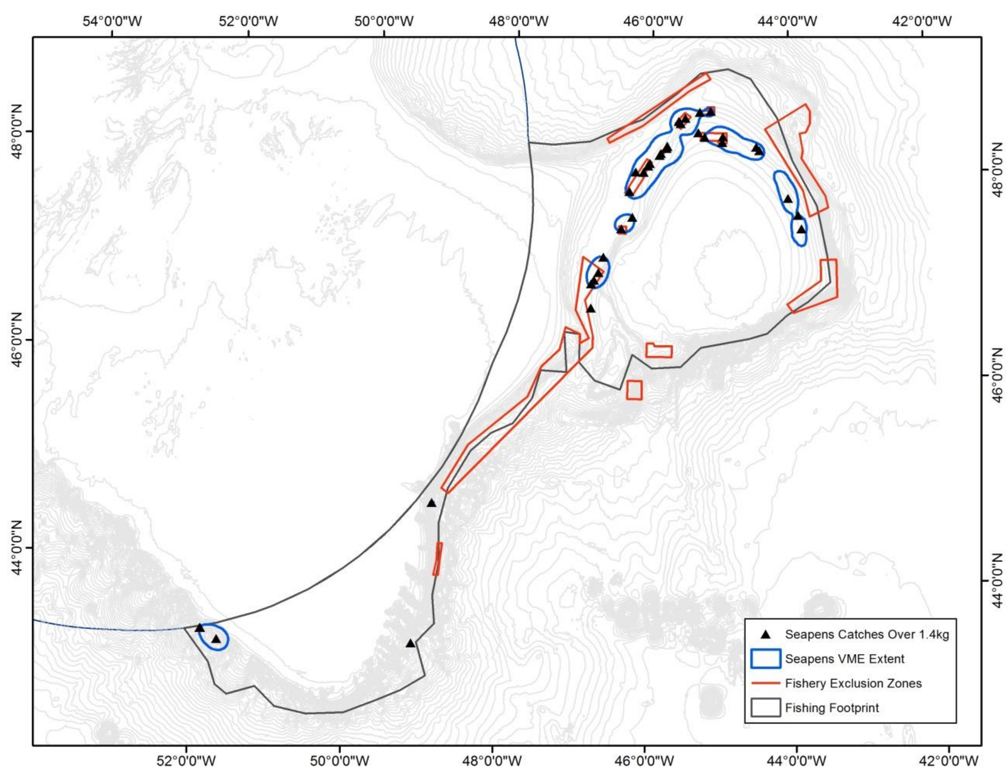

Fig. 3.8.13. Locations of the significant catches of sea pens.

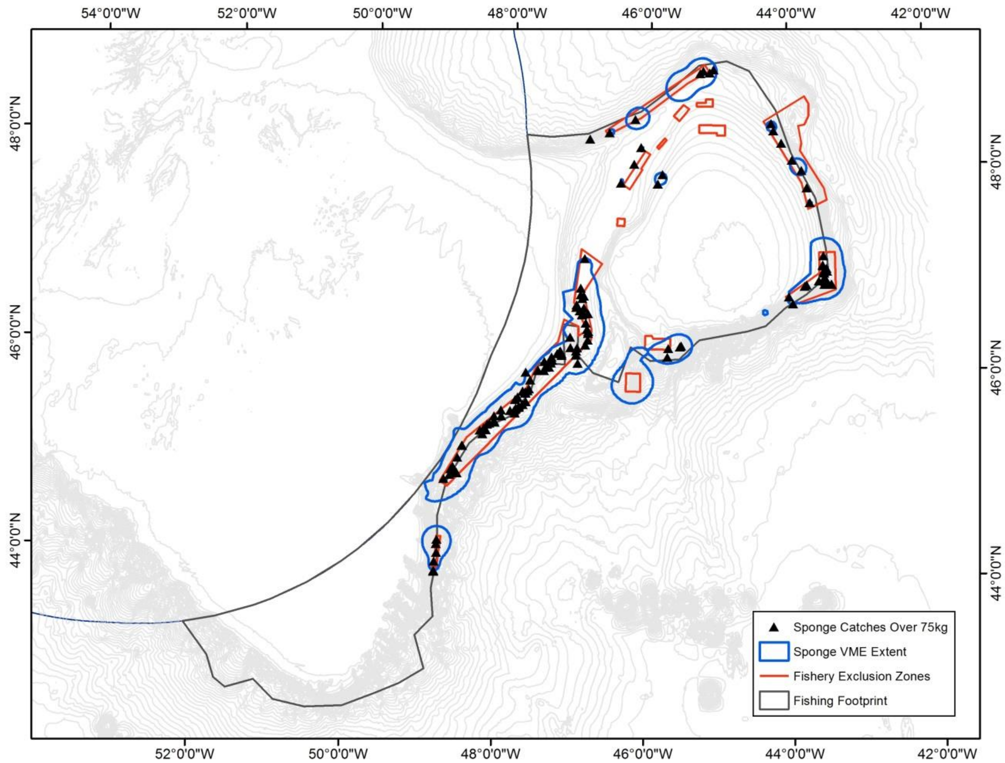

Fig. 3.8.14. Locations of the significant catches of sponges.

In regard to impacts of survey sampling on VME, an analysis of stations that exceeded the significant catch thresholds from kernel density showed that 79% of Large Gorgonian catches (n=24), 54 % of Sea Pen catches (n=37) and 87% of Sponge catches (n=133) occurred within the closed area boundary. This clearly indicates that continued sampling in these areas will generally imply high risk for impacts to these VME, in particular for Sponge and Large Gorgonian VME.

The WG noted there is finer scale length and/or age based analysis anticipated on the impact of removing closed areas from the RV sampling design on indices for stock assessments. Nevertheless, the WG considered the benefit of terminating sampling in these closed areas relative to the reduced impact to VME appears to supersede the impact on indices utilized for the provision of stock assessment advice. In addition to these results, the WG also discussed sampling in closed areas from (1) an ethical perspective and (2) from a practical perspective, given that conducting sampling in, for example, high density sponge closed areas also increases the likelihood of trawl damage or may violate the survey protocol in regard to being a representative sampling event.. Given these results, there was general consensus that sampling in closed areas should be avoided when planning for RV bottom trawl surveys until the analysis of the impacts on RV sampling indices can be quantified. This implies that the finer scale analysis, particularly for GHL, should be expedited.

ToR 3.9 Development in the use of non-destructive sampling techniques to monitorVMEs and options for integrating with existing survey trawl data (general discussion)

The WG discussed several aspects of the efficacy of continuing an RV bottom trawl sampling program in closed areas. There was agreement that non-destructive sampling surveys are preferred, for example camera-based surveys, but there would be trade-offs to consider in regard to obtaining adequate biological sampling. Another consideration was whether calibration of non-destructive surveys with bottom trawl surveys was possible to enable a combined series of the data for monitoring purposes. The WG suggested an ad hoc WG be created to explore the feasibility of non-destructive monitoring surveys with the aim of developing objectives for future monitoring as well as, to the extent possible, enable meaningful comparisons to existing bottom trawl surveys. Experts in both sampling methods should be sought.

Theme 4: Specific Requests

ToRs 4+

No additional requests wwere received from the Scientific Counciland hence there were no matters to report under this ToR.

ANNEX 1: WG-ESA 2016 MEETING AGENDA TERMS OF REFERENCE AND SPECIFIC TOPICS TO ADDRESS

Theme 1: Spatial considerations

ToR 1. Update on identification and mapping of sensitive species and habitats in the NAFO area.

1. Update on VME indicator species data and VME indicator species distribution
2. Discussion on up-dating Kernel Density Analysis and SDM's for VME indicator species especially for sea pens by 2018

Theme 2: Status, functioning and dynamics of NAFO marine ecosystems.

ToR 2. Update on recent and relevant research related to status, functioning and dynamics of ecosystems in the NAFO area.

1. Progress of analysis undertaken by EU NEREIDA funded research project
2. Approaches for analysing VMS data to determine actual fishing effort and swept area impacts
3. Progress on expanded single species, multispecies and ecosystem production potential modelling
4. Progress on multispecies and ecosystem analyses

Theme 3: Practical application of ecosystem knowledge to fisheries management

ToR 3. Update on recent and relevant research related to the application of ecosystem knowledge for fisheries management in the NAFO area.

1. Develop draft summary sheets at ecosystem level.
2. The Fisheries Commission requests the SC to continue progression on the review of the NAFO PA Framework, [FC Request 7].

In relation to the assessment of NAFO bottom fisheries, the Fisheries Commission endorsed the next re-assessment in 2021 and that the SC should:

3. Assess the overlap of NAFO fisheries with VME to evaluate fishery specific impacts in addition to the cumulative impacts;
4. Consider clearer objective ranking processes and options for objective weighting criteria for the overall assessment of risk;
5. Maintain efforts to assess all of the six FAO criteria (Article 18 of the FAO International Guidelines for the Management of Deep Sea Fisheries in the High Seas) including the three FAO functional SAI criteria which could not be evaluated in the current assessment (recovery potential, ecosystem function alteration, and impact relative to habitat use duration of VME indicator species).
6. Continue to work on non-sponge and coral VMEs (for example bryozoan and sea squirts) to prepare for the next assessment.
7. the SC further develop and compile identification guides for fishes (e.g. sharks and skates) that could be provided to observers.
8. Plan to continue work on the risk assessment of scientific trawl surveys impact on VME in closed areas, and the effect of excluding surveys from these areas on stock assessments. [FC Request #3].

9. Development in the use of non-destructive sampling techniques to monitor VMEs and options for integrating with existing survey trawl data.

AOB.

1. Up-date on potential extension of EU funded NEREIDA multi-annual R&D programme (2017 – 2020)

2. Participation and on-going resourcing of WGESA including appointment of new co-Chairs

3. Date and place of next meeting

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